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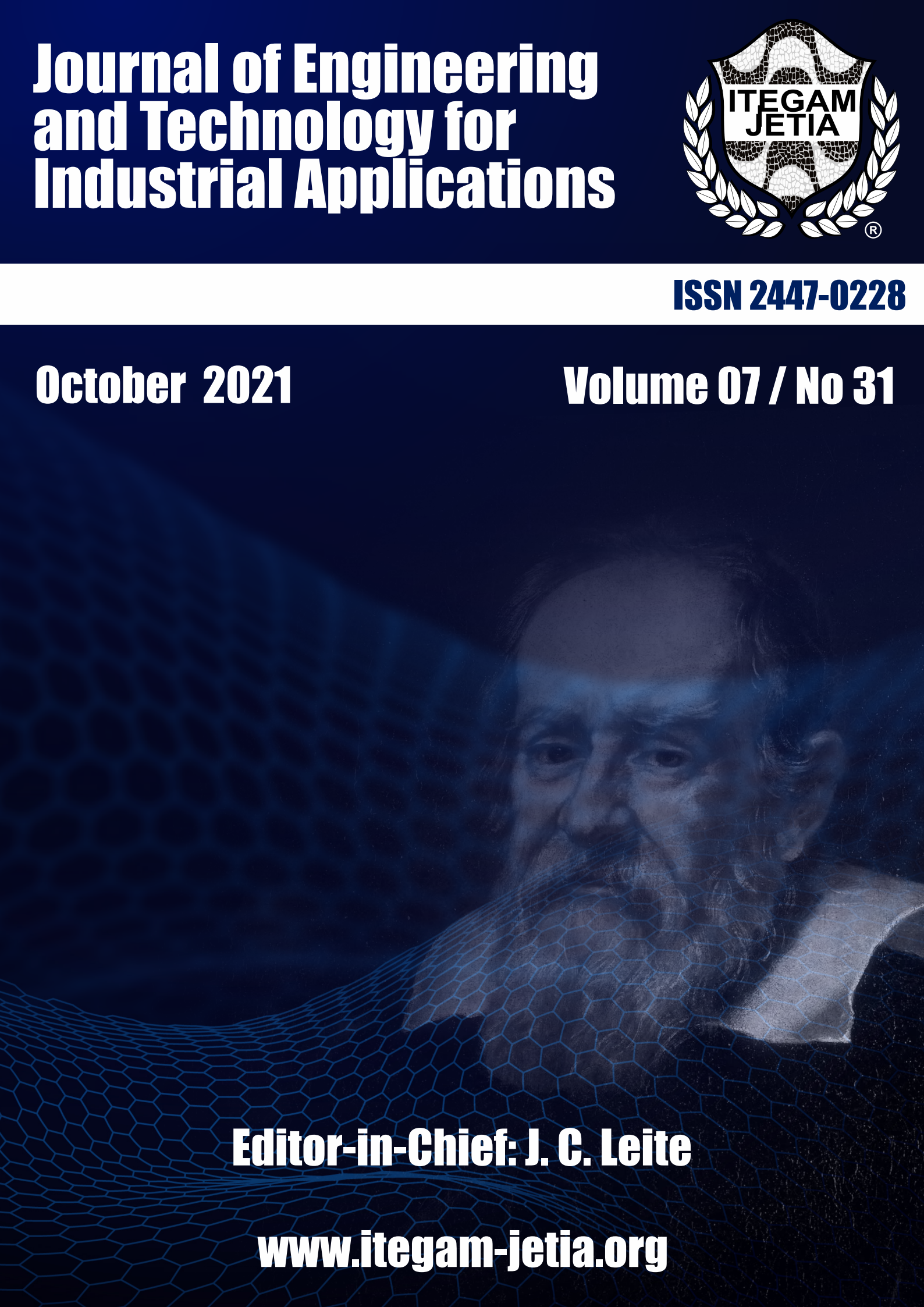

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Web page: www.itegam-jetia.org
Email: editor@itegam-jetia.org
Galileo Institute of Technology and Education of the Amazon (ITEGAM).

Joaquim Nabuco Avenue, No. 1950. Center. Manaus, Amazonas. Brazil.
Zip Code: 69020-031. Phone: (92) 3584-6145.

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SUMMARY

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RESEARCH ARTICLE OPEN ACCESS

THE INTEGRATION OF DFMA (DESIGN FOR MANUFACTURING AND ASSEMBLY) AND REVERSE ENGINEERING (ER) APPLIED TO A LANDING GEAR REDESIGN

Sanches Ismael de Oliveira*[1], Marcos Dantas dos Santos[2] and Antonio Claudio Kieling[3]

[1, 2, 3] Amazonas State University - UEA. Manaus, Amazonas, Brazil.

[1] http://orcid.org/0000-0001-5181-5419, [2] http://orcid.org/0000-0002-4356-491X, [3] http://orcid.org/0000-0002-0552-954X

Emails: *sanches.mec@gmail.com, mdsantos@uea.edu.br, antonio.kieling@yahoo.com

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ABSTRACT

The article addresses the redesign of a landing gear for a light aircraft that suffered from manufacturing and assembly problems. Numerical parameters of design features are related to design guidelines for identifying fabrication and assembly issues within 3D model analysis. For this work, the Lucas method of the DFMA integrated with reverse engineering was used as a methodology for the redesign, and its evaluation parameters for resizing the assembly item. Subsequently, the geometry of the redesigned component was defined, where significant reductions were obtained for the evaluation rates of the method used. Reduction from 20 pieces to just 6, which corresponds to a gain of 42% for functional analysis, reductions of 72% for power analysis and 84% for assembly analysis.

I. INTRODUCTION

The product development process (PDP) is complex for its multidisciplinary knowledge [1]. A structured PDP is essential for an industry's competitiveness and survival and is composed of multifunctional activities influenced by many internal and external factors [2]. Many companies competing in today's international scenario consider the PDP an important factor to hold competitive advantages [3]. Product redesign can be seen as a means of executing companies' competitive strategies. This technique, when inserted in a methodology for implementing product improvements, takes as a starting point the technical specifications of a product already launched on the market, aiming at technological improvement and not the simple copy of the existing product [4].

Between this techniques related to PDP, the term design for manufacturing (DFM) refers to the design for easy manufacturing of parts that form the product after assembly, while design for assembly (DFA) is related to product design for easy assembly. Design for manufacturing and assembly (DFMA) is a combination of DFA and DFM [5].

The design for manufacture and assembly (DFMA) aims at making product design and production planning happen simultaneously, based on a set of principles. In the redesign, DFMA helps to adapt the product in the best way to the characteristics of production and assembly, seeking to improve quality and reduce the time of manufacture and assembly [5].

There are several DFMA and DFA methods or techniques for concurrent engineering development. The three best known are the Boothroyd–Dewhurst DFMA method, the Hitachi Assemblability Evaluation and the Lucas DFA [6]. The Lucas DFA method was developed by the University of Hull and has the same research base as Boothroyd–Dewhurst [5], so they present some common characteristics, such as the reduction of the number of parts and the analysis of the parts' geometry regarding the assembly process [7].

Conversely, reverse engineering and shape reconstruction play an important role in design and manufacturing through the increased use of shape acquisition and processing technologies in the product development process. Geometric reverse engineering relies on a set of generic methods inherited from the geometric modeling and processing fields. Those methods encompass mesh

segmentation, surface reconstruction, and feature recognition. Moreover, geometric reverse engineering is nowadays supported by a digital thread from the raw acquired point cloud data to parametric feature-based cad models. [8]. Reverse engineering is used when you want to exchange or modify one part or software for another, with the same characteristics, but not all information about that part is available. Basically, it consists of a planned and organized attempt to obtain technology of product and process through the analysis of reference products (the best in that segment) [9]. The main application of the RE is in the redesign and improvement of existing parts, in which improvements are desired, such as cost reduction or even the inclusion of new features to the product.

The DFMA method is widely used as a support to improve the concept of projects or an existing project, in order to optimize the manufacturing and assembly steps. When integrated with RE, a more accurate and holistic assessment can be performed, obtaining greater gains.

Aircraft parts are complex precision-engineered products with tighter assembly tolerances produced by conventional and non-conventional manufacturing processes. Variations in these manufacturing processes have to be controlled, process risks mitigated, and managed effectively, to facilitate the ease of aero-engine assembly to reduce overall variation and improve the assembly quality [10].

In this regard, the main functions of an aircraft landing gear are to support the plane on the ground and to maneuver it during the taxiing, takeoff and landing processes. In most aircraft, the landing gear used has wheels, but there are cases where floats on seaplanes and skis are used for snow operation. The landing gear can be classified basically into two categories according to the arrangement of the wheels: tricycle or conventional [11].

An aircraft landing gear was selected in this case study, due to difficulties verified during the manufacturing and construction stages of the landing gear items to SAE aerodesign competitions, it took a long time to manufacture and assemble. In this way, was possible to analyze through the RE all the stages of manufacture and assembly, checking what can be changed.

The case study addresses on redesigning and formulating a methodology for stages of creating aircraft landing gear projects in order to reduce the amount of parts made, reduce assembly time and, consequently, increase the quality of the project. Concurrently DFMA integrated with RE, a more accurate and holistic assessment can be performed, obtaining greater gains.

II. METHODOLOGY

The work included an evaluation of the current design of the aircraft through reverse engineering method, it was carried in this way, to find possible failures and opportunities that through the DFMA method can be remedied and improved, aiming to optimize manufacturing, assembly and weight of the aircraft. The use of integrated methods between DFMA and ER will be addressed. Specifically between the DFMA methods, the Lucas method will be used, to evaluate the landing gear and to support a new concept to reformulate the current project.

Figure 1 is showed the operational sequence of the study development; it was summarized in a flowchart, which contains all the steps for analyzing an existing product and its redesign, in order to improve its assembly characteristics.

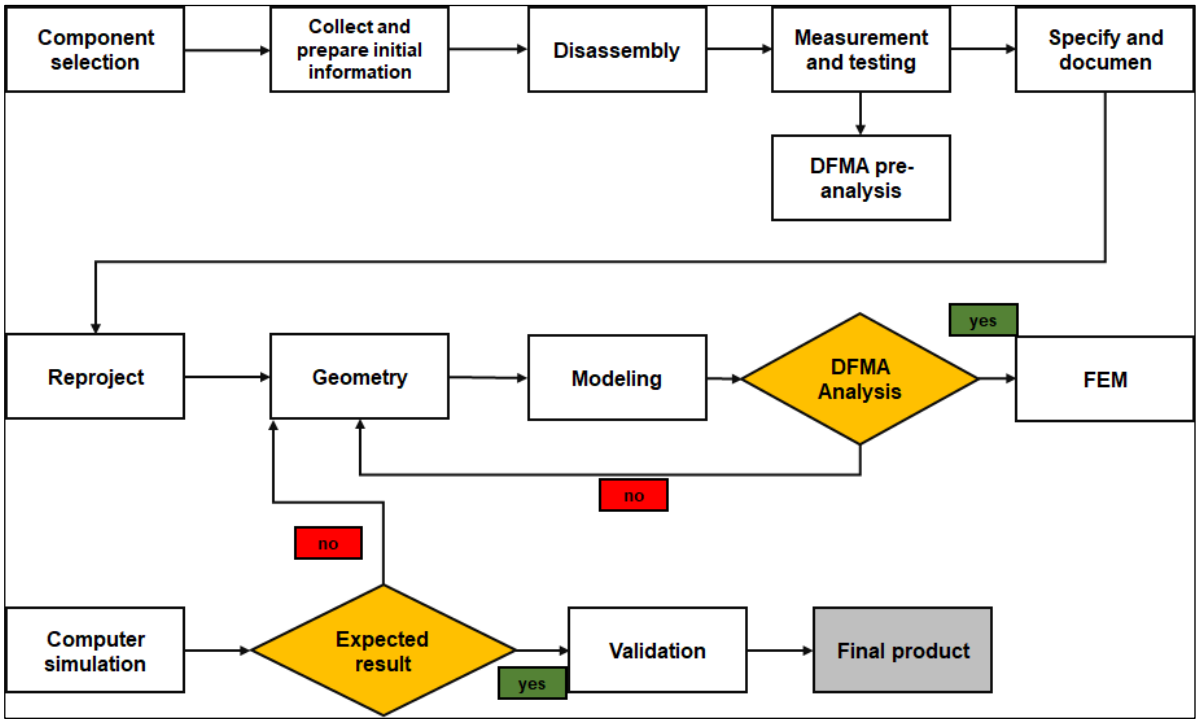

Figure 1: Study methodology applied to landing gear redesign.
Source: Authors, (2021).

The design geometry was redefined according to the evaluation carried out using the Lucas method. The method is based on standardized and tabulated parameters, which allows greater flexibility in input data and even in evaluation [2], aiming to improve assembly and manufacturing. The current landing gear material will not undergo major changes, as the purpose of the work is to improve the assembly and manufacturing criteria.

In this methodology is proposed that the new landing gear geometry is validated using DFMA tools. For its implementation, finite element analysis (FEM) through computer simulation was

also used. After completing these steps, the landing gear design can be validated and suitable for use in aerodesign aircraft.

The reference model used as the basis for the redesign and reformulation was the landing gear of the Urutau Aerodesign team from Amazonas - Brazil, identified in Figure 2, participating in the national competition SAE Brazil AeroDesign.

Figure 2: Current landing gear.
Source: Authors, (2021).

To assess the current conditions of the landing gear it was necessary to disassemble it to collect information about the parts, check the quantity of items and thus apply the DFMA method of Lucas [2].

The landing gear was disassembled and its parts were listed to start the analysis process, as shown in Figure 3.

1.Sheet metal
2. Plate screws
3.Steel cable
4.Showers
5.Wheels
6. Cable fixing screw
7. Wheel coating
8.Clips for cable
9. Nuts
10. Bearing

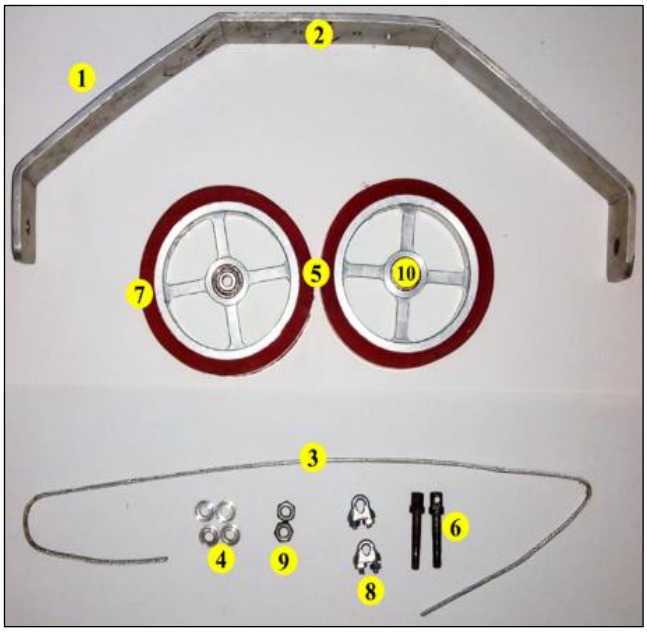

Figure 3: Classification of main landing gear items.
Source: Authors, (2021).

The evaluation of essentials items (α), are extremely important for the functioning of the product and also the non-essential items (β), it indicates even with the absence of the product functions can be performed normally.

The evaluation of essentials items (α), are extremely important for the functioning of the product and also the non-essential items (β), it indicates even with the absence of the product functions can be performed normally.

By obtaining these two variables, it is possible to carry out the analysis of the design functional efficiency index (Ed), feeding ratio and fitting ratio, according equations 1 to 3 used in Lucas method. In handling analysis, problems associated with handling the part are scored using an appropriate table. For each part, the individual feeding ratio is scored [12].

The equations to functional, handling and assembly analysis are employed as follows:

Functional analysis

$$Ed = \frac{\alpha}{(\alpha + \beta) * 100\%} \quad (1)$$

Handling analysis

$$Feeding\ Ratio = \frac{Total\ Feeding\ Ratio}{Number\ of\ essential\ components} \quad (2)$$

Assembly analysis

$$Fitting\ Ratio = \frac{Total\ Fitting\ Ratio}{Number\ of\ essential\ components} \quad (3)$$

Regarding competition requirements [13] says that the main types of loading on the landing gear are:

• Static loading on the ground;
• Dynamic loading on landing.

Loads can be tensile, compression, shear, torsion or bending loads.

The following conditions are evaluated: landing on three wheels, landing on two wheels and landing on a single wheel of the landing gear.

To validate the component, a drop test was performed with the physical prototype of the landing gear in accordance with the American standard for light aircraft [15].

To carry out the simulation of loading on the parts of the main landing gear, defined in the work, was used ©2002-2021 Dassault Systèmes SolidWorks Corporation software.

For the analyses, the tetrahedral mesh was used to obtain more accurate results accompanied by the Von Misses failure criterion, which can later be compared with the Tresca failure criteria.

III. RESULTS

III.1 ANALYSIS OF THE CURRENT LANDING TRAIN

The number of parts in this study was 15 functional and 5 non-functional. As reported in Table1 the efficiency rate of the current landing gear design is 25%. The Table1 data were processed by equation (4), according to [4].

$$Assembly\ metric\ design = \frac{Number\ of\ parts}{Theoretical\ minimum\ parts} \quad (4)$$

The efficiency index additionally informed in Table 1 it is lower than the 60% limit, it is not acceptable, requiring the elimination of some parts, until reaching the suggested efficiency.

Table 1: Functional analysis of the landing gear.

N	Part	Number of parts (Np)	Theoretical minimum parts
1	Sheet metal	1	1
2	Plate screws	2	0
3	Steel cable	1	0
4	Bushings	4	2
5	Wheels	2	2
6	Cable fixing screw	2	0
7	Wheel casing	2	0
8	Cable Clips	2	0
9	Nuts	2	0
10	Bearings	2	0
	Total	20	5
	Assembly metric design	25%	
	Goals	> 60%	

Source: Authors, (2021).

Parameters A, B, C, D, E and F shows in Table 2 are used to calculate feeding and fitting ratios, which provide values according to [14], involving information related to types of orientation, insertion and weight of parts for each situation in the analyzes.

Applying the corresponding values (19.9 to total feeting ratio and 5 to number of essential components in equation (2), a feeding ratio of 3.98 is reported in Table 2 related to handling analysis. Therefore, the feeding ratio is greater than 2.5, the project current cannot be considered acceptable, meaning that the items that are part of the assembly of the landing gear are not entirely suitable for handling, requiring a redesign.

Table 2: Result of landing gear handling analysis.

N	PART	A	B	C	D	TOTAL (A + B + C + D)
1	Sheet metal	1.0	0.6	0.1	0.0	1.7
2	Plate fixing screws	1.5	0.6	0.1	0.2	2.4
3	Steel cable	1.0	0.6	0.1	0.0	1.7
4	Bushings	1.0	0.6	0.5	0.4	2.5
5	Wheels	1.0	0.4	0.1	0.2	1.7
6	Cable fixing screws	1.5	0.6	0.1	0.2	2.4
7	Wheel casing	1.0	1.7	0.1	0.2	3.0
8	Steel cable clips	1.0	0.6	0.1	0.2	1.9
9	Nuts	1	0.2	0.1	0	1.3
10	Bearings	1	0.2	0.1	0	1.3
Total						19.9
Actual feed ratio						3.98
Optimal feeding ratio						<2.5

Source: Authors, (2021).

Substituting the values A, B, C, D, E and F according to [14], a fitting ratio of approximately 12.78 is obtained, Table 3, The adaptation rate for the design far exceeds the limit value of 2.5. Non-essential parts must be eliminated. From the current project, it must be redesigned using devices to redesign the component and establish new indices until satisfactory values are reached, such as the fitting ratio.

Table 3: Result of the landing gear assembly analysis.

N	PART	A	B	C	D	E	F	TOTAL (A + B + C + D + E + F)
1	Sheet metal	6	1.6	0.7	0	0	0	8.3
2	Plate screws	6	0	0	0	0	0.6	6.6
3	Steel cable	3.3	0.1	0	0	0.7	0	4.1
4	Bushings	3.3	0.1	1.2	0	0.7	0	5.3
5	Wheels	6	0.1	0	0	0.7	0	6.8
6	Cable fixing screw	6	0.1	0	0	0	0	6.1
7	Wheel casing	6	0.1	0	0	0.7	0.6	7.4
8	Cable Clips	6	1.6	1.2	1.5	0.7	0.6	11.6
9	Nuts	6	0	0	0	0	0	6
10	Bearings	1	0.1	0	0	0	0.6	1.7
Total								63.9
Actual fitting ratio								12.78
Optimal fitting ratio								<2.5

Source: Authors, (2021).

III.2 LANDING GEAR REDESIGN

Figure 4 is show a sketch of landing gear that was developed by Lucas method in relation to essential and non-essential items.

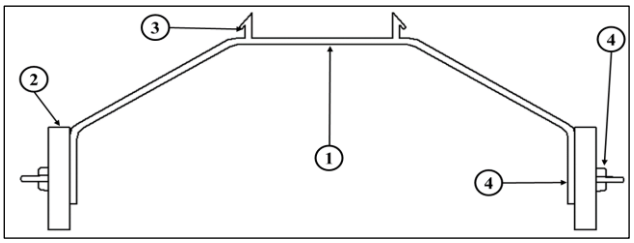

Figure 4: Sketch of the new landing gear.
Source: Authors, (2021).

Figure 5 shows image 3d of conceptual landing gear., it was modeled according to the idealization made with reverse engineering for modifications and improvements. Once the new geometry was established, the next step was the analysis of the conceptual landing gear, aiming to achieve results within the parameters of the Lucas method, both in efficiency and in the assembly.

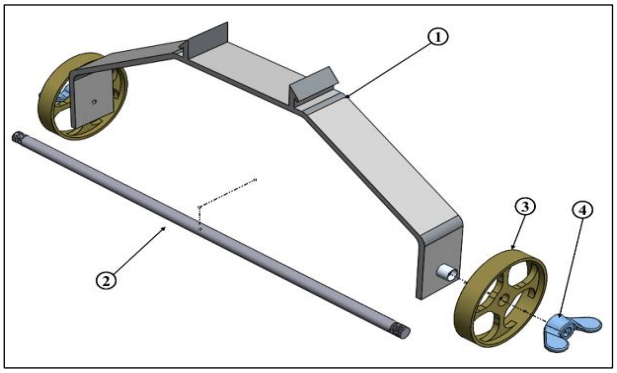

Figure 5: Conceptual landing gear.
Source: Authors, (2021).

III.3 CONCEPTUAL LANDING GEAR ANALYSIS

The number of parts for the new landing gear were, 4 functional and 2 non-functional.

The conceptual landing gear follow the initial design criteria, above 60% with a functional efficiency of 67%, shown in Table 4, as the project was carried out according to the premises of the DFMA.

Table 4: Functional conceptual landing gear analysis.

N	Part	Number of parts (Np)	Theoretical minimum parts
1	Main plate	1	1
2	Tube - shaft	1	1
3	Wheels	2	2
4	Nuts	2	0
	Total	6	4
	Assembly metric design	67%	
	Goals	> 60%	

Source: Authors, (2021).

After the redesign, the new value of the feed index decreased in relation to the previous one, now being 1.10, according to the parameters in Table 5, not only reducing the current but also meeting the criteria defined in the Lucas method.

Table 5: Result of the conceptual landing gear handling analysis.

N	PART	A	B	C	D	TOTAL (A + B + C + D)
1	Main plate	1	0.6	0.1	0	1.7
2	Tube - shaft	1	0.6	0.1	0	1.7
3	Wheels	1	0.4	0.1	0	1.5
4	Nuts	1	0.4	0.1	0.2	1.7
Total						6.6
Feed ratio						1.1
Optimal feeding ratio						<2.5

Source: Authors, (2021).

In the redesign, small fixing parts, such as screws and rivets, were avoided as much as possible to reduce insertion difficulties.

The index obtained for the current landing gear was 12.78, as already established in Table 3. After the redesign, this index decreased to 2.05, as can be evidenced in Table 6, for the conceptual landing gear, with an excellent design performance, as it not only reduced the value in relation to the previous project but also started to meet the criteria determined in the Lucas method, which indicates not to exceed the limit value of 2.5, the result being satisfactory for the redesign.

Table 6: Result of the analysis of the conceptual landing gear assembly.

N	PART	THE	B	Ç	D	AND	F	TOTAL (A + B + C + D + E + F)
1	Main plate	3.3	0.1	0.7	0	0	0	4.1
2	Tube - shaft	1	0	0	0	0	0	1
3	Wheels	6	0.1	0	0	0	0	6.1
4	Nuts	1	0.1	0	0	0	0	1.1
Total								12.3
Fitting ratio								2.05
Goals								<2.5

Source: Authors, (2021).

III.4 MATERIALS PROPERTIES AND SELECTION

Materials selection of landing gear in this study is shown in Table 7, were chosen observing the most used by teams participating in the aerodesign. Moreover, these materials are according to [15] and [16] similar works related to the construction of a landing gear.

Table 7: Materials and properties landing gear.

Properties /Materials	(1)	(2)	(3)	(4)	units
Elastic module (GPa)	2.6	8.3	69.0	70.0	N/m^2
Poisson's ratio	0.3	0.3	0.3	0.3	AT
Shear modulus (GPa)	1.0	3.2	26.0	5.0	N/m^2
Specific mass (x1000)	1.1	1.4	2.7	1.2	Kg/m^3
Tensile strength (MPa)	90.0	142.6	310	476.2	N/m^2
Flow limit (MPa)	103.6	139.0	275.	600.0	N/m^2

Legend Table 7: (1) PA Type 6; (2) Nylon 6/10; (3) Al 6061 T6; (4) Carbon fiber + resin.

Source: Adapted for authors, (2021).

III.5 LOAD ASSIGNMENT

Figure 6 shows the landing gear location under the aircraft. To carry out this project activity, the load distribution and previous work [13] and [17] were considered.

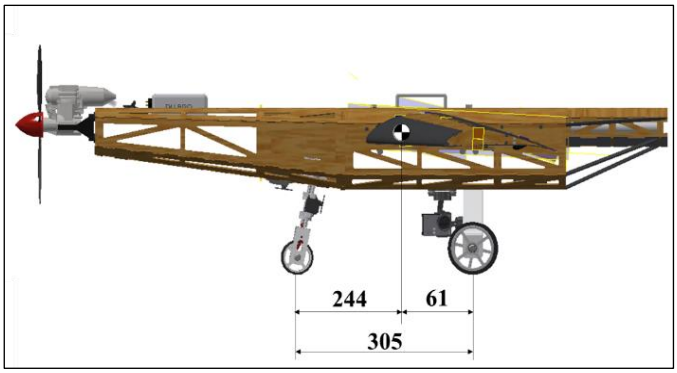

Figure 6: Landing gear location.
Source: Authors, (2021).

For the analysis criteria on the wheel, the most critical landing situation adopted were on a single wheel, in this way it makes the effort to be extreme. And for the main plate, the most critical situation is when it was supported on the two main wheels, that is, only on the main train, taking the plate to higher efforts. Therefore it is established:

- Maximum wheel load: Vg = 608 N vertical;
- Maximum load on the main plate: Vg = 304 N vertical.

Figure 7 shows the 3D simulation of the wheel following the Von Misses criteria, the location of the maximum and minimum stresses indicated by arrows and colors in the side legend can also be observed. The simulation it was considered, as already explained, the most critical situation.

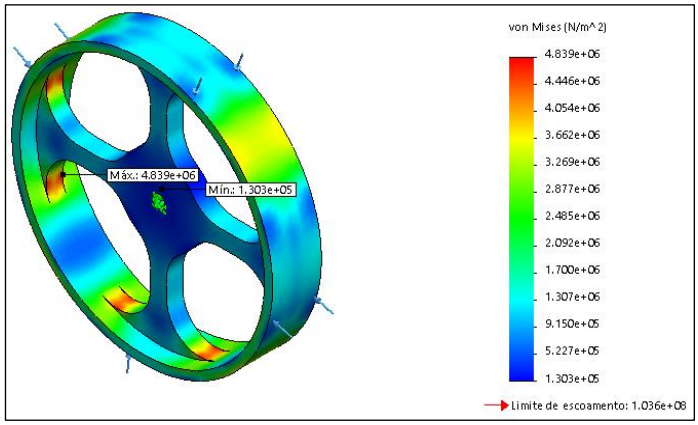

Figure 7: Result of Von Misses tension.
Source: Authors, (2021).

Table 8 summarizes the results related to wheel analysis comparing the materials used, it was possible to observe that all three situations established of material meet the analyzed criteria, thus they support the efforts and with minimum displacements. Furthermore a stress factor of 1.5 was used to compare the stresses and a, load factor of 3.8 was used to calculate the stresses, the design defined for the three materials is consistent with the real one. Therefore are within the criteria, the chosen materials one were according to lowest mass, since in the competition it is essential that the components have the least possible mass and maximum resistance, and then the wheel with PA Type 6 material was chosen to compose the redesign of landing gear conceptual.

Table 8: Result of the wheel analysis, with comparison between materials.

Material	Permissible stress (MPa)	Maximum stress (MPa)	Displacement (mm)	Deformation	Mass (kg)
PA TYPE 6	69.1	4.839	0.00583	0.000152	0.01796
Nylon 6/10	92.7	4,854	0.00184	0.000045	0.02245
Al 6061 - T6	183.3	4.841	0.00022	0.000006	0.04329

Source: Authors, (2021).

Figure 8 shows the 3D simulation of the landing gear following the von Misses criteria. The higher stresses were found on wheel supports, which have the first contact with the ground. This maximum stress value, which is 2.475 MPa, is much less than the allowable stress of 400 MPa, so there will be no concerns related to strength.

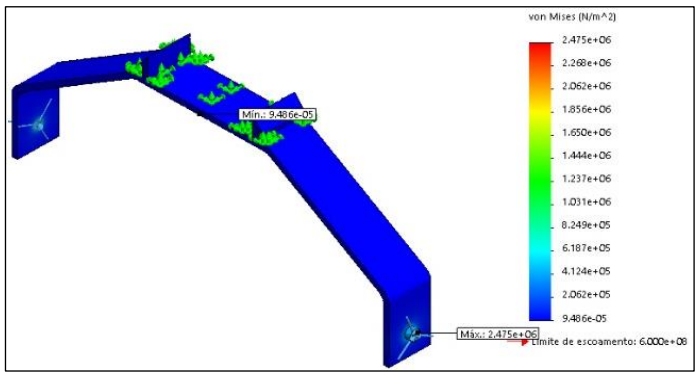

Figure 8: Result of stress analysis of the conceptual landing gear.
Source: Authors, (2021).

The latter analysis depicted in Figure 8, asses to certify that the conceptual landing gear can actually be used. Nevertheless, the most critical situation was considered, that is, with a simulation of the maximum load on the landing gear and a height above that established by Federal Aviation Administration [17], which is 230 mm, with this test being used 1000 mm.

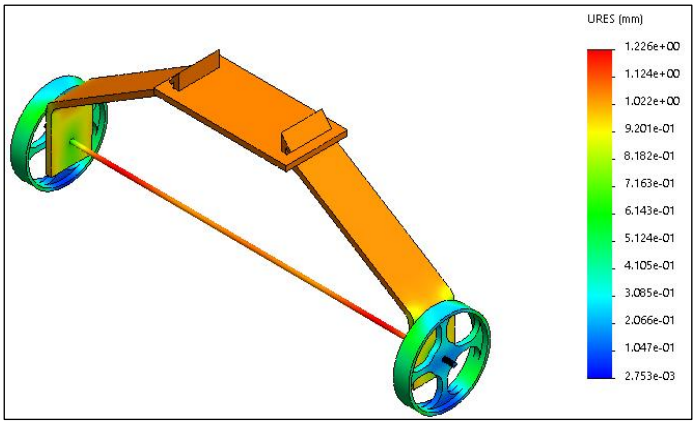

Figure 9: Result of the displacement analysis for the Drop test.
Source: Authors, (2021).

Figure 10 depicted drop test performed to a height of 1000 mm, this result report higher than the height required by the standard, for result certification.

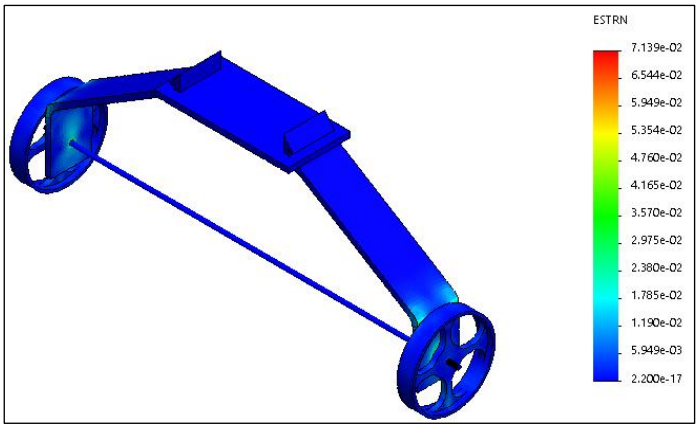

Figure 10: Result of deformation analysis in the Drop test.
Source: Authors, (2021).

After the Drop test simulation, it was observed that the results for displacement and deformation are favorable, with no major changes, enhance the integrity of the project, with this the conceptual landing gear will able to be used in the next competitions.

IV. DISCUSSION

Assembly efficiency values are of extreme importance for the validation of a good design. For the landing gear design, the results found were well below what was required for an acceptable design according to [14]. As well as the rates of feeding and adaptation, which also ran away from the satisfactory values required in [14]. These values justified the assembly difficulties encountered in the initial project of the proposed problem.

With the use of reverse engineering, to obtain data from the initial landing gear, as well as reported by [8] and with the use of CAD (computer-assisted design) technology, the new geometry

was modeled, based on the principles of the Lucas method of DFMA, for modifications and improvements. Being possible to design the conceptual landing gear assertively, ensuring the visualization of the project to verify possible assembly errors, being effective in the design of the parts, bypassing the difficulties based on the principles of reverse engineering.

To confirm the project visualized with CAD technology and the principles of DFMA integration and reverse engineering, the methods of [14][2] and [5] were put back to the test. This time, with a landing gear project showing an increase in efficiency, meeting the criteria established in [14] for the Lucas method of DFMA. The feed and adaptation indexes also changed, both meeting the expected expectations of results in [14], with reductions compared to the initial landing gear.

To complement CAD technology, the use of CAE (computer aided engineering) technology integrated into the finite element method contributed to the design and analysis of the projected parts, showing all the points of concentration of stress and deformations, ensuring that the redesign has reliability in its use. Confirming that the method adopted for the structuring of the new landing gear was effective.

The methodology aligned with the integration of reverse engineering, DFMA, CAD and CAE, proved to be efficient for the redesign of new components. Getting the challenge of redesign a complete aircraft, in order to, achieve greater assembly and construction efficiency.

V. CONCLUSION

The analyzes performed with Lucas DFMA method for the landing gear were very relevant and their results were significant, presenting a gain of 42% for the functional analysis, and reductions for the feed analysis and assembly analysis, these being respectively 72% and 84%, a fact that proves that the method used was efficient for the redesign of the landing gear, ensuring greater efficiencies.

The simulations carried out help to analyze the behavior of the parts that make up the landing gear in functional situations, helping to prevent possible design failures before its construction. Through the simulations it was possible to define the PA TYPE 6 as the material to be used in the wheels, and to prove that the materials defined for the other parts supported all loads.

The Drop Test, being one of the main tests to validate the landing gear, was performed by computational method, proving that the landing gear was fit for its functionality, presenting good parameters of stress and deformation.

It is expected that with this work, new project development techniques will be used to maximize the efficiency of assembling and manufacturing new items, as well as improving existing products.

VI. AUTHOR'S CONTRIBUTION

Conceptualization: Sanches Ismael de Oliveira and Marcos Dantas dos Santos.
Methodology: Sanches Ismael de Oliveira, Marcos Dantas dos Santos and Antonio Claudio Kieling.
Investigation: Sanches Ismael de Oliveira.
Discussion of results: Sanches Ismael de Oliveira and Marcos Dantas dos Santos.
Writing – Original draft: Sanches Ismael de Oliveira.
Writing – Review and editing: Marcos Dantas dos Santos and Antonio Claudio Kieling.
Resources: Marcos Dantas dos Santos and Antonio Claudio Kieling.
Supervision: Marcos Dantas dos Santos and Antonio Claudio Kieling.
Approval of the final text: Sanches Ismael de Oliveira, Marcos Dantas dos Santos and Antonio Claudio Kieling.

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RESEARCH ARTICLE OPEN ACCESS

A CLOSED-FORM SOLUTION TO MULTI-LEVEL IMAGE THRESHOLDING

Salah Ameer*[1]

[1] Electronics Engineering, Conestoga College, Kitchener, ON, Canada.

[1] http://orcid.org/0000-0001-7930-6691

Email: *salahameer@alumni.uwaterloo.ca

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ABSTRACT

This paper proposes an analytical formulation relying on the least square error. Similar results were also found for the cross correlation, within-class, and between-class variance. At first, a continuous distribution is hypothesized (for derivation purposes only) to produced a modified form of the well-known OTSU method. This hypothesis is "identical" to Otsu in terms of output performance and the need for an exhaustive search. However, apart from being derived from the continuous form, the proposed scheme requires less computational power. It turns out that the optimum threshold equals the average of the adjacent regions' means. For some images, the scheme can result in multi-level thresholdeds. A direct form was then suggested to obtain a non-exhaustive solution. The idea is simply to approximate the non-continuous error function (used by the least square formulation and OTSU) with a forth order polynomial defined in the normalized gray intensity range [0,1]. The optimum threshold can then be found as a function of the roots of a second order polynomial whose coefficients are the solution of a 2x2 linear system. The performance of the proposed non-exhaustive solution is slightly inferior to OTSU in general, however; some images produced improved performance. Nevertheless, The proposed scheme can be easily generalized to the multi-level case without the need for an exhaustive search. For n+1 levels (i.e. n thresholds), the output is obtained by solving an nxn linear system followed by finding the roots of a n-order polynomial. The computational cost is clearly superior to the exhaustive search. In addition, as validated with some images, the performance is encouraging. Extension to the general clustering case is highly envolved with the exception of the two-level case (for any dimension) that has been successfully derived in this work.

I. INTRODUCTION

Image thresholding is vital in many applications as it allows to separate objects in an image, typically based on their intensity. Various schemes have been proposed in the literature, a good review can be found in [1].

The histogram plays a crucial role in many of these schemes. Many schemes (e.g. [2], [3]) use the histogram as an approximation to a probability density function. An objective function is then formalized dependent on some features or attributes of the histogram, such as variance and entropy. The threshold is then selected as a solution to optimize this objective function.

Due to the fact that a histogram does not carry spatial information (2 different images can have the same histogram), higher dimensional histograms have been proposed [4-6].

The aforementioned schemes can be generalized to multi-level thresholding [7]. However, the computational price is too high. In addition, having many thresholds, the ensemble size for each region is reduced. This often results in inferior quality since statistics (or probability distribution, i.e., histogram) rely heavily on a large ensemble size [8].

There are many measures [1, 8-9] to evaluate the performance of a thresholding scheme. However, application dependant, a subjective decision may be preferred.

II. MATERIALS AND METHODS

II.1 ANALYTICAL FORMULATION

Consider the minimization of the within-class variance [2]

$$V_w = w_1\sigma_1^2 + w_2\sigma_2^2 \tag{1}$$

Where index 1(2) represent a parameter belonging to region 1(2) respectively, w is weight, m is mean, h is histogram, and σ^2 is variance.

Substuting their definitions according to [2] (with integral replacing summation), we have

$$V_w = w_1\int_0^T (t-m_1)^2\frac{h(t)}{w_1}dt + w_2\int_T^1 (t-m_2)^2\frac{h(t)}{w_2}dt$$

$$V_w = \int_0^T t^2h(t)dt - w_1m_1^2 + \int_T^1 t^2h(t)dt - w_2m_2^2$$

The combined integral in the above equation is independent of T, hence, the problem is to maximize

$$F_w = \frac{\left\{\int_0^T th(t)dt\right\}^2}{\int_0^T h(t)dt} + \frac{\left\{\int_T^1 th(t)dt\right\}^2}{\int_T^1 h(t)dt} \tag{2}$$

Setting the derivative w.r.t T to zero and avoiding zeros in the histogram, we obtain

$$\frac{2T\left\{\int_0^T h(t)dt\right\}\left\{\int_0^T th(t)dt\right\} - \left\{\int_0^T th(t)dt\right\}^2}{\left\{\int_0^T h(t)\right\}^2} = \frac{2T\left\{\int_T^1 h(t)\right\}\left\{\int_T^1 th(t)dt\right\} - \left\{\int_T^1 th(t)dt\right\}^2}{\left\{\int_T^1 h(t)\right\}^2}$$

The above result can be simplified using the same definitions used in (1) to

$$2Tm_1 - m_1^2 - 2Tm_2 + m_2^2 = 0$$

$$(m_2 - m_1)\{m_2 + m_1 - 2T\} = 0$$

$$m_1 + m_2 = 2T \tag{3}$$

As region means cannot be equal, the simplification in (3) was obtained. The result is still an exhaustive search, the procedure will be called Optimum Exhaustive (OE) henceforth. It can be clearly noticed that the computational burden is less than that required by the OTSU method.

An interesting observation of (1) is that the formulation can be modified to produce the least square error (LSE) between the original and the thresholded image. Hence, (3) and OTSU method can both be categorized as least square solutions. In other words, the objective function to minimize is actually

$$V_w = \int_0^T (t-m_1)^2h(t)dt + \int_T^1 (t-m_2)^2h(t)dt \tag{4}$$

The same result (with more elaborate mathematics) can be obtained using the between-class variance [2],

$$V_b = w_1w_2(m_2 - m_1)^2 \tag{5}$$

In fact, same result (using a similar procedure) can be obtained by minimizing the cross correlation between the histograms of the original image and that of the thresholded image, i.e. using the formulation

$$F_{Cross} = \frac{X_1 + X_2}{V_OV_T} \tag{6a}$$

$$V_O = \sqrt{\int_0^1 \{x-m\}^2h(x)dx} \tag{6b}$$

$$V_T = \sqrt{\int_0^T \{m_1-m\}^2h(x)dx + \int_T^1 \{m_2-m\}^2h(x)dx} \tag{6c}$$

$$X_1 = \int_0^T \{x-m\}\{m_1-m\}h(x)dx \tag{6d}$$

$$X_2 = \int_T^1 \{x-m\}\{m_2-m\}h(x)dx \tag{6e}$$

Interestingly, the complement feature formulation recently proposed [10] produces the same outcome as in (3). The complement feature is implemented in this work as the dot product between the original image and the thresholded image, i.e.

$$F_{Comp} = \int_0^T \{xm_1 + (1-x)(1-m_1)\}h(x)dx + \int_T^1 \{xm_2 + (1-x)(1-m_2)\}h(x)dx \tag{7}$$

Other features (e.g., entropy) can be treated in the same fashion as (1), however, the resultant description for the threshold is not as tractable as in (3).

The proposed scheme can be extended to multilevel thresholding resulting in an extended formulation to that in (3). In fact, (2) can be extended to multi-level as

$$F_n = \sum_{i=1}^{n} \frac{\left\{\int_{T_{i-1}}^{T_i} th(t)dt\right\}^2}{\int_{T_{i-1}}^{T_i} h(t)dt} \tag{8}$$

Following a similar derivation as above but more than one threshold, we obtain (please note that the number of means is more than the number of thresholds by one)

$$2T_jm_j - m_j^2 - 2T_jm_{j+1} + m_{j+1}^2 = 0$$

$$2T_j = \frac{m_{j+1}^2 - m_j^2}{m_{j+1} - m_j} = m_{j+1} + m_j \tag{9}$$

Unfortunately, the search is still an exhaustive one.

II.2 NON-EXHAUSTIVE SOLUTIONS

Despite the simple formulations obtained for two- and multi-level thresholding, as shown in (3) and (9) respectively, the solution can only be obtained through an exhaustive search.

Resulting in a computational cost almost exponentially dependent on the number of levels.

A closer look at (4) reveals the discontinuity of the error function implemented. Hence, continuous approximations to (4) will be investigated in this subsection. Polynomials are used to find a direct solution and further extend it to the multi-level case.

The essential idea is to reformulate (4) as

$$F = \int_0^1 S(t, m_1, m_2) h(t) dt \tag{10}$$

Where

$$S(t, m_1, m_2) \approx \begin{cases} (t - m_1)^2 & t < T \\ (t - m_2)^2 & t > T \end{cases} \tag{11}$$

One of the possibilities for *S* is shown in Figure 1. An important requirement to overcome the need for an exhaustive search is to force *S* to be a continuous function.

There are many ways to have a continuous representation for *S*. One suggestion would be to have a polynomial optimizing the objective function

$$F = \int_0^T \left\{ \sum_{i=0}^{n} b_i (t - T)^i - (t - m_1)^2 \right\}^2 dt + \int_T^1 \left\{ \sum_{i=0}^{n} b_i (t - T)^i - (t - m_2)^2 \right\}^2 dt \tag{12}$$

Where T is given by (3). Some simplifications can be used to ease the elaborate mathematics, however, a 7th order polynomial needs to be solved for n=4 (order of *S*). Unfortunately, the description in (12) cannot be easily modified to the multi-level case.

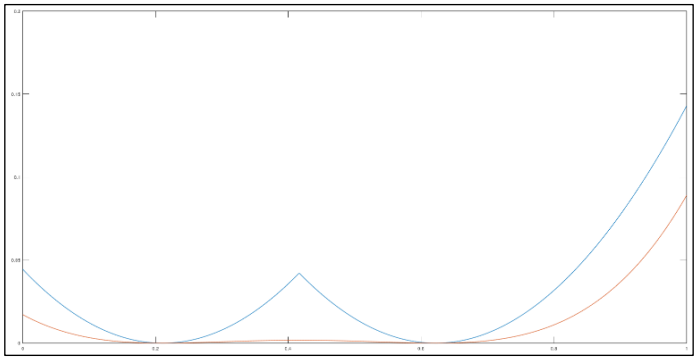

Figure 1: (blue) A possible plot for the function *S* defined in (11) and (red) a 4th order approximation.
Source: Author, (2021).

An easier and powerful (as will be shown later) solution would be to concentrate on special features of *S* rather than the global approximation. The most attracting features of *S* are its zeros that are also its minima. The simplest form to describe this behavior is the quadratic product (QP) shown as

$$S_2(t, m_1, m_2) = (t - m_1)^2 (t - m_2)^2 \tag{13}$$

The description in (13) has deviation all over the range (t ϵ [0,1]), (see Figure 1). This sacrifice enables for a more regourous solution of (10) as

$$F_{QP} = \int_0^1 (t - m_1)^2 (t - m_2)^2 h(t) dt \tag{14}$$

Setting the derivatives in (14) w.r.t m_1 and m_2 to zero results in

$$\frac{\partial F_{QP}}{\partial m_1} = \int_0^1 (t - m_1)(t - m_2)^2 h(t) dt = 0 \tag{15a}$$

$$\frac{\partial F_{QP}}{\partial m_2} = \int_0^1 (t - m_1)^2 (t - m_2) h(t) dt = 0 \tag{15b}$$

Subtracting (15a) from (15b) results in

$$\int_0^1 (t - m_1)(t - m_2)(m_2 - m_1) h(t) dt = 0 \tag{16}$$

Substituting (16) back into (15a), we have

$$\int_0^1 (t - m_1)(t - m_2) t h(t) dt = 0 \tag{17a}$$

$$\int_0^1 (t - m_1)(t - m_2) h(t) dt = 0 \tag{17b}$$

Define

$$y_i = \int_0^1 t^i h(t) dt \tag{18}$$

Using (18), we can rewrite (17) using polynomial notation as

$$y_0 P_0 + y_1 P_1 = -y_2 \tag{19a}$$

$$y_1 P_0 + y_2 P_1 = -y_3 \tag{19b}$$

Where P_i are the coefficients of a second order polynomial obtained from (17). Explicitly,

$$P_0 = m_1 m_2 \tag{20a}$$

$$P_1 = -(m_1 + m_2) \tag{20b}$$

The 2x2 linear system of (19) can now be solved for P_i. The solutions (P_1 and P_2) can then be used to find the two centers m_1 and m_2 as the roots of the second order polynomial given by

$$P_0 + P_1 x + x^2 = 0 \tag{21}$$

It should be clarified that P_i are used to find m_i without the explicit use of (20). This trick enables the procedure to be break into two simple subsystems (a linear system followed by a root-finding scheme) rather than solving a nonlinear set of equations.

The threshold is then found as the average of the centres m_i. Note the similarity with (3).

A more intuitive look at Figure 1 suggests that the threshold is the maxima of the polynomial (minima are the centres m_i). Hence, the derivative of (13) is

$$\frac{\partial}{\partial t} \{(t - m_1)^2 (t - m_2)^2\} = 0$$

$$(t-m_1)^2 2(t-m_2) + 2(t-m_1)(t-m_2)^2 = 0$$

$$(t-m_2)(t-m_1)\{t-m_1+t-m_2\} = 0 \qquad (22)$$

The first two terms are simply the minima and are of no use as a threshold. Hence, the useful term is the last one. To reduce computation, (22) can be directly obtained from the derivative of (21) as

$$2x + P_1 = 0 \qquad (23)$$

Table 1: Procedure flow of QP2.

#	Description
1	Find Image Histogram
2	Evaluate (18)
3	Solve 2x2 system (19)
4	Solve (23) to find threshold

Source: Author, (2021).

Interestingly, the solution obtained by (23) is the same as that given by (3). This clearly supports the optimum behaviour of the choice given in (13). Hence, the procedure relying on (14) will be called Quadratic Product for level 2 (QP2), see Table 1. The number 2 in QP2 is to indicate that the output is two-level (one threshold).

II.3 VARIATIONS TO (12)

A closer look at Figure 1 reveals the feature points of the function at 0, m_1, T, m_2, and 1. Satisfying the conditions (the function and/or the derivative) imposed by one or more of these feature points results in a higher order polynimial for *S* in (10). Unfortunately, the polynimial coefficients are also nonliear in terms of the unknowns m_1 and m_2. Despite the fact that finding the roots of a high order may be preferred over exhaustive search, the description does not lend itself to be generalized to multi-level thresholding.

One of the interesting formulations was shown in (14). All other trials were too complex except ones that are just a multiplication of (13) by a constant in the form

$$S_c(t, m_1, m_2) = C(T,R)(t-m_1)^2(t-m_2)^2 \qquad (24a)$$

$$2T = m_2 + m_1 \qquad (24b)$$

$$2R = m_2 - m_1 \qquad (24c)$$

Many forms similar to (24a) can be designed to produce various schemes with different level of complexty. One such scheme is

$$F_{Ratio} = \int_0^1 \left(\frac{t}{m_1} - 1\right)^2 \left(\frac{t}{m_2} - 1\right)^2 h(t)dt \qquad (25)$$

Leading to the solution (in a similar fashion to DS2)

$$\begin{bmatrix} y_1 & y_2 \\ y_2 & y_3 \end{bmatrix} \begin{bmatrix} P_0 \\ P_1 \end{bmatrix} = -\begin{bmatrix} y_3 \\ y_4 \end{bmatrix} \qquad (26)$$

It was noted that (26) can give slightly better results as compared to QP2. However, due to the denominators, the previous statement is valid either to the image or its negative (1 – image) but not both. Leading to a significant drawback for the multi-level case.

Many formulations of (24) have been investigated and found to produce solutions requiring the root finding of polynomials (in T) of order >6.

The function given in (13) can be further modified using just a multiplication constant. The simplest approaches were to exactly satisfy (11) at either t=0, T, 1, 1+T, or 1–T. Unfortunately, these suggestions were either mathematically involved or produce inferior performance (inefficient for some images). Another drawback is the inability of these schemes to generalize to the multi-level case.

The function *S*, given in (10), can be described using a polynomial of high order (>4) to better satisfy (11). Unfortunately, the resultant mathematics was found to be more involved for many suggestions including the ones described in the previous paragraph.

II.4 MULTI-LEVEL THRESHOLS

Another advantage of the suggestion in (13) is that it can be easily extended to multi-level thresholding through

$$S_n(t, m_1, m_2) = \prod_{i=1}^{n} (t-m_i)^2 \qquad (27)$$

Following a similar procedure to that obtained through (14) to (18), we obtain the following linear system

$$\begin{bmatrix} y_0 & \cdots & y_{n-1} \\ \vdots & \ddots & \vdots \\ y_{n-1} & \cdots & y_{2n-2} \end{bmatrix} \begin{bmatrix} P_0 \\ \vdots \\ P_{n-1} \end{bmatrix} = -\begin{bmatrix} y_n \\ \vdots \\ y_{2n-1} \end{bmatrix} \qquad (28)$$

Once P_i are obtained (note the extenstion from (20)), we can find m_i by finding the roots of

$$\sum_{i=0}^{n-1} P_i x^i + x^n = 0 \qquad (29)$$

Each threshold is then found by averaging the two adjacent centres in a similar fashion to (9). The same procedure leading to (22) can be extended to simplify the scheme of finding the thresholds as follows,

$$\frac{\partial}{\partial x} \prod_{i=1}^{n} (x-m_i)^2 = 0$$

$$\sum_{j=1}^{n} \prod_{i=1}^{n} \frac{2(x-m_i)^2}{(x-m_j)} = 0 \qquad (30)$$

Excluding the minima as the thresholds are the maxima (see Figure 1), we have

$$\sum_{j=1}^{n} \prod_{\substack{i=1 \\ i \neq j}}^{n} (x-m_i) = 0 \qquad (31)$$

Equivalently, (31) can be written as

$$\frac{\partial}{\partial x}\prod_{i=1}^{n}(x-m_i)=\frac{\partial}{\partial x}\left\{\sum_{i=0}^{n-1}P_i x^i+x^n\right\}=0$$

$$nx^{n-1}+\sum_{i=1}^{n-1}iP_i x^{i-1}=0 \qquad (32)$$

Obviously, the order of the polynomial in (32) is less by one compared to that in (29). In addition, it avoids the avaraging procedure required to find the thresholds from the obtained means m_i. The procedure will be called Quadratic Product for level n (QPn) as descibed in Table 2. Please note that QPn has n–1 thresholds.

Table 2: Procedure flow of QPn.

#	**Description**
1	Find Image Histogram
2	Evaluate (18)
3	Solve linear system (28)
4	Solve (32) to find thresholds

Source: Author, (2021).

II.5 EXTENSION TO CLUSTERING

Fortunately, a direct solution to the two-level case (for any number of dimensions) can be formulated as will be given shortly. Raw data will be used (without histogram) to ease the notation. Consider the optimization problem

$$F_{Dim}=\sum_i\left((x_i-m_1)^T(x_i-m_2)\right)^2$$

$$F_{Dim}=\sum_i\sum_{k=1}^{2}(x_{ik}x_{ik}-x_{ik}m_{1k}-x_{ik}m_{2k}+m_{1k}m_{2k})^2 \qquad (33)$$

Let's define

$$a_{jk}=\sum_i x_{ik}^j \qquad (34a)$$

$$b_k=a_{0k}a_{2k}-a_{1k}a_{1k} \qquad (34b)$$

$$c_k=a_{0k}a_{3k}-a_{1k}a_{2k} \qquad (34c)$$

$$d_k=a_{1k}a_{3k}-a_{2k}a_{2k} \qquad (34d)$$

Setting derivatives of F (33) to zero and performing a few simplifications, we obtain

$$b_k m_{2k}=c_k-b_k m_{1k} \qquad (35)$$

$$m_{1k}=\frac{c_k\pm\sqrt{c_k^2-4b_k d_k}}{2b_k} \qquad (36)$$

Please note that each of the equations (34) – (36) are actually a set written compactly together. In other words, for a 3D data, (36) is in fact a set of three equations.

The scheme (QPn) can be extended to levels more than two and higher dimensions (clustering), however, the resultant mathematics is too much envolved. Enforcing independency (sub-optimal) between the dimensions can reduce the complexity on the expense of ambiguity in the final results. The ambiguity manefists itself in the fact that n centers should be picked out of the produced n^k centers (k is the number of dimensions).

III. RESULTS AND DISCUSSIONS

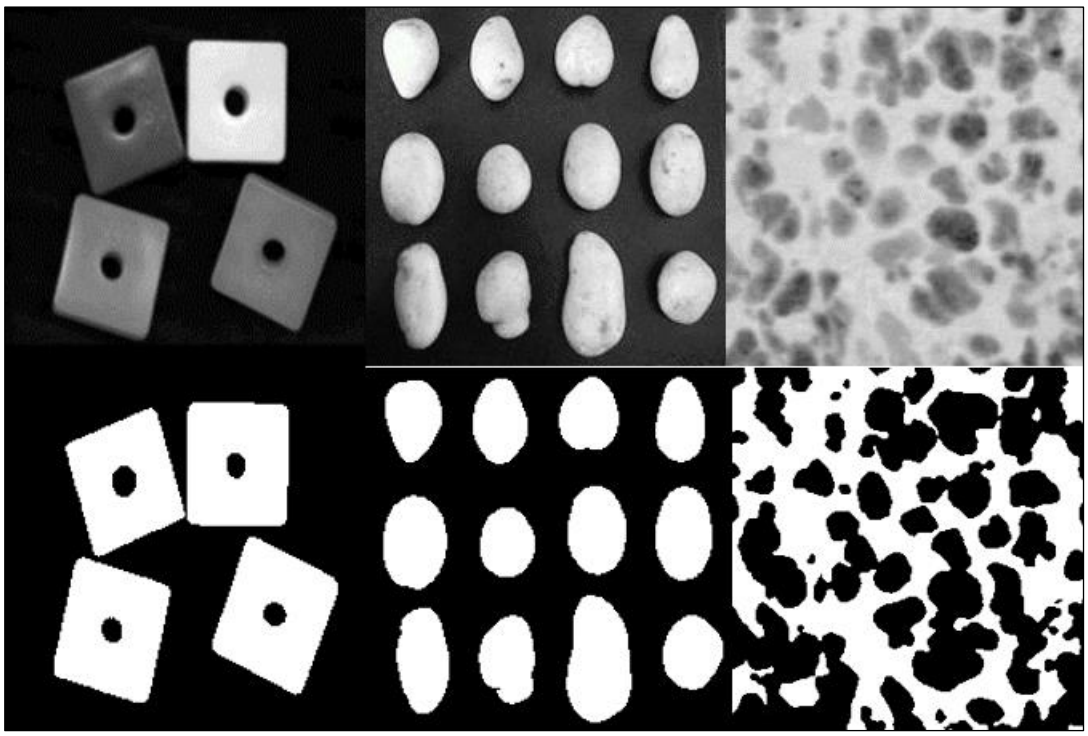

Figure 2: (First row) test images (1 – 3), (second row) their ground truth.
Source: Author, (2021).

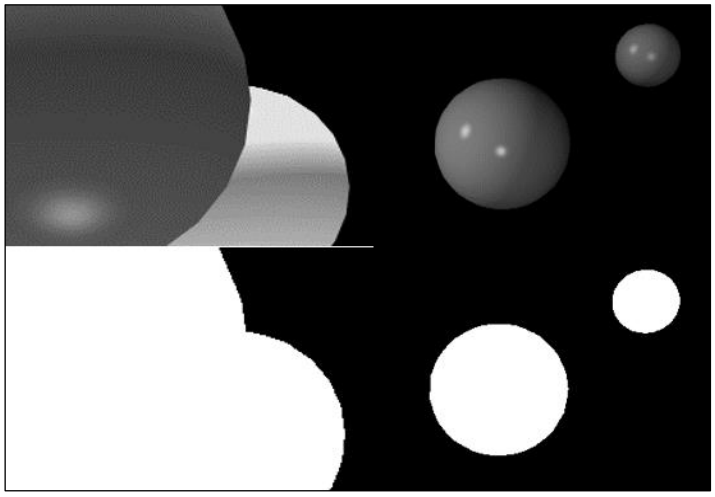

Figure 3: (First row) test images (4 – 5) and (second row) their ground truth.
Source: Author, (2021).

Five test images with their ground truth are shown in Figure 2-3. For comparison purposes, the outputs of OTSU, OE (3), and QP2 (see Table 1) are shown in Figure 4-5.

OE is clearly similar to OTSU. The thresholds are very close, however; for some images, OE produces more than one threshold, an observation that may wort further investigation.

Although the performance of QP2 is inferior to both OTSU and OE (more images are needed to obtain useful statistics for performance comparisons), the non-exhaustive behaviour is appealing. In addition, results for number of levels more than 2 is encouraging. Figure 6-7 shows the performance of QP3, and QP4 using the same set of images.

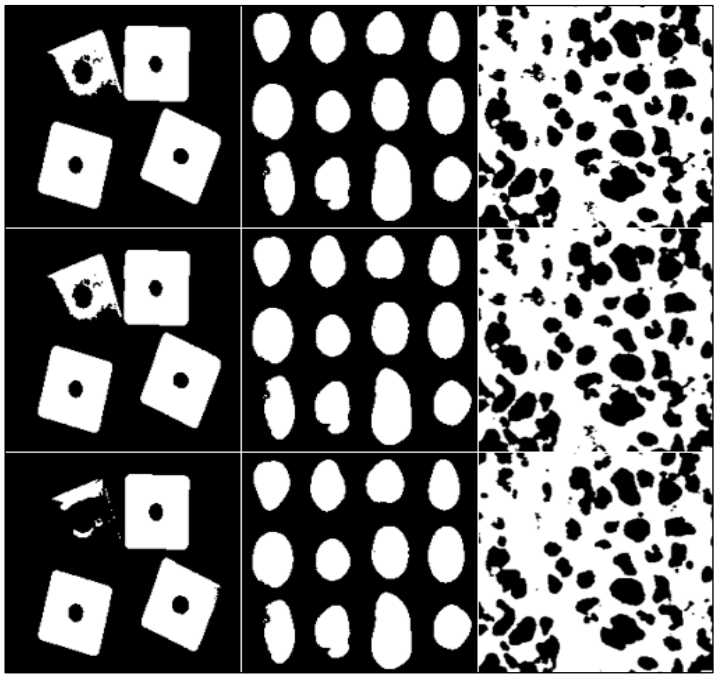

Figure 4: results of OTSU (First row), OE (second row), and QP2 (third row) for the test images (1 – 3).
Source: Author, (2021).

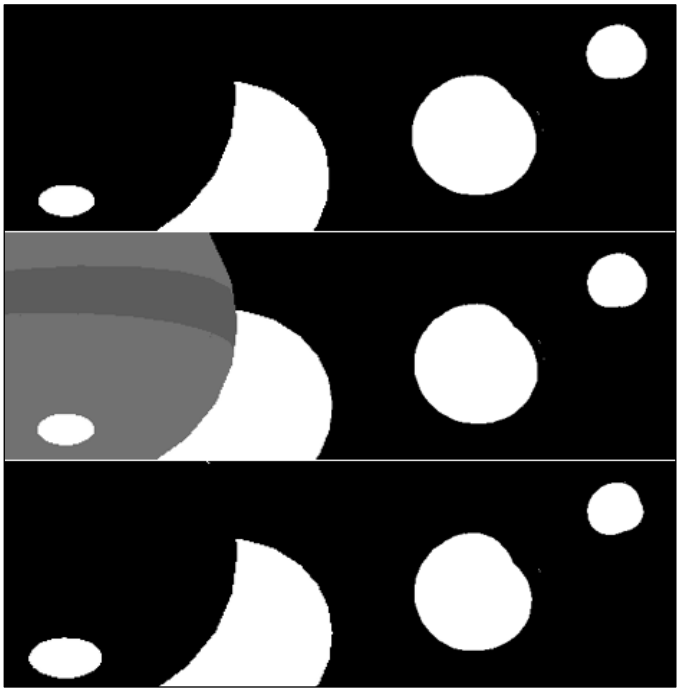

Figure 5: results of OTSU (First row), OE (second row), and QP2 (third row) for the test images (4 – 5).
Source: Author, (2021).

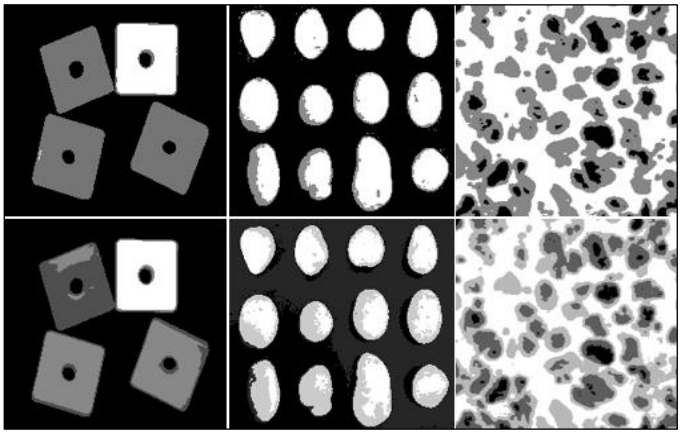

Figure 6: results of QP3 (First row) and QP4 (second row) for the test images (1 – 3).
Source: Author, (2021).

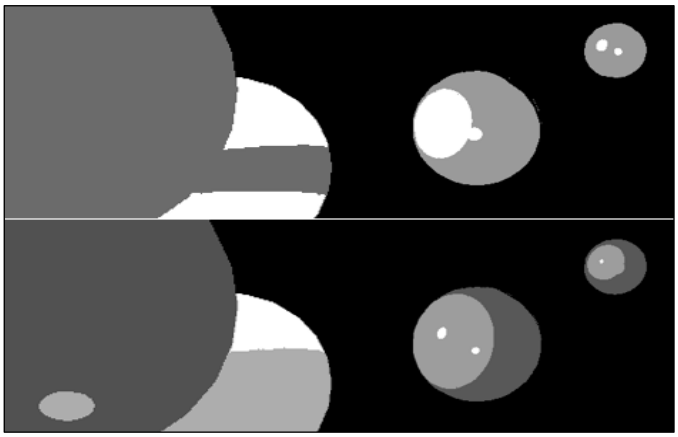

Figure 7: results of QP3 (First row) and QP4 (second row) for the test images (4 – 5).
Source: Author, (2021).

It was noticed that smoothing the histogram (through averaging and/or fitting) did not produce significant differences.

More images where thresholded using QP3 to further explore the performance as shown in Figure 8-9.

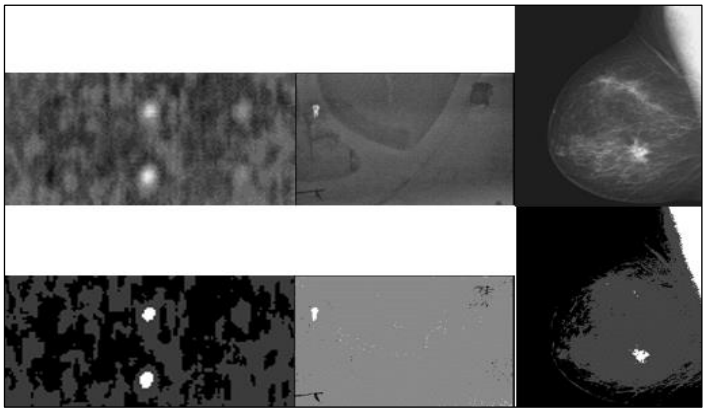

Figure 8: (First row) test images (6 – 8) and (second row) their QP3 output.
Source: Author, (2021).

Figure 9: (First row) test images (9 – 11) and (second row) their QP3 output.
Source: Author, (2021).

IV. CONCLUSIONS

A new optimized solution is suggested for the binary image thresholding problem using least square error. The formulation is equivalent to the commonly used OTSU method and the cross-correlation description. Although performance does not deviate too much from that of OTSU, a computational gain is obtained.

Inspired by the mentioned optimized solution, a non-exhaustive scheme was then developed using a polynomial approximation to the least square error function. A quadratic product was suggested as a general extension.

The quadratic product QP2 has shown encouraging results. In addition to its simplicity, the formulation can be easily extended to the multi-level thresholding case QPn.

Some variations (still non-exhaustive) have been tried without significant improvements in performance but are computationally demanding. Further insight into higher order polynomials may be needed to investigate a possible compromise between performance and complexity.

More weighting schemes, using (24), are currently under investigation to improve performance while keeping the mathematics tractable.

A more elaborate comparison is being conducted to further explore the extent of the proposed schemes in terms of output quality and computational cost.

V. AUTHOR'S CONTRIBUTION

Conceptualization: Salah Ameer.
Methodology: Salah Ameer.
Investigation: Salah Ameer.
Discussion of results: Salah Ameer.
Writing – Original Draft: Salah Ameer.
Writing – Review and Editing: Salah Ameer.
Resources: Salah Ameer.
Supervision: Salah Ameer.
Approval of the final text: Salah Ameer.

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RESEARCH ARTICLE OPEN ACCESS

PRODUCTION OF ANTIMICROBIAL COMPOUNDS USING THERMOPHILIC BACTERIA SPECIES *BACILLUS SUBTILIS* AND *BACILLUS TEQUILENSIS*

Helmi Andriyani[1], Natacia[2] and Edy Fachrial*[3]

[1, 2] Department of Clinical Pharmacy, Faculty of Medicine, Universitas Prima Indonesia.
[3] Laboratory of Molecular Biology, Faculty of Medicine, Universitas Prima Indonesia.

[1] http://orcid.org/0000-0001-5236-7232, [2] http://orcid.org/0000-0001-8818-9511, [3] http://orcid.org/0000-0002-5237-5803

Email: andriyani2906@gmail.com, natacia1515@gmail.com, *fachrial_edy@yahoo.co.id

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ABSTRACT

Infections caused by resistant bacteria are a growing public health problem, consequently, a new source of microorganisms that can be used for antimicrobial production is needed. One of the microorganisms capable of producing antimicrobials is the thermophilic bacteria, namely *B. subtilis* and *B. tequilensis.* Due to having hot temperature-resistant enzymes, they are not easily damaged. Therefore, this study aims to produce new antimicrobials from *B.subtilis* and *B.tequilensis*. The antimicrobial activity was observed in 5 thermophilic bacterial isolates using the disk diffusion method. The results showed the strongest zone of inhibition (disk diameter = 6mm) or antimicrobial activity against *S.aureus* which was classified as gram-positive was discovered in *B.subtilis* UTMP15 (10.27 mm) at the incubation time of 24 hours, and against *E.coli* classified as gram-negative,it was in *B. Subtilis* UTMP12 (8.59 mm) at 48 hours. Hence, the isolate is a potential antimicrobial agent.

I. INTRODUCTION

Thermophilic bacteria have an important role in energy metabolism and matter cycling [1]. Besides, an important parameter of microbial culture for survival is temperature with different ranges, causing microorganisms to be divided into psychrophiles, mesophiles, and thermophiles [2].The thermophiles are categorized as moderate (50ºC-60ºC), extreme (60ºC-80ºC) andhyperthermophiles (80ºC-110ºC) [3]. Thermophilic bacteria at temperatures of 90ºC-95ºC include *Termotoga maritime* and *Aquifex pyrophilus* [4]. Members of the genera *Pyrobaculum, Pyrodictium, Pyrococcus,* and *Melanopirus* which belong to *Archaea* are found at 103ºC-110ºC, while in Fungi, classes *Ascomycetes* and *Zygomycetes* grow under high temperatures. Because the described bacteria play an important role in various fields, studies have been conducted to obtain new genera and species around the world [5]. According to Madigan and Martinko (2006), the reason behind the places where thermophilic microorganisms live is a heat source (water or geothermal resources) from the ocean, making the protein structure of thermophilic microorganisms stable and resistant to chemical reagentes [2].

Microorganisms' enzymes are cultured in large quantities within a short time due to being more stable than those from plants or animals and they can be stored under less than ideal conditions for weeks without losing biological activity. Therefore, many microbial enzymes on the market are mechanical or cellular [6]. Niehaus et al (1999) said enzymes are proteins produced by animals, plants, and microorganisms to catalyze biochemical reactions through metabolism in cells [2]. Thermostable enzymes including amylase, cellulase, chitinase, pectinase, xylanase, protease, lipase, and DNA polymerase in thermophilic microorganisms growing at ≥ 50ºC, are very suitable for biotechnological processes at high temperatures [7]. According to Khalil (2011), currently, only two thermophilic bacterial enzymes such as cellulase, etc. from the *Thermus aquaticus* and *alkaliphiles* groups are widely used, because of their high thermostability and resistance to physical or chemical factors [8].

The thermophilic bacterial enzymes that have the potential to be used for antimicrobials and new antibiotics production include protease. Antibiotics produced with fungi, bacteria, and streptomyces are one of the important secondary metabolites exploited commercially. Drugs used in infectious disease chemotherapy are divided into two, namely synthetic drugs (synthesized by chemical procedures in the laboratory) and antibiotics [9]. The lack of antibiotic innovation and pharmaceutical industry funding for new drugs development is not in line with the elevation in irrational drug use that exacerbates this problem. Also, the increasing emergence of resistant pathogenic bacterial infections that create significant problems in human global health is due to the lack of production and introduction of new and effective antibiotic/antibacterial drugs in clinical practice [10]. The most recent threat to human populations worldwide is the continual rise in many drug-resistant microbes in the water and atmosphere [11]. Common antibiotics such as ampicillin, Streptomycin, ciprofloxacin, cefotaxime, and azithromycin are no longer useful for curing bacterial infections, leading to a frightening situation in society [12]. Studies showed COVID-19 is a viral infection that initiates direct antibiotic stress on microorganisms. Based on the data, 72% of COVID-19 patients had received antimicrobial agents, while 8% were co-infected by bacteria or fungi [13][14]. Up to 68.9% of such patients were also reported to have been using antibiotics (mainly azithromycin and ceftriaxone) before hospital admission with a self-medication rate of 33%. This relates to low & middle-income countries, where the lack of knowledge about antibiotics usage causes the associated control measures to be weak [15]. Antibiotic resistance is a major challenge in several fields including biomedical and pharmaceutical studies. For instance, *Staphylococcus aureus* is resistant to methicillin, while *Salmonella typhi* to ciprofloxacin, which extends to other pathogenic bacteria [16]. Antibiotics are needed by the wider community, therefore investigation on antibiotics production from various microorganisms needs to be performed. Since thermophilic bacteria survive at high temperatures, hot springs are one of their habitats which can be found in several parts of Indonesia [17] due to having a lot of geothermal activity and high biodiversity. This country also has the largest geothermal resources in the world, with 252 locations spread across 26 provinces [18][19], hence one of the sources of hot springs is in North Sumatra. Moreover, thermophilic microorganisms have the potential to synthesize antimicrobial compounds as a candidate for antibiotic production. The isolated and identified bacteria, namely *Bacillus subtilis* UTMP11, *Bacillus subtilis*UTMP12, *Bacillus tequilensis*UTMP14, *Bacillus tequilensis*UTMSA14, and *Bacillus subtilis* UTMP15 were previously reported to produce enzymes such as inulinase, protease, cellulase, and carbohydrase [20][21][22]. Moreover, antimicrobial activity tests have never been conducted, therefore this study aims to examine antimicrobial activity using the thermophilic bacteria isolated from hot springs in North Sumatra for antibiotic production.

II. MATERIALS AND METHODS

II.1 THERMOPHILIC ISOLATE SAMPLING

The samples used were obtained from a collection of thermophilic bacteria isolates from the molecular biology laboratory of Prima Indonesia University with the code *Bacillus subtilis* UTMP11, *Bacillus subtilis*UTMP12, *Bacillus tequilensis*UTMP14, *Bacillustequilensis*UTMSA14, and *Bacillus subtilis* UTMP15.

II.2 BIOCHEMICAL AND MORPHOLOGICAL CHARACTERIZATION

The thermophilic bacteria were characterized biochemically and morphologically in terms of color, size, colony shape, edges, elevation, gram staining, motility, catalase, citrate, and starch hydrolysis.

II.3 ISOLATION OF THERMOPHILIC BACTERIAL CULTURE

A total of 10ml of NutrientAgar medium was poured and solidified in a petri dish. Thermophilic bacteria were cultured on the solid media using the quadrant streak plate method by taking 1 tube of pure bacterial culture and scratching it on the media surface, then incubated at 45°C for 24 hours.

II.4 ANTIBIOTIC PRODUCTION MEDIA

Synthetic media consisting of 5.0g L-glutamic acid, 0.01g $CuSO_4.7H_2O$, 0.015g $CaCl_2.2H_2O$, 0.01g $FeSO_4.7H_2O$, 0.5g KH_2PO_4, 0.5g K_2HPO_4, 0.2g $MgSO_4.7H_2O$, 0.01g $MnSO_4.H_2O$, 0.01g NaCl, &1% glucose of the total production medium, weighed and dissolved in 1 liter sterile distilled water in an Erlenmeyer flask, was used as the antibiotic production media. Furthermore, up to 30ml of the antibiotic production media was filtered with a sterile Millipore filter and inserted into each of the flasks (50ml). Thermophilic bacteria inoculum was prepared in NB (Nutrient Broth) liquid media, then putintoeach test tube, and incubated at 45°C for 24 hours (10% inoculum in liquid media). Inoculum NB was added into each of the previous flasks, then placed in a shaker incubator that was run at a speed of 150rpm at 45°C. Every 24 hours, samples were collected for up to 72 hours, by pipetting 10 times (10ml) using a micropipette into each Eppendorf tube (sterile), followed by centrifuging for 10 minutes at 10,000 rpm to obtain a cell-free supernatant. Afterward,the cell-free supernatant were removed from the Eppendorf tube using a 10ml syringe & filtered again using a Millipore filter (disposable), then put inside a sterile test tube, and stored in the refrigerator. In the process of making antibiotic production media, the tools and materials used need to be sterile [23].

II.5 ANTIMICROBIAL ACTIVITY

About 10 ml of sterile NA (Nutrient Agar) media was poured into a petri dish until it solidified. The sterile cotton swab dipped in the test bacteria suspension was swabbed evenly on the surface of the media in a petri dish using the disk diffusion method. Next, the blank disks were dipped into each of the supernatants which was later placed on the surface of the swabbed media. This was followed by incubation for 24 hours in an incubator at 37°C. The results were observed and the visible clear zone was calculated using a caliper. Antimicrobial activity test was performed in triplicate in each sample, with observations within 24, 48, and 72 hours or for 3 consecutive days [24].

II.6 EFFECT OF INCUBATION TIME

Samples were incubated at 45°C in an incubator by setting a speed of 150rpm and they were taken for 24 hours from 0 to 72 hours. Cell-free supernatants from the samples were obtained at different times and used against test bacteria such as *Escherichia coli*&*Staphylococcus aureus*, then the clear zone formed around the bacterial colonies was measured [23].

III. RESULTS AND DISCUSSIONS

Results from the morphological and biochemical characterization *of Bacillus subtilis* UTMP11, *Bacillus subtilis* UTMP12, *Bacillus tequilensis* UTMP14, *Bacillus tequilensis* UTMSA14, and *Bacillus subtilis* UTMP15 can be seen in Tables 1 and 2, as well as Figures 1, 2, & 3.

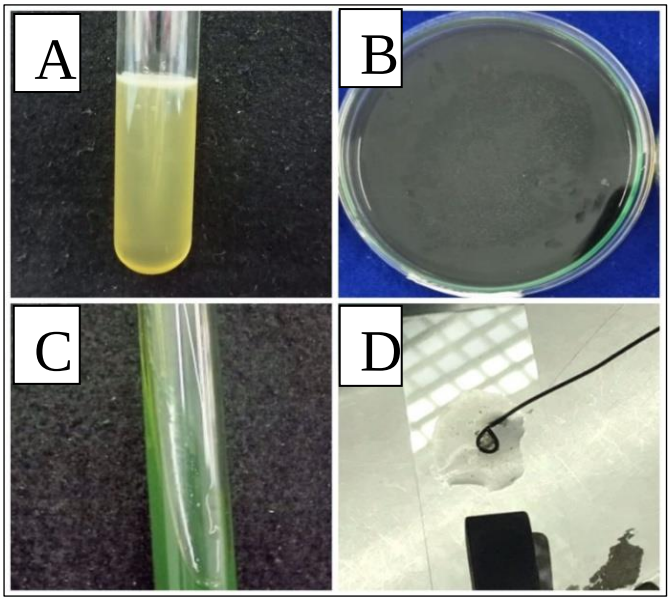

Figure 1: Results of biochemical characterization tests for *Bacillus subtilis* UTMP11, *Bacillus subtilis* UTMP12, *Bacillus tequilensis* UTMP14, *Bacillus subtilis* UTMP15 and *Bacillus tequilensis* UTMSA14 consisting of (a) motility, (b) starch hydrolysis, (c) citrate, and (d) catalase tests.
Source: Authors, (2021).

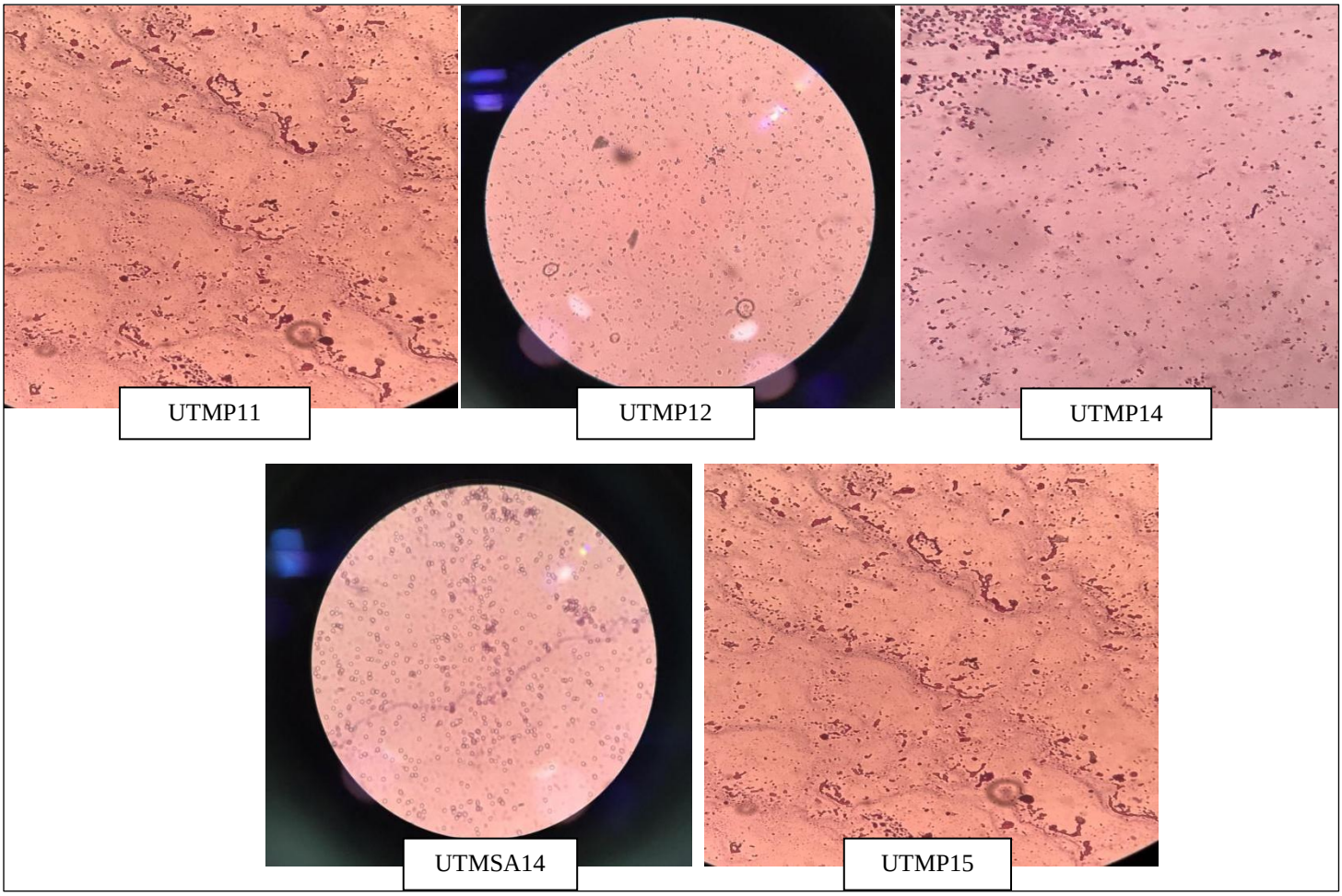

Figure 2: Morphological test results for microscopic observations of *Bacillus subtilis* UTMP11, *Bacillus subtilis* UTMP12, *Bacillus tequilensis* UTMP14, *Bacillus tequilensis* UTMSA14 and *Bacillus subtilis* UTMP15.
Source: Authors, (2021).

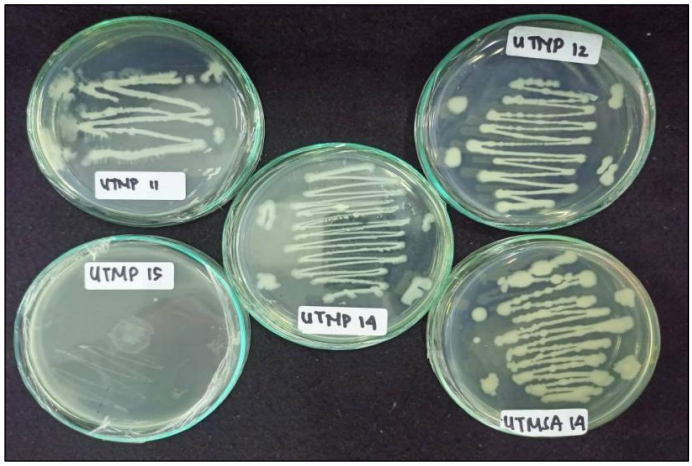

Figure 3: Culture results for macroscopic observations of *Bacillus subtilis* UTMP11, *Bacillus subtilis* UTMP12, *Bacillus tequilensis* UTMP14, *Bacillus tequilensis*UTMSA14, and *Bacillus subtilis* UTMP15 culture in NA (Nutrient Agar) media.
Source: Authors, (2021).

Table 1: Biochemical characterization of *Bacillus subtilis* UTMP11, *Bacillus subtilis* UTMP12, *Bacillus tequilensis* UTMP14, *Bacillus tequilensis* UTMSA14, and *Bacillus subtilis* UTMP15.

Isolates code	Motility test	Starch hydrolysis test	Citrate test	Catalase test
*Bacillus subtilis*UTMP11	+	-	-	-
*Bacillus subtilis*UTMP12	+	-	-	-
Bacillus tequilensis UTMP14	+	-	-	-
*Bacillus tequilensis*UTMSA14	+	-	-	-
*Bacillus subtilis*UTMP15	+	-	-	-

Source: Authors, (2021).

Table 2: Microscopic and macroscopic morphological tests for *Bacillus subtilis* UTMP11, *Bacillus subtilis* UTMP12, *Bacillus tequilensis* UTMP14, *Bacillus tequilensis* UTMSA14, and *Bacillus subtilis* UTMP15.

Isolates Code	Colony Morphology in Nutrient AgarMedia						
	Colony Shape	Colony Edges	Colony Elevation	Colony Size	Cell Color	Cell Shape	Gram Staining
Bacillus subtilis UTMP11	Filamentous	Filamentous	Convex	Moderate	Purple	Coccus	Gram-Positive
Bacillus subtilis UTMP12	Irregular	Undulate	Convex	Moderate	Purple	Coccus	Gram-Positive
Bacillus tequilensis UTMP14	Filamentous	Filamentous	Convex	Moderate	Purple	Coccus	Gram-Positive
Bacillus tequilensis UTMSA14	Irregular	Undulate	Convex	Moderate	Purple	Coccus	Gram-Positive
Bacillus subtilis UTMP15	Irregular	Undulate	Convex	Small	Purple	Coccus	Gram-Positive

Source: Authors, (2021).

Isolates *Bacillus subtilis* UTMP11, *Bacillus subtilis* UTMP12, *Bacillus tequilensis* UTMP14, *Bacillus tequilensis* UTMSA14, and *Bacillus subtilis* UTMP15 showed positive results on motility tests and negative on starch hydrolysis, citrate & catalase tests. The positive results characterized by the presence of culture spreading out of the inoculation line in the motility media indol sulfide proved bacterial motility [22]. Meanwhile, the negative results on starch hydrolysis tests characterized by the non-formation of clear zones around bacterial colonies during iodine solution administration indicated the absence of the hydrolysis process. Negative results on the citrate test were characterized by the absence of color changes,causing the media to remain green.Citrate tests are used ininvestigating the ability of microorganisms to use citrate. Meanwhile, the negative catalase tests were characterized by the absence of a reaction to gas bubbles' emergence. Catalase tests are performed to determine whether the test organism produces this enzyme.

The results of microscopic morphological tests seen in Table 2 and Figure 2 for the five isolates were obtained on gram-positive bacteria, with coccus cell shape and purple color. Having a thick peptidoglycan layer allows gram-positive organisms to maintain the crystal violet-iodine complex and their cell is stained as a purple color. The macroscopic test results, as seen in Figure 3 and Table 2, showed that irregular colony forms are more dominant than filamentous shapes. The edges of the colony undulate are more dominant in the aforementioned isolates than filamentous and they had convex elevation. In terms of size, 4 isolates codes show moderate colony and 1 indicates a small colony.

Bacteria of the genus *Bacillus* are a group characterized by the ability to produce strong spores and can be found in soil, water, or air [25]. *Bacillus* strains have biotherapeutic potential to interact with the host'sinternal environment by producing a variety of antimicrobial peptides and small extracellular effector molecules. They are also gram-positive, rod-shaped, spore-forming, and aerobic or facultative anaerobic bacteria that are found in soil, air, water, intestines of humans and animals, as well as from vegetables &and foods [26]. *B. subtilis* is the most prolific species which devotes 4-5% of its genome to synthesis, producing 66 antibiotics.Hence, 795 antibiotics have been identified from *Bacillus* species mainly frompeptides [25][27].

Commercially,*B. subtilis* is very important because it produces secondary metabolites in high and diverse quantities such as antibiotics, chemicals, and enzymes, as well as heterologous proteins, antigens, & vaccines to avoid being harmful to mammals including humans [25][28]. This bacterium grows in many environments and exhibits considerable genomic diversity. Therefore, the marine products *sp.*Hasa variety of secondary metabolites (lipopeptides,polypeptides,macrolactones, fatty acids, polyketides, lipoamides, and isocoumarins) [29]. There is a 99% similarity between *B. tequilensis* and *B. subtilis* based on the 16S rRNA gene sequence. *B. tequilensis* grows anaerobically, degrades tryptophan & starch but not urea, and uses citrate as a carbon source, while the motile, oxidase &catalase tests are positive.In addition, it withstands salt concentrations up to 8% physiologically and is gram-positive spore-forming [30].

III.1 ANTIMICROBIAL ACTIVITY

In this case, all thermophilic bacterial isolates with codes *Bacillus subtilis* UTMP11, *Bacillus subtilis* UTMP12, *Bacillus tequilensis* UTMP14, *Bacillus tequilensis* UTMSA14, and *Bacillus subtilis* UTMP15 were tested for inhibition zone to determine whether they had antimicrobial activity in the sample to inhibit the growth of pathogenic bacteria that were used as test bacteria namely *Escherichia coli* and *Staphylococcus aureus.*

Table 3: Zone of inhibition results for the thermophilic bacteria isolates against pathogenic bacteria (disk diameter = 6mm).

No.	Isolates code	Zone of inhibition (mm) (disk diameter = 6mm)					
		Escherichia coli			*Staphylococcus aureus*		
		24 Hours	48 Hours	72 Hours	24Hours	48 Hours	72 Hours
1.	*Bacillus subtilis*UTMP11	7.87	7.71	6.73	9.17	8.54	7.91
2.	*Bacillus subtilis*UTMP12	7.96	8.59	7.47	9.56	9.27	8.28
3.	*Bacillus tequilensis*UTMP14	7.55	7.74	6.0	8.52	7.86	7.84
4.	*Bacillus tequilensis*UTMSA14	7.53	7.82	7.46	8.80	8.64	8.2
5.	*Bacillus subtilis*UTMP15	7.14	7.85	7.72	10.27	8.32	8.90

Source: Authors, (2021).

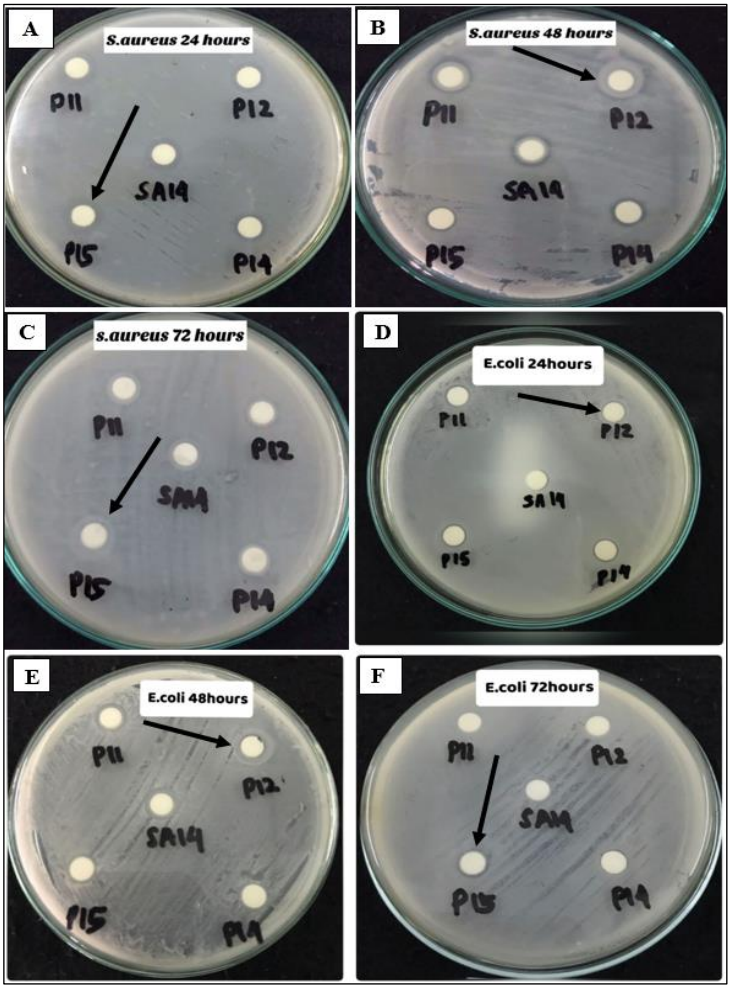

Figure 4: The results of the inhibition zone test for *Bacillus subtilis* UTMP11, *Bacillus subtilis* UTMP12, *Bacillus tequilensis* UTMP14, *Bacillus tequilensis* UTMSA14, and *Bacillus subtilis* UTMP15, where black arrows indicate a stronger inhibition zone at (a) 24 hours of *S.aureus* inhibition, (b) 48 hours of *S. aureus* inhibition, (c) 72 hours of *S. aureus* inhibition, (d) 24 hours of *E. coli* inhibition, and (e) 72 hours of *E. coli* inhibition.
Source: Authors, (2021).

Table 4 and Figure 4 show the results of the five isolates' zone of inhibition against pathogenic bacteria. The diameter of zone of inhibition against *Staphylococcus aureus* at incubation times of24, 48, and 72 hours was between 7.84 mm – 10.27 mm (disk diameter = 6mm), where the strongest was in *the Bacillus subtilis* UTMP15 at 24 hours and the weakest was in *the Bacillus tequilensis* UTMP14 at 72 hours. The diameter of the zone of inhibition against*Escherichia coli*at the same incubation time as the previous was between 6.0 mm – 8.59 mm (disk diameter = 6mm), where the strongest zone was in the *Bacillus subtilis* UTMP12 at 48 hours and the weakest was in the *Bacillus tequilensis* UTMP14 at 72 hours. *Bacillus subtilis* UTMP15 had better antimicrobial activity on *Staphylococcus aureus* than *Bacillus subtilis* UTMP12 tested with *Escherichia coli.*Furthermore, its zone of inhibition against *Staphylococcus aureus* was 10.27 mm (disk diameter = 6mm) while *Bacillus subtilis* UTMP12 was had 8.59 mm (disk diameter = 6mm). The results showed a stronger antimicrobial activity was exerted against the *Staphylococcus aureus* compared to *Escherichia coli.* This is also supported by Syukur Sumaryanti et al (2016) that stated *Staphylococcus aureus* is included in gram-positive bacteria which have a larger zone of inhibition usually when compared to gram-negative bacteria. This is due to several resistance mechanisms such as, the nature of the permeability barrier which in the outer layer inhibits an antimicrobial compound's entry. Another mechanism also disables the specific resistance of the compound to prevent cytoplasmic membrane penetration or intracellular increases [31].

The cell envelope of gram-positive bacteria consists of an inner plasma membrane surrounded by a permeable cell wall (not restrictive to antibiotics diffusion into the cell), and a thick layer of peptidoglycan, composed of an outer layer of cells, in contrast to gram-negative bacteria which have a distant peptidoglycan layer. Furthermore, it is surrounded by a second membrane consisting of a phospholipid and lipopolysaccharide (LPS) double layer called the outer membrane which serves to provide extra protection for the cell and plays a major role in preventing the diffusion of hydrophobic molecules, including many antibiotics, into the cell to ensure these compounds only enter through selective porins, providing intrinsic resistance [32].

The results in table 3 show the strongest zone of inhibition in pathogenic bacteria *Staphylococcus aureus* and *Escherichia coli* at 24 and 48 hours compared to the incubation time of 72 hours. These observations are supported by a report from Syed Aun Muhammad (2009) which conducted an inhibition zone test and examined antimicrobial activity in *Bacillus* SAT4, where the strongest activity (24mm) was obtained at the incubation time of 24 hours and 48 hours [23].

Some of the factors constituting the inhibition zone are described by Muaaz *et al* (2007) which said, at an incubation time of 48 hours in sample bacteria, a relatively large zone of inhibition is produced. Therefore, it can be interpreted that the antimicrobial compounds synthesized are derived from secondary metabolites. In other studies, Ren *et al* (2010) reported that strains of bacteria isolates from extreme habitats such as thermophiles derived from hot water temperatures exhibit antimicrobial activity against some common pathogenic bacteria such as. *S.aureus* which are classified as gram-positive. The antimicrobial activity at 45°C is indicative of the isolates' thermotolerant properties as well as their antimicrobial compounds. Moreover, the antimicrobial activity from bacteria with extreme temperatures shows the possibility of bioprospecting these organisms for use [33]. Glucose is one of the factors in inhibition zone formation where the effect of its concentration on antibiotic production is studied and increased concentration is found to have a positive effect. Also, as an excellent source of carbon for bacterial growth, it interferes with the synthesis of many secondary metabolites. In some microorganisms, the inhibition effect of this molecule has been associated with a decrease in pH and is due to the acidification caused by organic acids accumulation [23].

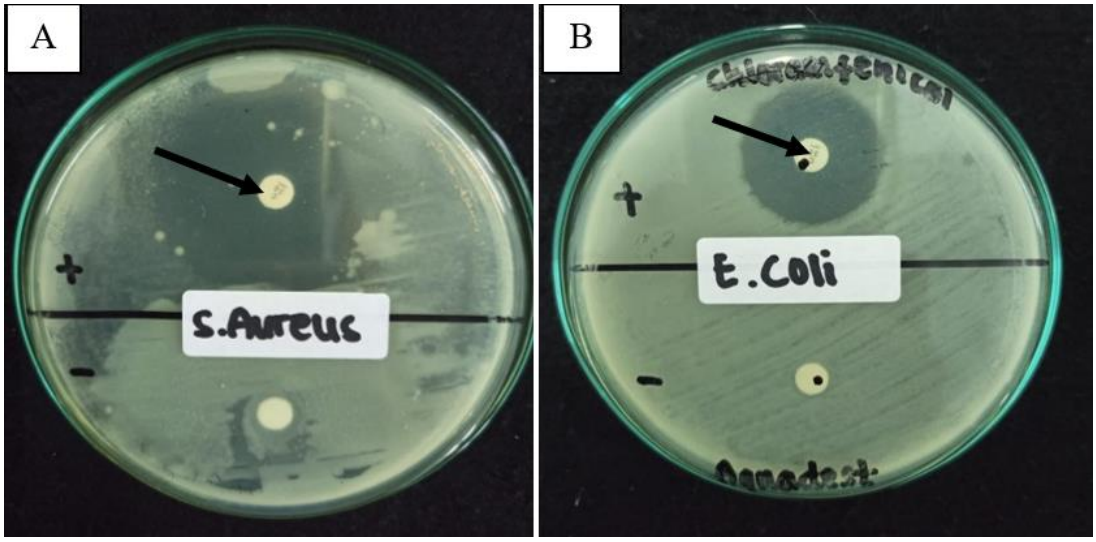

Figure 5: Test results for (a) *Staphylococcus aureus* and (b) *Escherichia coli* bacteria, where positive control used chloramphenicol antibiotic discs with a concentration of 30 and negative controls employed aquadest. The black arrow indicates the inhibition zone in the positive control test with the chloramphenicol used against both bacteria.
Source: Authors, (2021).

According to Figure 5, in the positive control test performed using a disc of antibiotic chloramphenicol with a concentration of 30, clear zones were formed in the *Staphylococcus aureus* and *Escherichia coli*. In the negative control where blank disks that have previously been dipped in the aquadest were employed, no clear zone was formed.

IV. CONCLUSIONS

Based on the results, thermophilic bacteria namely *Bacillus subtilis* and *tequilensis* species are potential producers of antimicrobials. They can be used for this purpose due to being stable at higher temperatures and having the strongest antimicrobial activity against gram-positive bacteria. Moreover, the strongest zone of inhibition against *Staphylococcus aureus* is in *the Bacillus subtilis* UTMP15 at an incubation time of 24 hours at 45ºC, while that of *E. coli* is in *Bacillus subtilis* UTMP12 at 48 hours within the same temperature. Compared to *E.coli* which is classified as gram-negative, the strongest antimicrobial activity against *S.aureus* classified as gram-positive bacteria is in *B.subtilis* UTMP15 (10.27 mm) at 24 hours, hence the isolate is a potential antimicrobial agent.

V. AUTHOR'S CONTRIBUTION

Conceptualization: Helmi Andriyani,Natacia and Edy Fachrial.
Methodology: Edy Fachrial.
Investigation: Helmi Andriyani and Natacia.
Discussion of results: Helmi Andriyani, Natacia and Edy Fachrial.
Writing – Original Draft: Helmi Andriyani and Natacia.
Writing – Review and Editing: Helmi Andriyani,Natacia and Edy Fachrial.
Resources: Helmi Andriyani, Natacia, and Edy Fachrial.
Supervision: Edy Fachrial.
Approval of the final text: Edy Fachrial.

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RESEARCH ARTICLE OPEN ACCESS

EFFECTS OF LUBRICOOLING CONDITIONS ON MACHINING FORCES AND SURFACE ROUGHNESS IN RADIAL GROOVING

Elias S. C. Espindola[1], Heraldo J. Amorim[2] and André J. Souza*[3]

[1, 2, 3] Department of Mechanical Engineering (DEMEC), Federal University of Rio Grande do Sul (UFRGS), Porto Alegre, Rio Grande do Sul, Brazil.

[1] http://orcid.org/0000-0003-2845-4373, [2] http://orcid.org/0000-0002-0498-6378, [3] http://orcid.org/0000-0001-5649-7333

Email: eliasespindola.engenheiro@gmail.com, amorim@mecanica.ufrgs.br, *ajsouza@ufrgs.br

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ABSTRACT

Radial grooving is a machining process usually applied to generate grooves for thread relief, O-ring positioning, or even cutting-off operations. Due to the high machining forces and difficult chip removal, radial grooving is considered a critical process, and cutting fluids are usually applied for cooling, lubricating, and assistance on the chip removal. Compressed air (AIR) and minimum quantity lubrication (MQL) are lubri-cooling methods studied as environmentally-friendly alternatives to conventional flood (WET) applications of cutting fluids. Although already applied for years in several machining processes, the research associated with using alternative lubri-cooling techniques in radial grooving is incipient. This work presents a comparative analysis of these methods (WET, MQL, and AIR) and their radial grooving effects. In each case, a factorial design of experiments was used to evaluate the influence of lubri-cooling conditions, cutting speed, and feed rate over feed force, cutting force, and surface roughness. Results indicate that both AIR and MQL may be suitable substitutes for traditional WET lubrication when active force components and surface finish are considered. Besides, smaller cutting forces were obtained with AIR machining for radial grooving, followed by MQL and WET machining.

I. INTRODUCTION

Radial grooving is a variation of turning where the tool moves in the radial direction towards the rotation axis of the part. The main applications of this machining process are the production of radial grooves, e.g., to provide thread relief or to position O-rings [1], and parting-off. If this process is carried out until the rotation axis, the workpiece is separated into two parts, and the process is then called parting-off. The main process parameters in radial grooving are cutting speed (v_c), feed rate (f), and depth of cut (a_p). While f occurs in the radial direction, a_p is usually defined by the length of the main cutting edge (except in "partial grooving", where only a fraction of the cutting edge is used). Grooving and parting-off processes are subjected to several problems such as excessive forces, vibrations, and difficult chip removal.

In the radial grooving and parting-off process, the main cutting edge and both secondary flanks are in simultaneous contact with the workpiece. Thus, forces and heat generation concentrate on the weakest region of the cutting tool, making radial grooving a critical operation. Figure 1 presents a schematic representation of the orthogonal components of the machining force in the radial grooving and parting-off process. The vector sum of feed force (i.e., radial force F_x) and cutting force (i.e., tangential force F_y) denote the active force in the work plane. Both F_x and F_y are associated with relative tool/part movements. Passive force (i.e., axial force F_z) is related to possible deformations, strains, and vibrations experienced by the cutting tool in a direction orthogonal to the work plane.

Cutting fluids are commonly used to reduce the adverse effects of heat and friction on the tool and workpiece [2]. The primary functions of cutting fluid in radial grooving are heat removal and lubrication, thus reducing temperatures and friction in the tool-workpiece and tool-chip contact interfaces. However, cutting fluids can also represent a considerable threat to humans and the environment. Cutting fluid additives such as bactericides and fungicides, combined with reaction products originating from the cutting fluid and contaminants, may cause diseases. Also, the growth of microorganisms may degrade the quality of cutting fluids and pose health risks to workers [3]. The excessive increase in costs related to the use and disposal of cutting fluids, combined with new

laws concerning environmental and health protection, led to in-depth scientific research on green machining [1]. Dahmus and Gutowski [4] report that, although environmental concerns related to material removal rate are focused on power consumption, the environmental problems related to cutting fluid preparations and cleaning are tied more closely to the liquid and hazardous waste that may cause issues in both local and global levels.

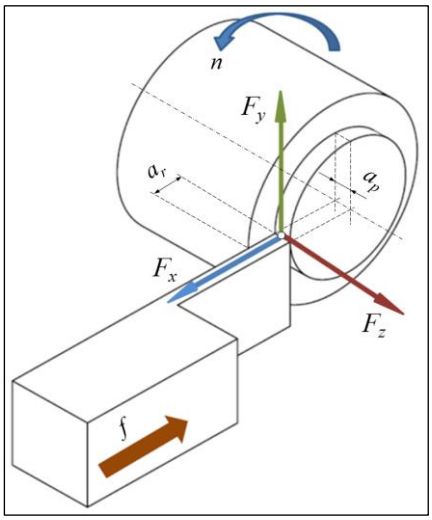

Figure 1: Schematic representation of the orthogonal components of machining force in single grooving (SG): cutting force (F_y), feed force (F_x), and passive force (F_z).
Source: Authors, (2021).

Considering the necessity of protecting humans and the environment, the focus on cutting fluids changed over the years, from biodegradation to renewability. Several techniques were developed to control the temperature in the cutting zone for enhancing machining performance, like solid lubricants, minimum quantity lubrication (MQL), near dry machining, high-pressure coolant, internal tool-cooling, compressed air/gas cooling, and cryogenic cooling [5]. Moreover, techniques aiming at reducing the use of cutting fluids, as MQL, or even eliminate their use as DRY cutting or compressed air-cooling (CAC) machining have received considerable attention. DRY and MQL techniques, classified as friendly to the environment, have been successfully applied in several machining processes [6, 7]. Otherwise, the use of vegetable oils as cutting fluids is also studied to reduce the environmental impact of the machining processes [8-11].

In MQL machining, minimal quantities of cutting fluid, usually a straight oil, are applied to the cutting area. With MQL, the combination of DRY cutting advantages (i.e., low cost and clean production) with benefits of flood (WET) machining (i.e., lubrication, cooling, and chip removal) is very well achieved. Ranganath and Vipin [12] cite that when only surface roughness and cutting force are considered, MQL turning offers more advantages than WET turning.

According to Varghese et al. [13], the general use of cutting fluids offers inadequate temperature reduction in the machining of advanced engineering materials since they do not effectively reach the tool-chip interface. Dhar et al. [14] observed that the use of MQL allowed a substantial reduction of temperature in the cutting zone and resulted in better accuracy in turning of AISI 1040 steel. Lohar and Nanavaty [15] presented similar results, in whose smaller forces and temperatures and better surface finish were noticed in hard turning of AISI 4140 with MQL compared with DRY and WET turning using CBN tools. Kurgin et al. [16] evaluated the convective heat transfer coefficient for different lubri-cooling conditions and concluded that the mist oil volume does not significantly influence the convective heat transfer, therefore strongly dependent on the air pressure. However, the same study observed that convective cooling is not as significant for temperature reduction in machining as the presence of oil, concluding that the lubricating effect of MQL is more critical than convective cooling for temperature reduction. Islam [17] obtained lower average roughness (R_a) values for MQL than DRY and WET machining in turning AISI 1030 steel. Frăţilă and Caizar [18] found no relevant differences between the surface roughness of AISI 1045 after DRY, WET, and MQL turning. However, Tasdelen et al. [19] studied the contact length of chips in orthogonal cutting with different lubri-cooling methods. They concluded that MQL and CAC are potential candidates for grooving and parting-off due to the narrower chips noted after machining with these lubri-cooling methods, especially when compared with DRY cutting.

Better surface finishes were also associated with MQL in the hard turning of AISI 4340 steel [20, 21]. Okokpujie et al. [22] concluded that MQL is the best lubri-cooling technique, but there is still necessary to develop a single technique that can multi-deliver lubricant with efficient performance.

Several studies focused on the effect of the characteristics of the MQL over the machining results. Masoudi et al. [23] compared MQL turning with different nozzle positioning, finding better outcomes for the simultaneous cutting fluid application in the tool flank and rake face. When only one nozzle is used, better results were found when the rake face receives the MQL. Rahim and Dorairaju [24] studied the influences of the nozzle size and positioning for MQL turning and concluded that a wider nozzle provides better cooling and reduction of cutting forces. Another study also focuses on the characteristics of the MQL oil and its influence on the machining results. Sani et al. [25] evaluated the performance of some lubricant mixtures supplied via MQL in the orthogonal cutting of AISI 1045 steel and found a reduction of 4-5% in the cutting force, 7-10% in cutting temperature, and 8-11% in tool-chip contact length.

WET and MQL applications in machining have issues related to fluid disposal and mist generation, respectively. While the former is usually associated with environmental hazards and pollutions, the second might cause health problems to operators [26], which may, fortunately, be eliminated with mist extractors. Considering the limitations of both WET and MQL conditions, the challenge for researchers is to achieve environmentally-friendly machining without sacrificing process performance. Gas-cooled machining is a technique that may allow the industry to achieve these goals: it does not have any adverse effect on health and can be regarded as an alternative to WET machining [27].

Gas coolants are generally referred to as substances in the gaseous form at room temperature and are regarded as environmentally friendly. The CAC machining is a particular case of gas-cooled systems. In addition to being clean, this technique can be readily implemented since air is a natural resource and is available in the desired form in most floor-shop industries.

Stanford et al. [28] studied the use of gases, including compressed air (AIR) and nitrogen (gas N_2 and liquid LN_2) cooling in turning of EN32B (SAE 1016) steel. AIR machining resulted in a lower formation of crater wear compared to DRY cutting and N_2 cooling. Also, machining forces were lower in turning with AIR than with N_2 cooling and flood (WET) machining. Likewise, it was observed that oxygen generates a low lubricating effect in the cutting zone for continuous cutting operations. Sarma and Dixit [29] studied the DRY and AIR turning performance of grey cast iron with mixed ceramic insert. The authors noted that, compared with DRY cutting, AIR reduced both cutting force and feed force.

Additionally, AIR machining significantly reduced the flank wear rate and allowed higher tool life at high cutting speeds (at least 400 $m \cdot min^{-1}$), thus being an economical and sustainable option.

Cryogenics express the utilization and study of materials at temperatures below −150 °C and have several industrial applications. The application of these extremely low temperatures in machining is called cryogenic (cryo) machining [30]. The most common cryogenic coolants are liquid nitrogen (LN_2), liquid carbon dioxide (LCO_2), and liquid helium (LHe). However, CO_2 is a greenhouse effect gas and is considered an air pollutant [31]. Due to the lower temperatures achieved, most studies involving cryo-machining concentrate on difficult-to-cut heat-resistant alloys [32, 33]. Nevertheless, some studies evaluated cryogenic cooling in machining AISI 1045 steel [34, 35].

Despite the increasing number of papers approaching DRY or near dry machining (NDM), research involving alternative lubri-cooling techniques in radial grooving is incipient. Obikawa et al. [36] compared MQL, DRY, and WET grooving of a 0.45% C steel and concluded that the lubrication at the tool-chip interface is strongly affected by the transportation mechanism of the oil into the interface. Machai et al. [37] compared the effect of various lubri-cooling techniques on the grooving of different tempers of β-titanium alloy, achieving higher tool lives with MQL and LCO_2.

Thus, this paper presents a comparative study of the effects of different lubri-cooling methods in radial grooving. The study focuses on the influence of minimum quantity lubricant (MQL), compressed air (AIR), and conventional flood (WET) machining on the active components of the machining force and surface roughness of the groove walls in single grooving (SG) and partial grooving (PG). Tests were performed with three different cutting speeds and feed rates to verify the feasibility of using sustainable cooling methods in different machining conditions.

II. MATERIALS AND METHODS

The experimental procedure consisted of the machining of radial grooves in cylindrical workpieces. Due to the low quantity of research papers concerning radial grooving, it was decided to use a material whose machining behavior was well documented, especially in turning. For this reason, the runs were performed in cylindrical parts of 170 HV AISI 1045 steel. Grooving runs were carried out on a CNC lathe Mazak QTN 100-II, with 3.0 mm wide PVD-TiAlN/TiN coated carbide inserts (Sandvik N123F2-0250-0002-CM 4125) and a LF123F20 2020B tool holder.

In order to enable the assessment of surface roughness in inner faces, 8 mm wide grooves were machined in 50.8 mm diameter workpieces, resulting in three plunges. The first plunge consisted of a single grooving (SG), where the depth of cut was defined by tool width (3.0 mm). The second and third plunges were done with a_p = 2.5 mm. In this case, only one secondary cutting edge contacted the workpiece; this variation of the cutting process is named in this paper as "partial grooving" (PG). Surface finish for a_p = 3.0 mm was measured in Face#1 of each groove, while Face#2 was generated with a_p = 2.5 mm. Each workpiece (Fig. 2) allowed the machining of three grooves.

Three lubri-cooling conditions were tested: flood (WET), with BD-Fluid B90 water-miscible bio-lubricant at 20% wt. and 720 $l \cdot h^{-1}$ flowrate; MQL, with Quimatic Jet water-based synthetic fluid applied at 400 kPa with 0.24 $l \cdot h^{-1}$ flowrate; and compressed air (AIR), provided at 600 kPa and 2500 $l \cdot h^{-1}$ flowrate. BD-Fluid B90 is a biodegradable 100% oil-free bio-lubricant developed by the Bondmann Chemical Co. This cutting fluid allies high lubricity, similar to straight oils, with high cooling capacity without toxic steams. Since it was developed especially for MQL application with the Nebulizer IV sprinkler, Quimatic Jet was used for the MQL tests. It is a synthetic, water-based cutting fluid developed by the Tapmatic Co. This oil was selected due to its lubricating and cooling capabilities, noticed in recent publications [38, 39], and, according to the manufacturer, it is not hazardous to the machine operator or the environment. Nebulizer IV was fixed in the lathe turret during the experiments, and the spray nozzle was positioned 25 mm from the tool cutting edge. AIR was also delivered through the Nebulizer IV system, in the same position used for MQL. Figure 3a presents the cutting fluid supply placed for the WET machining tests, and Figure 3b shows the positioning of the nebulizer nozzle for MQL and AIR machining tests.

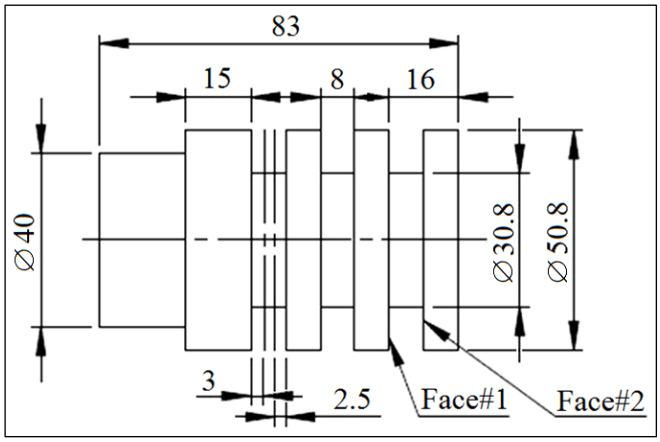

Figure 2: Workpiece geometry and dimensions (mm).
Source: Authors, (2021).

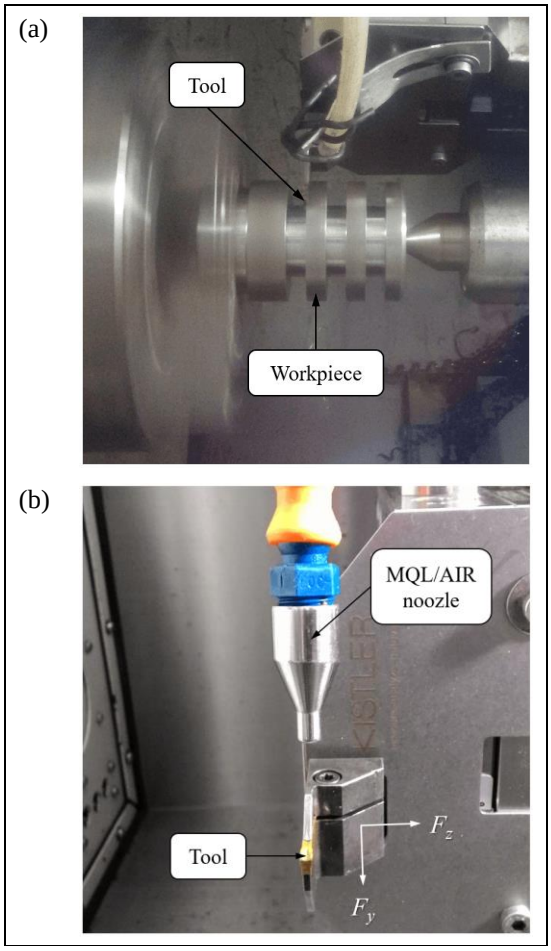

Figure 3: Experimental setup: (a) positioning of cutting fluid hose for WET machining; (b) MQL/AIR nozzle positioning.
Source: Authors, (2021).

A factorial DOE (design of experiments) was used where three machining parameters (cutting speed, feed rate, and lubri-cooling condition) were tested at three levels, resulting in 27 treatments for each grooving type (single or partial grooving). Three replications were used, each in the same workpiece. The influence of tool wear was controlled using a new cutting edge for each tested condition. Table 1 presents the machining parameters used in the experiments.

Table 1: Machining parameters and conditions.

Input variables	Levels
Cutting speed (v_c)	150, 175, 200 m·min^{-1}
Feed rate (f)	0.05, 0.075, 0.1 mm·rev^{-1}
Depth of cut (a_p)	3.0 mm (SG), 2.5 mm (PG)
Groove depth (a_r)	10 mm
Lubri-cooling method	WET, MQL, AIR

Source: Authors, (2021).

The assessment of the orthogonal components of machining force (F_x, F_y, F_z) in radial grooving was carried out with a Monitor System composed of a Kistler® 9129A piezoelectric dynamometer, a Kistler 5070A charge amplifier, a Measurement Computing PCIM-DAS 1602/16 DAQ board, and a dedicated PC with LabVIEW 9.0. The data acquisition rate was set at 1 kHz, allowing for at least 30 samples per revolution.

The surface finishing of the machined grooves was evaluated through average (R_a) and total (R_t) roughness with a Mitutoyo SJ 201P roughness tester, using a 4 mm evaluating length with 0.8 mm sampling length according to DIN EN ISO 4288. The roughness of the machined surfaces was measured in three equidistant points around the workpiece circumference.

The influence of controllable input parameters over the response variables was investigated through the Analysis of Variance (ANOVA).

III. RESULTS AND DISCUSSIONS

III.1 ANALYSIS OF MACHINING FORCE

In this study, the active components of machining force were measured under different cutting conditions, defined through a factorial DOE. Figure 4a presents two-factor graphs of average feed forces (F_x) considering a_p = 3.0 mm (single grooving). F_x results for a_p = 2.5 mm (partial grooving) are presented in Figure 4b. In Figure 4c, F_x values are presented against cutting speed (v_c) for the lubri-cooling methods tested (WET, MQL, AIR) for single grooving (SG), while Figure 4d presents F_x against v_c for partial grooving (PG). Compared with the same cutting condition in WET machining, MQL presented feed forces 5.3% smaller on average, against 10.1% for AIR machining in PG. The worst result for feed forces in MQL machining for PG was observed for the tests performed with the lowest feed rate and cutting speed (+6.6%), and the best result (–17.8%) occurred with the most aggressive cutting condition, which indicates better penetration of lubricant in MQL than in conventional WET machining at high cutting speeds and feed rates. For the AIR condition, the best result in PG (–24.9%) was registered with a cutting speed of 150 m·min^{-1} and a feed rate of 0.1 mm·rev^{-1}, and the highest value of feed force (+3.7%) at the same v_c with f = 0.075 m·min^{-1}. Both AIR and MQL turning presented similar average differences from WET machining (–5.0% for AIR and –4.0% for MQL) in SG. As noted for PG, the worst result for MQL occurred with the mildest machining conditions (+14.1%) and the best result with the most aggressive condition (–17.1%), confirming the high performance of this lubri-cooling condition in higher cutting speeds. As for MQL tests, both best (–20.7%) and worst (+8.8%) relative results for AIR machining in SG occurred in the same conditions noticed for PG.

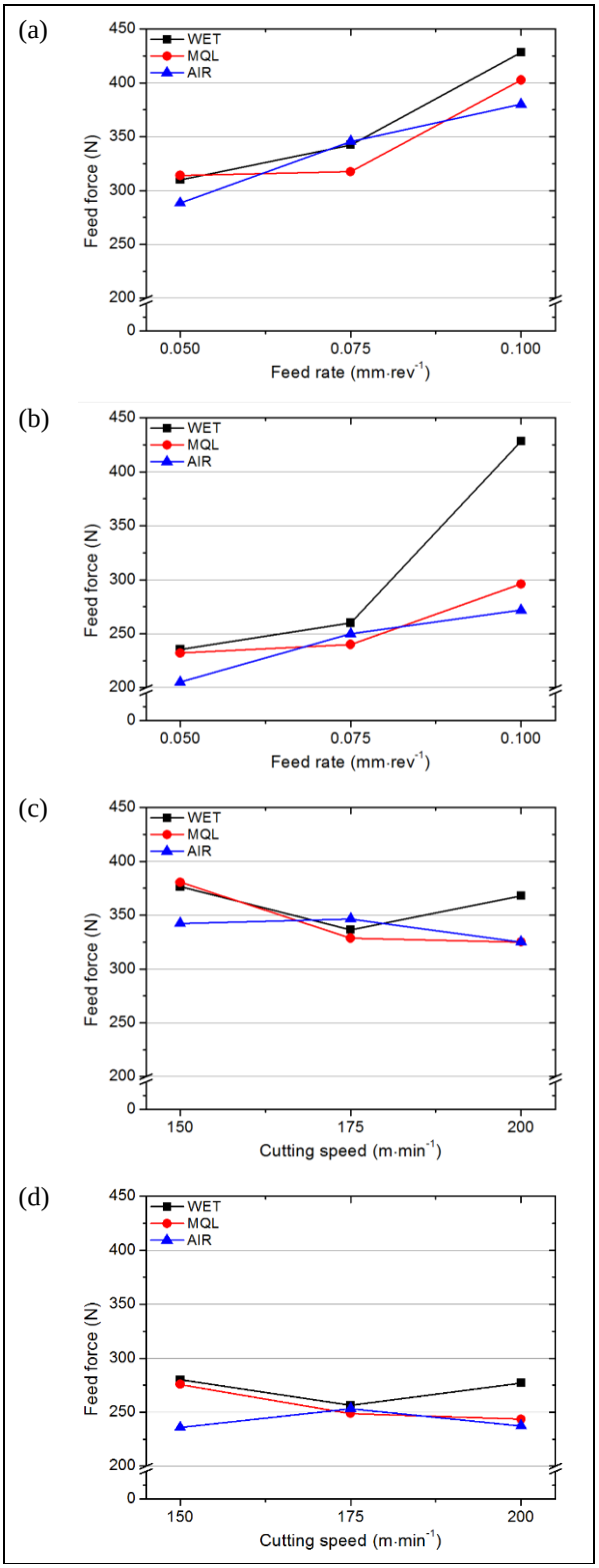

Figure 4: Average feed force (F_x) as a function of: (a) feed rate for SG; (b) feed rate for PG; (c) cutting speed for SG; (d) cutting speed for PG.
Source: Authors, (2021).

The ANOVA of the results indicated a significant influence of all evaluated parameters and interactions over feed force (F_x) for

both single grooving (SG) and partial grooving (PG). For the three lubri-cooling conditions, it was observed that F_x values rise with the increase of feed rate (f). Three different behaviors were identified for the three tested lubri-cooling conditions when the cutting speed (v_c) is considered: as v_c is increased from 150 to 175 m·min^{-1}, a decrease is noticed for F_x under MQL and WET machining. However, while a new increase to 200 m·min^{-1} shows low influence when MQL is used, it increases the F_x under WET machining. For SG, AIR machining results showed a slight increase from 150 to 175 m·min^{-1}, followed by a decrease of F_x when grooving with 200 m·min^{-1}. PG presented an initial growth of F_x, followed by a stable behavior between 175-200 m·min^{-1}.

Figure 5a presents two-factor graphs of average cutting force (F_y) against feed rate (f) for single grooving (SG). The equivalent plot for PG is presented in Figure 5b. As shown in Figure 4 for feed force (F_x), F_y values also increase with feed rate (f), but, in this case, the relationship appears to be linear for all the lubri-cooling methods evaluated. Since higher f implies the increase of the cutting section, the behavior observed for F_x and F_y is expected. Figure 5c presents the average F_y versus cutting speed (v_c) for SG, while Figure 5d presents the equivalent plot for PG. As noticed for F_x in Figure 4, each lubricant condition presented a distinct behavior, replicated on a different scale for SG and PG. The average differences between the cutting forces measured for the MQL condition, compared to AIR and WET, were –3.1% and –8.2% for PG, against –2.5% and –6.0% for SG. When comparing each value with the reference (WET machining in the same cutting condition), the worst average F_y for MQL was noted with the mildest machining condition (f = 0.05 mm·rev^{-1} and v_c = 150 m·min^{-1}) for both PG (+1.6%) and SG (+2.6%). The best results for MQL were also associated with the same condition (highest cutting force and feed rate) and were –5.6% for both PG and SG. These results indicate better performance of MQL at the higher levels of v_c and f tested, reinforcing the better access of lubricants in the cutting zone for this condition while evidencing that WET machining can perform better in low cutting speeds.

Compressed air (AIR) condition resulted in the lowest cutting forces (F_y) for all cutting speeds and feed rates, followed by MQL. This effect is explained by the thermal softening of workpiece material due to the higher temperatures related to compressed-AIR machining than the other lubri-cooling techniques tested [40, 41]. This effect can also be observed for feed force (F_x), especially for high cutting speeds. During machining with the highest v_c (200 m·min^{-1}), both AIR and MQL systems allowed significantly lower F_x values than WET machining. According to Hadad and Sadeghi [42], the more effortless penetration of oil droplets in the cutting zone that reduces the friction in tool-workpiece and tool-chip contact interfaces explains the high performance of the MQL system. Thus, there is a high probability that both AIR and MQL allow smaller cutting forces than WET machining due to different mechanisms.

The relation between cutting force and feed rate followed similar patterns for single grooving (SG) and partial grooving (PG), with minor scale differences observed for the results related to the different lubri-cooling techniques. As expected, the increase of feed rate (f) results in a proportional increase in the cutting section, with a proportional increase in the cutting force. On the other hand, no significant influence was noted between the cutting force and the cutting speed other than a slight reduction tendency with MQL. This result agrees with Amorim and Kunrath [43], which studied the relationship between cutting force and maximum flank wear in turning AISI 1045 steel with a carbide tool and found no significant influence of cutting speed (v_c).

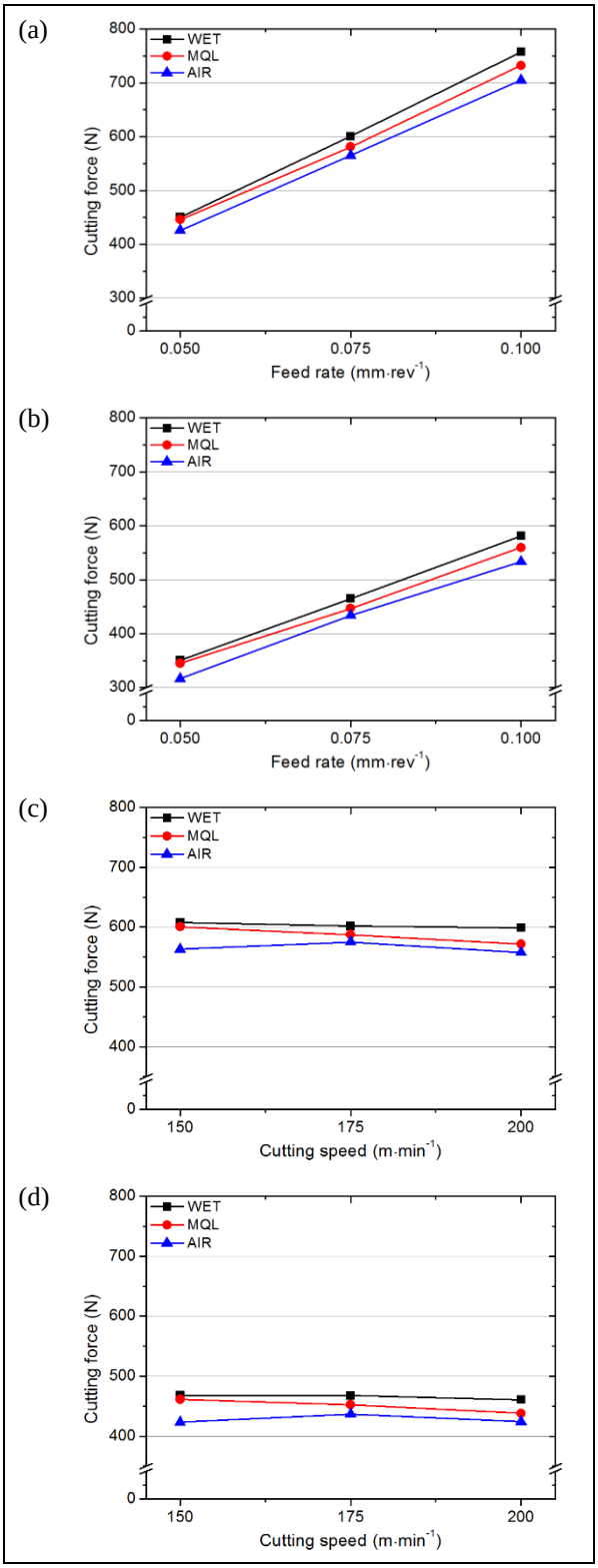

Figure 5: Average cutting force (F_y) as a function of: (a) feed rate for SG; (b) feed rate for PG; (c) cutting speed for SG; (d) cutting speed for PG.
Source: Authors, (2021).

The analysis of the results measured in SG and PG indicates similar feed force (F_x) and cutting force (F_y) behavior in both cutting operations. However, the differences were noticed when SG grooving was performed with a_p = 3.0 mm, while PG was executed with a_p = 2.5 mm. Despite the 16.7% reduction in the cutting section, an average reduction of 23.4% was observed in F_y. Probable causes for this difference are associated with higher

friction in SG due to the contact between the workpiece and the two secondary cutting edges and the easier chip removal in PG.

As mentioned, passive forces (F_z) represent possible vibrations, strains, and deformations experienced by the grooving tool. The main difference between single grooving (SG) and partial grooving (PG) is that, while the former has opposing F_z due to two tool corners in simultaneous cut, F_z in PG is not balanced, thus being susceptible to more significant fluctuation and generating vibrations that affect surface finish regardless of cutting parameters or lubricant condition.

Tests performed with WET grooving presented a decrease of average F_z as cutting speed (v_c) increases from 150 to 175 m·min^{-1}, followed by a rise from 175 to 200 m·min^{-1}. Testes carried out with AIR showed a slight increase of F_z from 150 to 175 m·min^{-1}, followed by decreasing these values at higher v_c. On the other hand, tests executed with MQL presented a slight decrease of F_z throughout the tests, with an apparent tendency to stabilize at higher v_c.

III.2 ANALYSIS OF MACHINED SURFACE ROUGHNESS

Surface roughness is a widely used quality parameter, usually a technical requirement for mechanical products [44]. Considering its importance as a project requirement, knowing the relationship between surface roughness and cutting conditions is extremely important to allow the machining parameters correctly. Thereby, this study measured the average (R_a) and total (R_t) roughness parameters under different cutting conditions, defined through a factorial DOE.

Figure 6a presents two-factor graphs of average roughness (R_a) versus feed rate (f) for the surface generated by single grooving (a_p = 3.0 mm) and Figure 6b for partial grooving (a_p = 2.5 mm). Despite the good agreement observed between the active force components' behavior, surface finish results for SG showed poor agreement with results obtained for PG. Similar results are presented for total roughness (R_t) against feed rate in Figure 6c and Figure 6d. The results presented in Figure 6a and Figure 6c indicate that higher roughness was obtained in SG using AIR machining, with WET and MQL machining resulting in statistically equivalent surface roughness (R_a and R_t) for all tested feed rates. For PG, similar behavior was observed for average roughness (R_a) after AIR and WET machining, while MQL resulted in a smaller R_a with f = 0.05 mm·rev^{-1} and higher R_a for the other feed rates. The behavior presented for total roughness (R_t) in Figure 6d agreed with the shown in Figure 6b for R_a with AIR and MQL. However, R_t for WET machining was significantly higher than those noted for tests performed with AIR.

The measured roughness values are plotted against cutting speed (v_c) for SG (a_p = 3.0 mm) and PG (a_p = 2.5 mm) in Figure 7. Both WET and MQL machining allowed smaller values of R_a than AIR for SG (in Fig. 7a) at all cutting speeds. Similar behavior was observed for R_t in Figure 7c. For PG, R_a varies between 2.9 µm and 3.6 µm for all conditions except for MQL at the highest cutting speed, reaching 4.2 µm (Fig. 7b). A decrease of R_t with the increase of v_c was noted for all lubricant conditions (Fig. 7d). Smaller values of R_t were noticed in all v_c for tests with AIR, followed by MQL.

ANOVA indicates a significant influence of all evaluated parameters over R_a for single grooving (SG) tests. Both the lubricant condition and feed rate (f) presented significant influences over R_t for SG. No significant interaction effect was identified for SG for the roughness parameters evaluated. However, only the interaction between the lubricant condition and cutting speed (v_c) for R_t was not significant in PG.

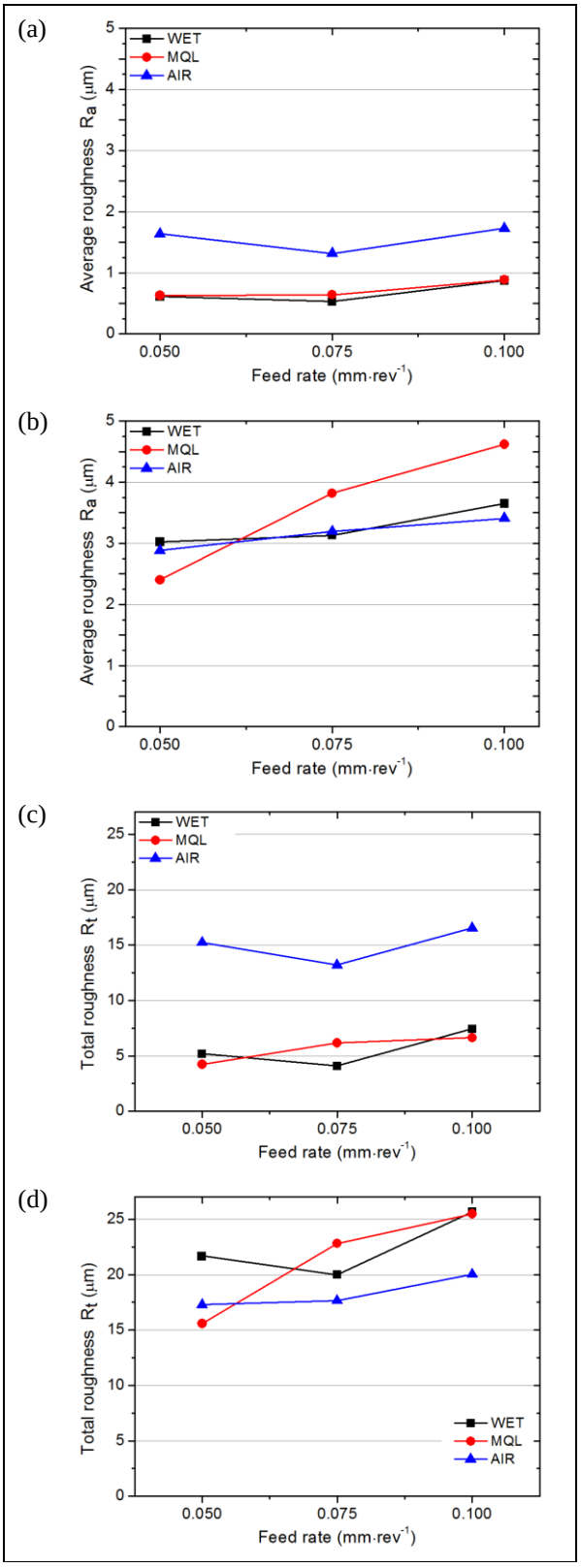

Figure 6: Effect of feed rate on: (a) average roughness (R_a) for SG; (b) average roughness (R_a) for PG; (c) total roughness (R_t) for SG; (d) total roughness (R_t) for PG.
Source: Authors, (2021).

A slight tendency in decreasing R_a and R_t values as cutting speed (v_c) is increased was observed for single grooving (SG). This effect is even more pronounced for R_t after PG and may be related to the temperature increase in the cutting zone in higher v_c, reducing the material hardness and decreasing the friction in the tool-workpiece and tool-chip interfaces.

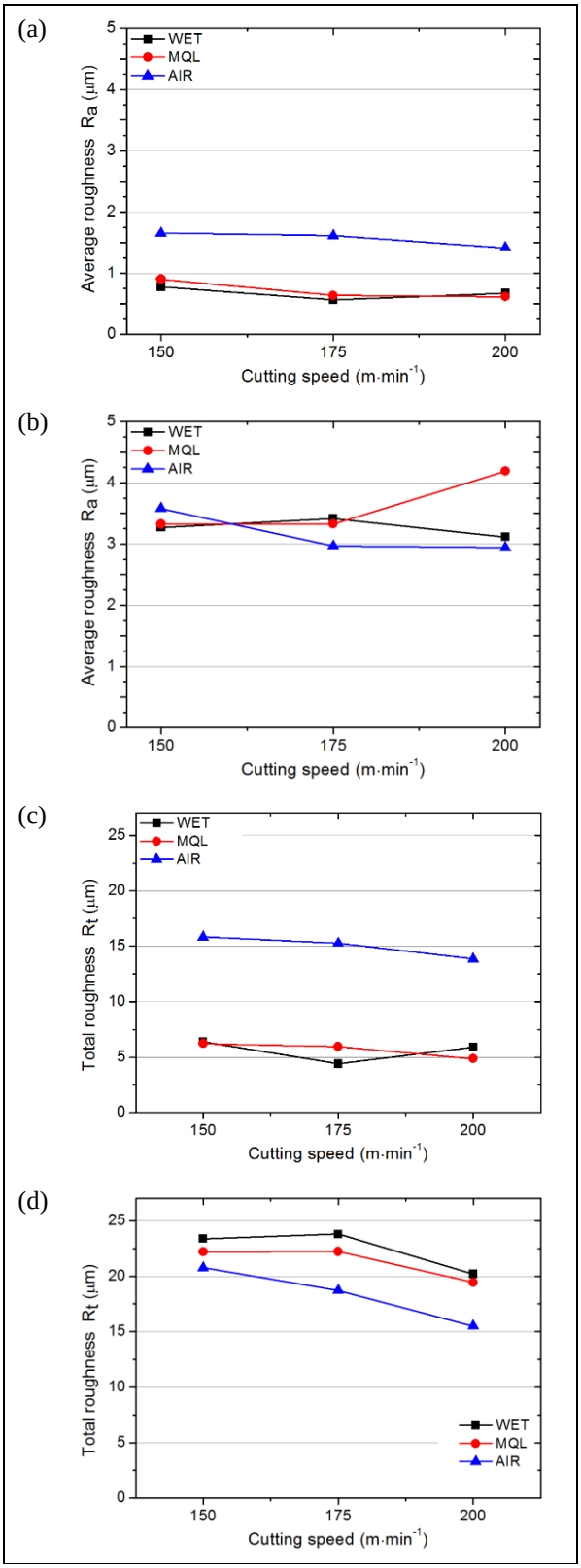

Figure 7: Effect of cutting speed on: (a) average roughness (R_a) for SG; (b) average roughness (R_a) for PG; (c) total roughness (R_t) for SG; (d) total roughness (R_t) for PG.
Source: Authors, (2021).

For SG (a_p = 3.0 mm), both WET and MQL systems allowed the best results for surface roughness. The smaller surface roughness values resulted from the application of both systems using v_c = 175 m·min^{-1} and f = 0.05 mm·rev^{-1} with corresponding R_a = (0.45 ± 0.08) µm and R_t = (4.01 ± 1.54) µm for WET machining, and R_a = (0.47 ± 0.06) µm and R_t = (3.28 ± 0.39) µm for MQL machining. The smaller values expanded the uncertainty of the results indicates a more stable grooving with MQL. AIR system, on the other hand, delivered the worst surface finishing for SG. Possible reasons for this poor behavior are the lack of lubrication in the tool-workpiece and tool-chip interfaces and the weak chip removal assistance.

Surface finishing results for PG (a_p = 2.5 mm) are not as well-conditioned as noticed for SG (a_p = 3.0 mm), with surface roughness results, both R_a and R_t, significantly higher. Also, while SG showed no significant interactions over roughness parameters, all interactions were statistically significant for R_a in PG, and only one was not significant for R_t. The high quantity of significant parameters and interactions may indicate the influence of parameters not evaluated in this study.

AIR machining resulted in better surface finishing for PG (a_p = 2.5 mm) in several cases, such as at higher v_c (175 and 200 m·min^{-1}) and higher f (0.075 and 0.1 mm·rev^{-1}), which can be partially explained by the workpiece softening, which facilitates chip formation [45]. However, the best results were found with AIR and MQL machining using v_c = 200 m·min^{-1} and f = 0.05 mm·rev^{-1}. The roughness values found with AIR condition were R_a = (2.42 ± 0.15) µm and R_t = (11.35 ± 1.36) µm; with the MQL, the values were R_a = (2.08 ± 0.20) µm and R_t = (11.59 ± 1.27) µm.

IV. CONCLUSIONS

This study conducted a comparative evaluation of lubri-cooling methods in radial grooving of AISI 1045 steel. The initial hypothesis adopted was that the application of minimum quantity lubricant (MQL) and compressed air (AIR) could lead to results equivalent to those obtained with conventional flood (WET) machining regarding active force components and surface roughness. The following conclusions can be drawn from the analysis of the results:

- AIR machining resulted in lower cutting forces (F_y) in most tested conditions, implying lower energy consumption. It means that this condition is more economical and sustainable from an energetic point of view. The highest F_y observed in this study occurred in tests performed with WET machining.
- The lubri-cooling condition significantly influenced the feed force (F_x), with higher forces related to the WET condition in most tested conditions. AIR machining resulted in smaller F_x values for the lowest and highest levels of cutting speed (v_c) and feed rate (f) tested.
- The difference between F_x generated under WET, MQL, and AIR machining grows when v_c and f increase. This outcome is possibly related to higher heat removal in WET than AIR and the lower lubrication of this condition than MQL.
- Cutting forces in MQL, when compared with WET machining, were constantly higher at the lowest cutting speed tested, with the best results (highest percent reduction) at all times noticed for the highest v_c. These data support the hypothesis that the cutting fluid in WET machining does not penetrate the cutting interface at high cutting speeds, while MQL droplets do.
- MQL and WET machining generated lower surface roughness for single grooving (SG) tests, while AIR machining resulted in higher roughness for both evaluated roughness parameters (R_a and R_t) evaluated in all tested conditions. The poor surface finishing with AIR indicates that the access of the compressed air in the groove is not sufficient to assist the chip removal.
- AIR machining led to lower total roughness R_t values in partial grooving (PG) for all cutting speeds tested and decreased

average roughness R_a values as cutting speed increases. This effect is probably related to the easier chip removal associated with this condition.

- PG led to poorer surface finishing compared to SG for both roughness parameters considered. The main reason for this is the higher stability of SG due to the opposed components of passive force (F_z). Considering that F_z occurs in the direction where the grooving tool presents its lowest rigidity (and, thus, most prominent tool deflection), the absence of an opposite force in PG leads to vibrations, increasing surface roughness.

The conclusions indicate that MQL is a suitable substitute for WET machining when lower machining forces (and thus energy consumption) and high-quality surface finishing are required. MQL is also better than WET machining when the green machining process is considered. Finally, applying AIR machining allowed smaller F_x and F_y values in the most tested conditions and seemed a suitable substitute for WET machining in certain conditions.

V. AUTHOR'S CONTRIBUTION

Conceptualization: Elias S. C. Espindola and André J. Souza.
Methodology: Elias S. C. Espindola and André J. Souza.
Investigation: Elias S. C. Espindola and Heraldo J. Amorim.
Discussion of results: Elias S. C. Espindola, Heraldo J. Amorim and André J. Souza.
Writing – Original Draft: Elias S. C. Espindola.
Writing – Review and Editing: Heraldo J. Amorim and André J. Souza.
Resources: (not applicable).
Supervision: Heraldo J. Amorim and André J. Souza.
Approval of the final text: Elias S. C. Espindola, Heraldo J. Amorim and André J. Souza.

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VII. DATA AVAILABILITY

All experimental data that support this study are available online in Mendeley Data entitled "Radial grooving of AISI 1045 steel under different lubri-cooling methods" with the identifier https://doi.org/10.17632/rjxgw8d4fz.1.

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SMART PEDAGOGY: FOCUS ON THE PROSPECTS AND CHALLENGES OF THE FLIPPED CLASSROOM APPROACH IN NIGERIAN ARCHITECTURAL EDUCATION

Miriam Chukwuma-Uchegbu*[1]

[1] Department of Architecture, Federal University of Technology, Owerri, Imo State, Nigeria.

[1] http://orcid.org/0000-0002-4090-0842

Email: *mimchuks@gmail.com

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ABSTRACT

Architectural education in a developing country like Nigeria has remained largely dependent on the traditional learning approach/module where the architectural educator is the centre of knowledge in executing activities such as lectures, studio instructions, lab work, among others. A shift away from this method has been advocated especially in this era of information technology advancement. This study through a questionnaire survey of four higher institutions of learning in Nigeria, evaluates the prospects and challenges of implementing the flipped classroom approach. Using purposive sampling techniques, the well-structured questionnaire was used to gather data from both students and lecturers in (University of Lagos, Federal University of Technology Owerri, Federal Polytechnic Nekede Owerri and Yaba College of technology Lagos) regarding the subject of this study. The gathered data were analyzed using appropriate descriptive statistical tools and ANOVA. It was found that 80% of the lecturers are computer literate but only 20% opted for the use of the flipped classroom approach. Also 85% of the students prefer the use of the flipped classroom approach in architecture education. A significant relationship was observed in the perception of the students and lecturers regarding the use of flip classroom approach in Architecture education in Nigeria. The challenges and implications of implementation of flip classroom pedagogical approach for architectural education in Nigeria were also highlighted. Sustainable solutions were proffered for making architectural education more responsive to the rapid global technological development in the pedagogical approach in architectural education.

I. INTRODUCTION

The goal of architectural education is subsumed in the general concept of education, which is to prepare people to improve and perpetuate their society. This is achieved by taking due cognizance of the society's political, social and economic circumstances in the design of the educational programme [1, 2]. Architectural education in Africa and by extension Nigeria has been found to be plagued by three issues highlighted by [3] to include the inadequacy of the existing curriculum to deal with emerging urban problems as well as rural ones and insufficiency in the number of trained architects which emanates from the dearth of teaching resources and facilities in the schools. More fundamental is the inability to adapt architectural education to the changing socio-economic and global advancement of the built environment particularly in the method of dissemination of this education [4]. From the inception of architectural education in Nigeria, the traditional learning approach/module in which the architectural educator is seen as the center of knowledge in executing activities such as lectures, studio instructions, laboratory work, formulation and review of homework and administration of examinations has been adopted.

However over the years, it has been discovered that this module of learning has failed as posited by [5] who succinctly

argued on the need for a new approach in the delivery of architectural education, stressing that in view of information technological changes, the increasing complexity in building projects and vagaries in the economy, a paradigm shift in the method of delivery of architectural education in Nigeria is necessary. This notion is supported by [6] who claimed that the quality of architectural education in Nigeria is low compared with international standards; hence, there is a need to enhance the quality of education in terms of learning and teaching methodology. [7] and [8] in their submission asserts that if the profession of architecture's body of knowledge is to be enhanced, learning excellence must become the essence of architectural education. The students not the educators must become the focus of the learning experience where they participate actively in the teaching-learning practice in higher education [9, 10].

This active participation of students in learning according to [11] is known as the flipped classroom concept; a student-centred approach to learning where the students are more active than the instructor in the classroom activity. In this case, the instructor acts as a facilitator to motivate, guide, and give feedback on students' performance. This type of activity also increases students' collaborative learning outside the class [12].

The curriculum contents and specific subjects of study of schools of architecture in Nigeria are categorized into seven instruction modules namely: Architectural Design; Arts and Drawing; Historical and Theoretical Studies; Building Systems Technology; Humanities and Social Studies; Environmental Control System; and Physical Sciences. Many of our current teaching practices assume that students are "empty vessels" and the role of architectural educators is to fill them with knowledge. However research by [13] and [14] on student learning suggests that dialogue is more appropriate in that it emphasizes the interactive, cooperative and rational aspects of teaching and learning. He further posited that once faculty shift from the empty vessel model to a dialogic and communal one which is what the flip pedagogical approach is all about, a lecture class will no longer entail simply a scripted delivery of information but will then include a variety of active learning techniques that truly engage students in collective dialogue.

Based on the forgoings, this study aims to determine the prospects and challenges of incorporating the flipped classroom approach in Nigerian Architectural Education. The objectives of this study are; 1) to determine the infrastructural readiness of the architecture schools studied for the smart flipped pedagogy, 2) to ascertain if there is a significant difference in the students' preference for the smart flipped pedagogy across architecture schools studied, and 3) to ascertain if there is a significant difference in the lecturers' preference for the smart flipped pedagogy across architecture schools studied.

Much of the pedagogy of architectural education in Nigeria today is guided by implicit assumptions based on the notion that students are empty containers that need to be filled by the architectural educators who are at the center of the learning activities. This paper is based on the need to fill the knowledge gap currently existing in the literature of the flip architectural pedagogy in order to contribute to the larger conversation occurring in architectural education research.

II. LITERATURE REVIEW

II.1 THE FLIPPED CLASSROOM CONCEPT

Flipped classroom is also known as a student-centred approach to learning where the students are more active than the instructor in the classroom activity. In this case, the instructor acts as a facilitator to motivate, guide, and give feedback on students' performance [15]. It is also defined as a model of delivering instruction that shifts lectures from a class time activity to an at home activity and shifts "homework" from an at home activity to an in-class, critical thinking set of activities.

Flipped learning in the words of [16] is a pedagogical approach in which direct instruction moves from the group learning space to the individual learning space, and the resulting group space is transformed into a dynamic interactive learning environment where the educator guides students as they apply concepts and engage creatively in the subject matter. Traditional teaching on the other hand is the practice of a teacher led, in-class lecture as the primary learning activity in the classroom and comprehension activities assigned as homework. [17] succinctly submitted that the intention of a flipped classroom approach is to provide students with the opportunity to become engaged with the learning process, as students work on a question or task designed to help them understand a concept. Theoretically, the flipped classroom approach allows students to follow a flexible learning process which intends to give them the opportunity to improve their achievements supported by a more creative and innovative teaching approach compared to traditional way of teaching [18].

II.2 TYPES OF FLIPPED CLASSROOM

II.2.1 The Standard Inverted Classroom

Students are assigned the "homework" of watching video lectures and reading any materials relevant to the next day's class. During class time, students practice what they've learned through traditional schoolwork, with their teachers freed up for additional one-on-one time.

II.2.2 The Discussion-Oriented Flipped Classroom

Teachers assign lecture videos, as well as any other video or reading related to the day's subject. Class time is then devoted to discussion and exploration of the subject. This can be an especially useful approach in subjects where context is everything like architectural history, or Humanities.

II.2.3TheDemonstration-Focused Flipped Classroom

Especially for those subjects that require students to remember and repeat activities exactly — think chemistry, physics, and just about every math class — it is most helpful to have a video demonstration to be able to rewind and re-watch. In this model, the teacher uses screen recording software to demonstrate the activity in a way that allows students to follow along at their own pace.

II.2.4The Faux-Flipped Classroom

This flipped classroom model has students watching lecture video in class — giving them the opportunity to review materials at their own pace, with the teacher able to move from student to student to offer whatever individual support that is needed.

II.2.5 The Group-Based Flipped Classroom

This model adds a new element to help students learn — each other. The class starts the same way others do, with lecture videos and other resources shared before class. The shift happens when students come to class, teaming up to work together on that day's assignment. This format encourages students to learn from one another and helps students to not only learn what the right

answers are but also how to actually explain to a peer why those answers are right.

II.2.6 The Virtual Flipped Classroom

The flipped classroom can in some cases eliminate the need for classroom time at all. Some college and university professors now share lecture video for student viewing, assign and collect work via online learning management systems, and simply require students to attend office hours or other regularly scheduled time for brief one-on-one instruction based on that individual student's needs.

II.3 FLIPPING THE TEACHER

In the flipp classroom approach videos are not only created by the teacher but by the students as a means of demonstrating proficiency and passing on their own ideas to the teacher.

Table 1: Traditional versus the flip Pedagogy.

S/N	Traditional pedagogy	Flip pedagogy
1	Teacher-Centered	Learner-Centered
2	Focus is on instructor	Focus is on both students and instructor
3	Focus is on language forms and structures (what the instructor knows about the language)	Focus is on language use in typical situations (how students will use the language)
4	Instructor talks; students listen	Instructor models; students interact with instructor and one another
5	Students work alone	Students work in pairs, in groups, or alone depending on the purpose of the activity
6	Instructor monitors and corrects every student utterance	Students talk without constant instructor monitoring; instructor provides feedback/correction when questions arise
7	Instructor answers students' questions about language	Students answer each other's questions, using instructor as an information resource
8	Instructor chooses topics	Students have some choice of topics
9	Instructor evaluates student learning	Students evaluate their own learning; instructor also evaluates
10	Classroom is quiet	Classroom is often noisy and busy

Source: [19].

II.4 PROSPECTS AND CHALLENGES OF FLIP PEDAGOGY

Researchers [20], [21] have submitted that the flipped pedagogy allows for greater freedom and learning flexibility of students. It has the capacity to promote cross-national and multidisciplinary perspectives in the educational practice thereby equips students and faculty with tools and resources that would enable them to successfully engage the academic world of the 21st century. The research by [22] show that electronically based systems like audio or video materials such as instructional videos, YouTube, screencast,podcast etc. for out-of-class learning and regular (instead of optional) face-to-face class meetings as the two necessary elements of flipped classroom approach.These however require internet access which is still at its infancy stage coupled with unsteady electricity supplies are challenges that can get in the way of learning and knowledge dissemination using the flip mode in Nigeria. In the words of [23]adopting the flip mode will require considerable initial start up preparations infrastructurally and in training and re-training of facilitators, which may be burdensome for institutions operating on tight budgets.

III. RESEARCH METHODOLOGY

This study employed a descriptive research methodology with four case studies; University of Lagos, Federal University of technology Owerri, Federal Polytechnic Nekede Owerri and Yaba College of technology Lagos. A well-structured questionnaire based on a 5-point Likert scale was adopted in the study. The target participants in the study were students and lecturers of Architecture, in the built environmental faculties/schools of the case studies. Two sets of questionnaires were adopted; the first was administered to 240 students (60 in each school) using a purposive sampling technique; to ascertain the students' perception of the flipped classroom approach. The second set of questionnaires (20 in each school) were purposively administered to the architecture lecturers (From the ranks of technologists to senior lecturers) to find out their state of preparedness in terms of infrastructural and curriculum appropriateness for the implementation of the flipped classroom approach.

A total of 186 usable questionnaire responses were obtained for the students group in the 4 higher institutions of learning. The break down shows that 49 responses were obtained from UNILAG, 45from FUTO, 44 from YABATECH, and 48 from FED.POLY NEKEDE. The 186 responses represent an effective response rate of 77.50%. For the Lecturers group, a total of 60 usable questionnaire responses were obtained from the 4 higher institutions of learning. The break down shows that 14 responses were obtained from UNILAG, 19 from FUTO, 12 from YABATECH, and 15 from FED.POLY NEKEDE. The 60 responses represent an effective response rate of 75.00%. Prior to th actual analysis, the gathered data were subjected to reliability test. The data reliability test was executed using Cronbach's alpha test which shows that the alpha's value is above 0.70; thus, implying high internal consistency and reliability. Data analysis were done using descriptive statistical tools and ANOVA.

IV. RESULTS AND DISCUSSIONS

IV.1 DEMOGRAPHIC INFORMATION OF RESPONDENTS

The result of the analysis of respondents demographic data is shown in Table 2 and 3. Table 2 displays the demographic profiles of the student respondents. From the table, 67.20% of the students are between 18-24 years of age, 29.57% are between 25-30, 2.69% are above 30 years of age. With regards to their gender, 81.18% are males, and 18.82% are females. With this, the students participants are of age and can give reliable information to aid meeting the study objective.

Table 2: Students' demographic profile.

	Variables	Freq.	%
Age	18-24	125	67.20
	25-30	55	29.57
	30 and above	5	2.69
	Missing	1	0.54
	Total	**186**	**100.00**
Gender	Male	151	81.18
	Female	35	18.82
	Total	**186**	**100.00**

Source: Author (2021).

Table 3 displays the demographic profiles of the lecturers group. In terms of their ranks, 23.33% are senior lecturers and Lecturer 1 each, 20.0% are Lecturer 11, 18.33% are assistant lecturers, and 15.0% are technologist. This shows a fair representation of the lecturers of the sampled institutions. Concerning the gender of the lecturers, 58.33% are males and 41.67% are females. This also shows a fair representation of the male and female genders in the sampled institution.

Table 3: Lecturers' demographic profile.

Variables	SCHOOLS				Total	%
	A	B	C	D		
Rank						
Senior Lecturers	4	5	2	3	14	23.33
Lecturer 1	4	2	4	4	14	23.33
Lecturer 11	2	6	2	2	12	20.00
Asst. lecturer	2	4	2	3	11	18.33
Technologist	2	2	2	3	9	15.00
Total	**14**	**19**	**12**	**15**	**60**	**100.00**
Gender						
Male	8	11	6	10	35	58.33
Female	6	8	6	5	25	41.67
Total	**14**	**19**	**12**	**15**	**60**	**100.00**
A= UNILAG; B=FUTO; C=YABATECH; D=FEDPOLY NEKEDE						

Source: Author (2021).

IV.2 LECTURERS' PEDAGOGICAL PREFERENCE

The lecturers' pedagogical preference of the lecturers is shown in Table 4. It can be seen that a greater number of the lecturers preferred the flip pedagogical approach (71.43% at UNILAG, 63.16% at FUTO, 75.0% at YABA TECH., and 66.67% at FED POLY NEKEDE) to the traditional lecture mode (28.57% at UNILAG, 36.84% at FUTO, 16.67% at YABA TECH., and 26.67% at FED POLY NEKEDE).

Overall, 41(68.33%) of the sampled lecturers prefer flip pedagogical approach, 17(28.33%) prefer the traditional lecture mode, and 2(3.33%) prefers a combination of the flip pedagogical approach and the traditional lecture mode.

Table 4: Lecturers' Pedagogical Preference.

School	Preferred Pedagogy	Freq.	%
UNILAG	flip	10	71.43
	traditional	4	28.57
	Total	**14**	**100.00**
FUTO	Flip	12	63.16
	traditional	7	36.84
	Total	**19**	**100.00**
YABA TECH	Flip	9	75.00
	traditional	2	16.67
	Combined	1	8.33
	Total	**12**	**100.00**
FED POLY NEKEDE	Flip	10	66.67
	traditional	4	26.67
	Combined	1	6.67
	Total	**15**	**100**

Source: Author (2021).

IV.3 ASSESSMENT OF LECTURER'S COMPUTER LITERACY

Furthermore, the computer literacy of the lecturers was assessed, and the results show that most of the lecturers are computer literate (100% at UNILAG, 78.9% at FUTO, 100% at YABA TECH. and 80% at FED POLY NEKEDE). This to a large extent shows the state of readiness of the lecturers to adopt the smart flip pedagogical approach.

Table 5: Computer literacy.

School	Response	Frequency	%
UNILAG	Yes	14	100.00
	No	0	0.00
	Total	**14**	**100.00**
FUTO	Yes	15	78.9
	No	4	21.1
	Total	**19**	**100**
YABA TECH	Yes	12	100.0
	No	0	0.00
	Total	**12**	**100.00**
FED POLY NEKEDE	Yes	12	80.0
	No	3	20.0
	Total	**15**	**100.00**

Source: Author (2021).

IV.4 STUDENTS' PERCEPTION OF INFRASTRUCTURAL SUITABILITY FOR FLIPPED PEDAGOGY

The students were asked to rate the infrastructural suitability for flipped pedagogy in their schools. The analysis of the responses are shown in Table 6. The scale for deciding the suitability of infrasturcture for suitability for flipped pedagogy in percentage are; 81 to 100% = Very high suitability; 61 to 80%= High suitability; 41 to 60% =Moderately suitable; 21 to 40% =Low suitability; and below 20% = Very Low suitability.

It can be seen that accross the schools, students in UNILAG considered the infrastructure suitability for flip pedagogy to be low, those at FUTO, YABATECH and FED.POLY. NEKEDE students consider it moderately suitable. Overall, it can be concluded that available infrastructures are not suitable enough for the implementation of the flip pedagogy.

Table 6: Infrastructural suitability for flipped pedagogy.

S/N	Schools	1	2	3	4	5	N	Total	Mean	%
1	UNILAG	1	47	1	0	0	49	98	2	40.00
2	FUTO	1	35	8	1	0	45	99	2.2	44.00
3	YABATECH	2	32	5	4	1	44	102	2.32	46.36
4	FED.POLY. NEKEDE	4	35	6	1	2	48	106	2.21	44.17

Source: Author (2021).

IV.5 LECTURERS' PERCEPTION ON THE CURRICULUM SUITABILITY FOR FLIPPED PEDAGOGY

Lecturers were asked to rate the curriculum suitability for flipped pedagody on a 5-point Likert scale. The resutl of the analysis is shown in table 7. The present curriculum suitability of the schols sampled revealed that the lecturers considered the curriculum adequate for the implementation of the flip pedagogy (71.60% at UNILAG, 62.60% at FUTO, 80% at YABATECH and 72% at FED.POLY. NEKEDE.

Table 7: Curriculum suitability for flipped pedagogy.

S/N	Schools	1	2	3	4	5	N	Total	Mean	%
1	UNILAG	1	0	5	4	4	14	52	3.58	71.6
2	FUTO	1	2	6	6	4	19	67	3.13	62.6
3	YABATECH	1	0	1	5	5	12	49	4.00	80.0
4	FED.POLY. NEKEDE	0	0	8	5	2	15	54	3.60	72.0

Source: Author (2021).

IV.6 LECTURERS' PREFERENCE FOR THE SMART FLIPPED PEDAGOGY

The result of the descriptive statistics of the data gathered from lecturer on their preference for smart flipped pedagogy is displayed in Table 8. The cut-off points for determining the level of preference/agreement for the smart flipped pedagogy based on the mean values as modified from [16] are; mean value of ≥ 4.50= "very strongly"; 3.50-4.49 = "strong"; 2.50-3.49 = "moderate"; 1.50-2.49 = "weak"; and 1.00-1.49 ="very weak".

The lectrurers at UNILAG and FUTO have a very strongly preference for smart flipped pedagogy with mean vbalues of 4.75 and 4.63 respecttively. Furthermore, Lecturers at YABATECH and FED.POLY. NEKEDE have a strong preference for smart flipped pedagogy. Overall, the preference for smart flipped pedagogy is high; this shows agreement among the lecturers of high institutions of learning in Nigeria. Furthermore, a look at column 6 and 7 of table 8 shows the skewness and kurtosis values. Data are considered to be in excellent form where the skewness range is fewer than 2 and kurtosis fewer than 7. These further strengthen the evidence the gathered data are accurate and reliable.

Table 8: Descriptive Statistics of Preference for the smart flipped pedagogy.

S/N	Schools	Mean Statistic	Std. Devi.	Rank	Skewness	Kurtosis	Decision
3	UNILAG	4.75	0.43	1	-1.168	-0.646	Very Strong
1	FUTO	4.63	0.86	4	-0.395	-0.438	Very Strong
4	YABATECH	4.06	1.26	2	-0.929	-0.829	Strong
2	FED.POLY. NEKEDE	3.79	1.14	3	-1.407	1.448	Strong

Source: Author (2021).

IV.6.1 Test of Homogeneity of Variances

The assumption for ANOVA which is Homogeneity of Variance was carried out to validate the instrument used in the analysis. A value greater than 0.05 means that the variability is about the same. That the scores in one condition do not vary too much more than the scores in the second condition. Scientifically, it means that the variability in the conditions studied is not significantly different. Using Levene statistic, a significant value of 0.075 was obtained. This shows that the homogeneity assumption was fulfilled (see Table 9).

Table 9: Levene statistic.

Levene Statistic	df1	df2	Sig.
2.458[a]	3	56	0.075

Source: Author (2021).

If the Sig (2-Tailed) value is greater than .05, then one can conclude that there is no statistically significant difference among your conditions. One can conclude that the differences between condition Means are likely due to chance. If the Sig (2-Tailed) value is less than or equal to 0.05 one can conclude that there is a statistically significant difference between your two conditions. One can conclude that the differences between condition Means are not likely due to chance. Also, ANOVA shows the output of the ANOVA analysis and whether there is a statistically significant difference between the architecture schools studied. We can see that the significance value is 0.057 (i.e., p = .057), which is greater than 0.05. and, therefore, there is no statistically significant difference in the lecturers' preference for the smart flipped pedagogy across architecture schools studied (see table 10).

Table 10: ANOVA.

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	108.296	4	27.07	0.057	0.994
Within Groups	21814.1	56	389.5		
Total	21922.4	60			

Source: Author (2021).

V. CONCLUSION AND RECOMMENDATION

The purpose of this study is to determine the infrastructural readiness, prospects and challenges of the smart-flip pedagogy in Nigerian Architecture schools. The study sampled students and lecturers in four higher institutions using a questionnaire survey and purpsive sampling techniques. The four instautions are; University of Lagos (UNILAG), Federal University of Technology Owerri (FUTO), Federal Polytechnic Nekede Owerri (FED.POLY NEKEDE) and Yaba College of technology Lagos (YABATECH). The gathered data were analyzed using appropriate descriptive statistical tools and ANOVA, and critical findings were made.

It was found that architectural educations in Nigeria are infrastructurally ill equipped for the implementation of the flipped pedagogy. The curriculum was found to be adequate for the flip mode. It further shows that there is no significant difference in the lecturers' or students' preference for the smart flipped pedagogy across the architecture schools studied. Furthermore, the prospects and challenges are homogeneous across the schools studied.

The study recommends the incorporation of computer labs and media centers into architecture schools to enable students have access to technology for off class work. Offline media such as flash drives/DVDS can be explored for pre-recording of lectures for after school assignments/review particularly in situations where the students lack access to the internet.

This study adds to the few exsiting studyes on architectural pedagogy education in Nigeria and other developing countires of the world. It will also be useful to key players in the education sector of Nigeria, expecially for the architectural education in making decisions that will impact the teaching and learning of architecture in the Nigerian higher institutions of learning. Lectuers would benefit from the outcome of this study as they would have seen areas were their performance and productivity can be improved upon.

Notwithsanding the importance of this study, it is limited by geographic boundary and sample size, therefore, cae should be taken in generalising the findings. Based on this, a similar study could be undertaken in other states of nigeria or developing countries so that results will be available for comparison. In addition, a further research needs to be carried out on the effect of the use of the flip pedagogy on architecture students performance across the Nigerian or other developing countries higher institutions of learnings.

VI. AUTHOR'S CONTRIBUTION

Conceptualization: CHUKWUMA-UCHEGBU, Miriam.
Methodology: CHUKWUMA-UCHEGBU, Miriam.
Investigation: CHUKWUMA-UCHEGBU, Miriam.
Discussion of results: CHUKWUMA-UCHEGBU, Miriam.
Writing – Original Draft: CHUKWUMA-UCHEGBU, Miriam.
Writing – Review and Editing: CHUKWUMA-UCHEGBU, Miriam.
Resources: CHUKWUMA-UCHEGBU, Miriam.
Supervision: CHUKWUMA-UCHEGBU, Miriam.
Approval of the final text: CHUKWUMA-UCHEGBU, Miriam.

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ANTIFUNGAL EFFECTIVENESS TEST FRAGRANT LEAF ETHANOL EXTRACT (*PANDANUS AMARYLLIFOLIUM ROBX*) AGAINST FUNGUS *PITYROSPORUM OVALE* IN VITRO

Angelika Sinaga*[1], Saadah Siregar[2], Vincentia Ade Rizky[3] and Riana Topia[4]

[1] Faculty of Pharmacy, Institut Kesehatan Medistra Lubuk Pakam, Jl. Sudirman No.38, Lubuk Pakam, Deli Serdang 20512, North Sumatra, Indonesia.

[2, 3] Medical Laboratory Technology, Faculty of Pharmacy, Institut Kesehatan Medistra Lubuk Pakam, Jl. Sudirman No.38, Lubuk Pakam, Deli Serdang 20512, North Sumatra, Indonesia.

[4] Graduate Program of Pharmacy, Faculty of Pharmacy, Institut Kesehatan Medistra Lubuk Pakam, Jl. Sudirman No.38, Lubuk Pakam, Deli Serdang 20512, North Sumatra, Indonesia.

[1] http://orcid.org/0000-0001-9488-9063, [2] http://orcid.org/0000-0002-0664-4873, [3] http://orcid.org/0000-0002-2866-1236, [4] http://orcid.org/0000-0001-5580-1647

Email: *angelikasinaga54@gmail.com, ghozalirusman@gmail.com, vincentiarizky@gmail.com, rianatopia@gmail.com

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ABSTRACT

Dandruff is one of the fungal infection problems that causes lack of confidence and discomfort due to complaints of itching that accompanies it. The fungus that causes dandruff is *Pityrosporum ovale*. *Pityrosporum ovale* has been reported to be resistant to the use of these azole drugs. One of the plants that has the potential as herbal medicine is pandan leaves (*Pandanus amaryllifolius Roxb*). The purpose of this study was to determine the antifungal activity of fragrant pandan leaf extract (*Pandanus amaryllifolius Roxb*) on the growth of *Pityrosporum ovale* in vitro. The research method used an experimental method with the extract concentrations used were 10%, 20%, 30%, and 40%. The antifungal testing method uses the agar diffusion method using the Kirby Bauer method. The results showed that pandan fragrant leaf extract with concentrations of 10%, 20%, 30% and 40% had moderate strength antifungal inhibition against *Pityrosporum ovale*. The largest inhibition zone was at a concentration of 40%, which was 9.43 mm. This indicates that the fragrant pandan leaf extract has antifungal effect on *Pityrosporum ovale* which causes dandruff. So that the results of this study can be used as a product to reduce the problem of dandruff.

I. INTRODUCTION

Indonesia is an archipelagic country located on the equator and has a tropical climate, making it possible for the development of infectious diseases caused by fungi. One of the most common fungal infections is dandruff. Dandruff is one of the problems on the scalp that occurs in almost half of the world's population regardless of gender and socio-culture. No resident in any geographical area is free without being affected by dandruff in daily life.

Dandruff is one of the fungal infection problems suffered by humans, although dandruff is not a life-threatening disease, but currently dandruff is a prominent problem among the general public. This is because for sufferers, dandruff can cause a lack of confidence due to cosmetic problems or aesthetic disturbances it causes and cause discomfort due to complaints of itching that accompanies it [1].

Dandruff belongs to seborrheic dermatitis is a common abnormal skin condition characterized by peeling and itching. Dandruff affects 50% of the population world. This disorder is caused by several factors, namely the activity of the sebaceous glands, the fungus genus *Malassezia* and individual sensitivity. The fungus that causes dandruff is Malassezia sp. One of the species is *Pityrosporum ovale* [2]. This fungus is actually a

normal flora in the hair, but there are several factors that affect the excessive growth of the fungus *Pityrosporum ovale* on the scalp, causing a scaly head [3]. Factors that influence the incidence of dandruff, among others increased sebum production in the sebaceous glands, individual susceptibility factors, environmental factors (temperature and humidity of the environment), and stress.

In *Malassezia sp*. (*Pityrosporum ovale*) has been reported to be resistant to the use of these azole drugs. Research in Japan reported that zinc pyrithione at sublethal doses was reported to be teratogenic and toxic to medaka fish (*Oryzias latipes*) [4]. Meanwhile, according to Stecher, Zinc pyrithione (ZPT) also has side effects such as dermatitis that occurs on the scalp and hair damage (hair loss, discolored, and broken).

The side effects of synthetic drugs and the 'back to nature' lifestyle that are starting to be widely developed by people in Indonesia are now encouraging researchers to look for alternatives. The alternative is in the form of active compounds from plants that can be used as antifungals and do not cause side effects. The plant was chosen because it was predicted to have an active compound as an antifungal, namely the fragrant pandan leaf (*Pandanus amaryllifolius Roxb*).

II. MATERIALS AND METHODS

II.1 STUDY SITE

This research was conducted at the Botany of Laboratory and Microbiology & Virology Laboratory of the Faculty of Pharmacy Institute of Health Medistra Lubukpakam. Samples were taken from Gg. Pantai Cermin Kiri Hamlet V, Pantai Cermin District, Bedagai Serdang, North Sumatra Province.

II.2 SAMPLING PROCEDURE

The sample used was 10 kg of Pandan Wangi Leaves (*Pandanus amaryllifolius Roxb*) obtained from Gg. Mirror Beach Kiri, Hamlet V, Pantai Cermin District, Serdang Bedagai Regency, North Sumatra Province. Sampling was done purposively, that is, without comparing with other areas.

Pandan leaves are washed with running water to clean them from dust and other foreign objects. Then chopped to facilitate the drying process. Drying was carried out in light indirect sunlight, using a black cloth as a cover over the sample. The dry product was then crushed using a blender machine, then sieved using a 40 mesh sieve so that the same size powder was obtained (Figure 1). Then, the dry powder was extracted using the maceration method [5].

Figure 1: Pandan Leaves (*Pandanus Amaryllifolius Roxb*).
Source: Authors, (2021).

II.3 MAKING FRAGRANT PANDAN LEAF ETHANOL EXTRACT

The simplicia powder of fragrant pandan leaf extract was carried out using 96% ethanol as a solvent. A total of 500 grams of simplicia powder of fragrant pandan leaves is put into a glass container, 3.75 liters of 96% ethanol is added, close the lid, leave for 5 days protected from light while stirring frequently, sprinkle, squeeze, wash the dregs with a sufficient amount of filter liquid. Transfer to a closed vessel, leave in a cool place, protected from light for 2 days. Precipitated pour or filtered. The results obtained were concentrated with a rotary evaporator at a temperature of 40°C until most of the solvent had evaporated and continued with the evaporation process on a water bath until a thick extract was obtained [6].

II.4 PHYTOCHEMICAL SCREENING

Phytochemical screening of simplicia powder includes examination of alkaloids, flavonoids, saponins, and tannins.

Alkaloids: A total of 0.5 grams of simplicia powder plus 1 ml of 2 N hydrochloric acid and 9 ml of distilled water, the comparison on a water bath for 2 minutes, filtering and filtering. The filtrate used for the alkaloid test is as follows: a) 3 drops of filtrate plus 2 drops of Mayer's reagent solution will form a white or yellow lumpy precipitate; b) 3 drops of filtrate is added with 2 drops of Bouchardat reagent solution, a brown to black precipitate will be formed; c) 3 drops of filtrate is added with 2 drops of Dragendorff's reaction solution, a red or orange precipitate will be formed. Alkaloids are positive if they occur on the surface or turbidity in at least two of the three experiments above [7].

Flavonoid: A total of 10 grams of simplicia powder was added to 10 ml of hot water, boiled for 5 minutes and filtered in a hot state, into 5 ml of the filtrate added 0.1 grams of magnesium powder and 1 ml of concentrated hydrochloric acid and 2 ml of amyl alcohol, shaken and allowed to separate. Positive flavonoids occur if the color is red, yellow or orange on the amyl alcohol layer [8].

Saponins: As much as 0.5 grams of simplicia powder was put in a test tube, added 10 ml of hot water, brought to a boil and then shaken vigorously for 10 seconds, if 1-10 cm high foam is formed which is stable for not less than 10 minutes and does not disappear with the addition of 1 drop. 2N hydrochloric acid indicates the presence of saponins [9].

Tanin: A total of 0.5 grams of simplicia powder was extracted with 10 ml of distilled water and then filtered, the filtrate was diluted until it was colorless. 2 ml of the solution is taken and 1-2 drops of 1% iron (III) chloride reagent are added, if a blackish blue or blackish green color occurs, it indicates the presence of tannins [10].

II.5 MAKING VARIATIONS OF ETHANOL EXTRACT CONCENTRATION OF FRAGRANT PANDAN LEAVES (*PANDANUS AMARYLLIFOLIUS ROXB*)

The ethanol extract of fragrant pandan leaves was made in concentrations by weighing the extracts of 100 mg, 200 mg, 300 mg, 400 mg, respectively. then each was dissolved with 10 ml of DMSO (dimethyl sulfoxide). The concentration of ethanolic extract of fragrant pandan leaves is 10%, 20%, 30%, 40%.

II.6 RESISTANCE TEST

Fragrant pandan leaf extract solutions as samples were made at concentrations of 10%, 20%, 30%, and 40%. As a positive control, ketoconazole 2% was used and a negative control was used DMSO 1%. Ethanol extract preparations from pandan fragrant leaves were tested for antifungal activity against *Pityrosporum ovale* using the disk diffusion method (Kirby-Bauer test) with positive and negative controls. SDA (Sabaroud Dextrose Agar) medium was made to be put into a petridish. Sterile SDA medium was put into a petri dish as much as 20-25 ml, then allowed to solidify. Make a mushroom inoculum/suspension solution by taking a few oses of *Pityrosporum ovale* isolate into 0.9% NaCl and compare the turbidity with 0.5 Mac Farland. Put 0.1 ml of *Pityrosporum ovale* suspension in a spread plate on its surface. Place the paper disc that has been soaked in a combination solution of Pandan Wangi leaf extract with various concentrations, 2% Ketoconazole solution and 1% DMSO solution on the surface of the SDA medium. Repeat in triples. Then incubated in an incubator for 3 x 24 hours at 37°C. The diameter of the inhibition zone formed (clear area around the paper disc without fungal growth) was measured with a caliper and expressed in millimeters [11][12].

III. RESULTS AND DISCUSSIONS

III.1 PHYTOCHEMICAL SCREENING

The class of chemical compounds on the simplicia powder of pandan leaves was carried out to obtain information on the class of secondary metabolites contained in it. The results of the examination of the Alkaloid, Flavonoid, Saponin, and Tannin compound groups (Table 1).

Table 1: Results of chemical compound group of pandan leaves simplicia powder.

No	Parameters	Information	Results
1	Alkaloid	Precipitates a white solid	+
2	Flavonoid	Orange solution	+
3	Saponin	formed foam	+
4	Tannin	Blue-black solution	+

Note: (+) = contain test's compound (-) = not contain test's compound.
Source: Authors, (2021).

Screening for alkaloids using chloroform and mayer reagents, the results are indicated by the presence of a white precipitate which means that the extract contains alkaloids. Alkaloids have been studied extensively for their biological activities and medicinal uses. Research that has been done shows that Alkaloids have significant pharmacological effects, such as anticonvulsant, analgesic, antifungal, anthelmintic, anti-inflammatory, antimalarial, anti-bacterial and cardiotonic [13].

Screening of flavonoids using Magnesium and HCl concentrated reagent, the results marked with the solution changes color orange, which means that there is a flavonoid extract. Research that has been conducted reports that fragrant pandan leaves contain flavonoids. Flavonoids are bioactive bases that are responsible for antimicrobial activity [14].

Testing of saponins on pandan pandan leaf extract showed positive results which were indicated by the formation of foam resulting from the reaction between saponin compounds and aquadest. Saponins have a high toxicity to fungi. The mechanism of antifungal activity is its interaction with membrane sterols [15].

Testing of Tannin compounds on fragrant pandan leaves using $FeCl_3$ reagent. Where a positive reaction is produced which is indicated by a change in the color of the solution to blue-black. This shows that the extract contains tannin compounds. Tannins are polyphenolic tannin compounds (commonly referred to as tannic acid). Tannins are recognized as outstanding antimicrobial compounds. Extensive analysis has revealed that tannins have antimicrobial properties by inhibiting the activity of microorganisms including fungi, yeasts and bacteria [16].

III.2 INHIBITORY TEST OF ETHANOL EXTRACT OF FRAGRANT PANDAN LEAVES (*PANDANUS AMARYLLIFOLIUS ROXB*) AS ANTIFUNGAL AGAINST PITYROSPORUM OVALE

Based on the research that has been done the results obtained in Table 2. The study was conducted in a positive control using ketoconazole 2%, negative controls using 1% DMSO, as well as variations Concentrations of ethanol extract fragrant pandan leaves that is 10%, 20%, 30% and 40%.

Table 2: The results of the inhibition test of fragrant pandan leaf extract (*Pandanus amaryllifolius Roxb*) as antifungal against *Pityrosporum ovale*.

Extract Concentration	Repetition I	Repetition II	Repetition III	Average	Information
DMSO 1% (Negative Control)	0	0	0	0	Weakness
Ketoconazole 2% (Positive Control)	9.5	9.8	10	9.76	Moderate
10%	7.7	7.9	8.0	7.86	Moderate
20%	8.3	8.5	8.8	8.53	Moderate
30%	8.5	8.8	9.0	8.76	Moderate
40%	9.2	9.5	9.6	9.43	Moderate

Source: Authors, (2021).

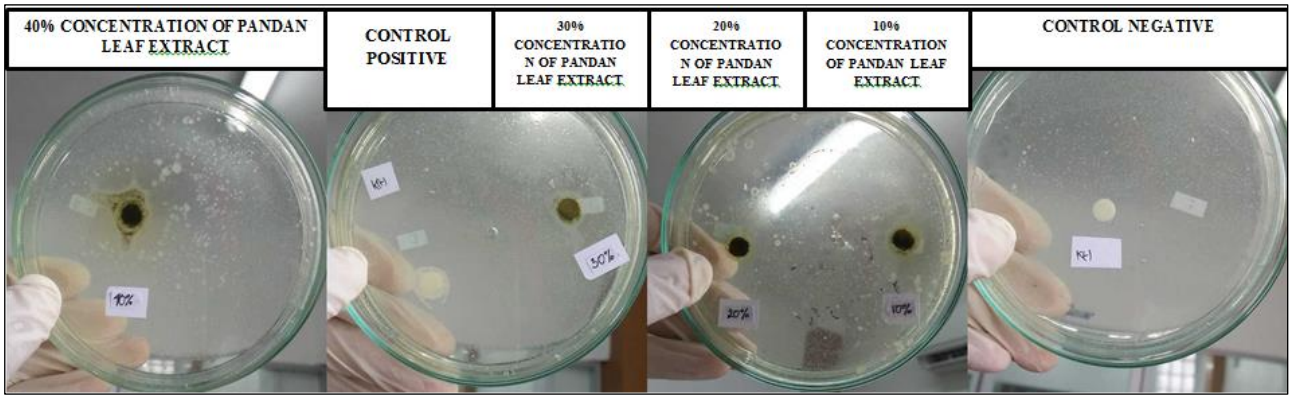

Figure 2: The results of the inhibition test were indicated by the formation of a clear zone around the colony.
Source: Authors, (2021).

In Figure 2 it can be seen that the negative control does not have a clear zone, this indicates that 1% DMSO does not have the ability to inhibit the growth of the fungus. This is also supported by previous research which stated that 1% DMSO at 24 hours growth could not significantly inhibit fungal growth. If DMSO is used >2% with a growth time of 48, 72, and 96 hours, it will inhibit the growth of the fungus [17]. Previous studies also reported that DMSO 2% significantly slowed growth and decreased growth in several *Candida* species tested, but DMSO 1% had no significant effect on growth kinetics. In addition, DMSO is a very polar and stable substance, so it is often used as a solvent and neutralizer [18].

In this study, the positive control used was 2% ketoconazole. The results showed that ketoconazole 2% had an antifungal inhibition of *Pityrosporum ovale* with an average of 9.76 mm (Table 2). Based on research that has been done, ketoconazole is an antifungal drug used to and with the help of oral fluconazole can kill fungus to 91% [19]. Ketoconazole is an antifungal that acts by inhibiting the cytochrome P450 14 α-demethylase enzyme which leads to the inhibition of lanosterol to ergosterol. This will change the permeability of the cell membrane. In addition, ketoconazole inhibits the biosynthesis of fungal triglycerides and phospholipids as well as peroxidative enzymes involved in fungal detoxification that cause cellular necrosis [20].

Based on the results of the study, it was shown that the ethanolic extract of fragrant pandan leaves at concentrations of 10%, 20%, 30%, and 40% had different inhibitory effects on *Pityrosporum ovale* (Figure 2). At a concentration of 10% it has an inhibitory power of 7.86 mm, a concentration of 20% has an inhibitory power of 8.53 mm, a concentration of 30% has an inhibitory power of 8.76%, and at a concentration of 40% has an inhibitory power of 9.43%. This shows that the greater the concentration of ethanolic extract of pandan leaves, the greater the inhibitory power produced.

According to Davis Stout [21], antifungal strength is classified into 4 groups, namely weak (<5 mm), moderate (6-10 mm), strong (11-20 mm), and very strong (> 20 mm). So, based on the research that has been done, it can be stated that of the 4 variations in the concentration of pandan fragrant leaf extract, the inhibition zone for *Pityrosporum ovale* is moderate, with the highest inhibition zone at a concentration of 40%. This is because the fragrant pandan leaf extract has bioactive compounds that act as antifungals such as alkaloids, flavonoids, saponins and tannins.

There is little information about the antimicrobial properties of the leaf extract of this plant. Previous research stated that pandan fragrant leaf extract was not effective in inhibiting the growth of the bacteria *Micrococcus (Staphylococcus) auereus* and *Escherichia coli*. This is possible due to the content of certain alkaloids in fragrant pandan leaves, such as Norpandamarilactonine-A,-B, Pandamarilactam3x,-3y, Pandamarilactone-1, PandamarilactonineA,-B,-C, Pandamarine, Pandanamine [22].

This is supported by previous studies that say that the fragrant pandan leaf extract at a concentration of 15% were able to reduce the Total Plate Count and Number of Mold on traditional foods. This is due to the chemical compounds present in the fragrant pandan leaves, namely Alkaloids, Flavonoids, Tannins and Saponins. Tannins are complex compounds that are soluble in water, polyhydric phenolic compounds that are toxic to humans fungi, bacteria, and yeast/yeast, as well as inhibit the growth of the virus. Alkaloids contain natural organic nitrogen base with a heterocyclic ring. This compound has antimicrobial properties due to its ability to damage DNA. Flavonoids have antimicrobial properties because of its ability to combine with bacterial cells extracellular membranes and proteins. Saponins is cytotoxic because it can change the permeability membrane so that lysis occurs from microbial cells [5].

Previous research on the antibacterial activity of pandan pandan leaf extract against bacteria (*S. sangnguinis, S. Mutans, S. Salivarius and P. gingivalis*) showed the presence of zones of inhibition resulting from various concentrations. The inhibitory power produced is due to the content of fragrant pandan leaf extract in which there are phenolic and flavonoid compounds [23].

IV. CONCLUSIONS

Based on the results of the study, it can be concluded that pandan fragrant leaf extract with concentrations of 10%, 20%, 30% and 40% had moderate strength antifungal inhibition against Pityrosporum ovale. The largest inhibition zone was at a concentration of 40%, which was 9.43 mm. These results were comparable to the zone of inhibition produced by ketoconazole 2% (positive control).

V. AUTHOR'S CONTRIBUTION

Conceptualization: Angelika Sinaga and Saadah Siregar.
Methodology: Saadah Siregar and Vincentia Ade Rizky.
Investigation: Angelika Sinaga and Riana Topia.
Discussion of results: Saadah Siregar, Vincentia Ade Rizky and Riana Topia.

Writing – Original Draft: Vincentia Ade Rizky and Riana Topia.
Writing – Review and Editing: Saadah Siregar and Angelika Sinaga.
Resources: Vincentia Ade Rizky and Riana Topia.
Supervision: Saadah Siregar and Angelika Sinaga.
Approval of the final text: Saadah Siregar and Vincentia.

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RESEARCH ARTICLE OPEN ACCESS

ASSESSMENT OF COMPLIANCE WITH NR-20 IN A DISTRIBUTOR OF FUELS DERIVED OF PETROLEUM AND BIOFUELS

Everaldo de Queiroz Lima*[1], Alexandra de Lima Pereira[2] and Mateus Queiroz Lima[3]

[1, 2, 3] Occupational Safety Engineering, IEMAC - UNYLEYA, Manaus-Amazonas, Brazil.

[1] http://orcid.org/0000-0002-6887-4594, [2] http://orcid.org/0000-0003-4517-7806, [3] http://orcid.org/0000-0002-0371-3829

Email: *everaldolima.am@gmail.com, alexandralp1989@gmail.com, mateusql.tec@gmail.com

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ABSTRACT

With a view to greater control in the process of managing activities involving flammable and combustible products, the Ministry of Labor and Employment (MTE) standardized Regulatory Standard 20 (NR-20). In this context, a case study was carried out at a Fuel Distributor located in the city of Manaus/AM. Taking into account the stored volume and based on the NR-20, a check-list with items of the standard was created and applied and the compliance with the requirements of construction conditions, maintenance, operation, health and safety was verified. The company presented 95% Compliance, which demonstrates a good management system in occupational health and safety, given its performance in the storage, transfer and handling of liquid fuels.

I. INTRODUCTION

According to the Brazilian Statistical Yearbook of Petroleum, Natural Gas and Biofuels of the National Agency of Petroleum Natural Gas and Biofuels (ANP) in 2014, in 2013, national sales of oil products by distributors increased by 4,7%, totaling 125, 4 million m^3. Sales of diesel oil were those that had the greatest increase in relation to 2012, with an increase of 2,6 million m^3 (4,6%), totaling 58,5 million m^3, volume corresponding to 46,6% of the total of sales of oil products in 2013. In turn, sales of gasoline C increased by 1,7 million m^3 (4,2%), totaling 41,4 million m^3 and those of fuel oil grew by almost 1,1 million m^3 (26,9%), reaching 5 million m^3 [1].

All Brazilian regions recorded an increase in sales of diesel oil compared to 2012, the largest, in percentage terms, obtained by the Midwest (8,9%), which concentrated 12,6% of sales of this derivative. In terms of volume, the Southeast Region had the highest growth in diesel sales, of 717,3 thousand m^3, concentrating 41,9% of total sales. The North, Northeast and South regions accounted for 10%, 16,4% and 19% of diesel sales, respectively. The diesel oil market was supplied by 133 distributors, with the four leading sales companies concentrating 79,3% of the market: BR (38,6%), Ipiranga (22,8%), Raízen (14,8%) and Alesat (3,1%) [1].

All this volume of fuel sold must be transported, stored and handled by licensed companies, meeting all applicable legal requirements. Due to the nature of the stored product, the entire installation and storage system for oil products and other fuels is a potentially or partially polluting enterprise that generates environmental accidents, since leaks of oil products and other fuels can cause contamination of bodies underground and surface water, soil and air, in addition to presenting risks of fire and explosions, resulting from these leaks [2].

However, the handling and handling of these products requires a well-established risk management plan, as accidents in these cases can have fatal consequences for workers and the environmental impacts can take on quite significant proportions, such as what happened in Buncefield, England in 2005 and in 2015 at Ultracargo in Santos - SP [3, 4].

II. THEORETICAL REFERENCE

II.1 FUEL DISTRIBUTION IN BRAZIL

The national supply of fuels is declared to be of public utility under Brazilian law. In this sense, it is up to the ANP to guarantee the quality and supply of fuels to consumers throughout Brazil. In exercising this competence, the ANP prepares and publishes technical resolutions that regulate the activities included in the national fuel supply system, currently composed of more than 100 thousand economic agents operating at different levels. The distribution of fuels is essential to guarantee national supply [5].

More than 300 economic agents authorized by the ANP operate in the segments of liquid fuels, LPG, asphalt, aviation fuels and solvents. The market for the distribution of automotive liquid fuels in the country involves a universe of about 300 economic agents that work with diesel oil, gasoline, ethanol and biofuel. ANP defines the requirements for the exercise of this activity and authorizes the construction and operation of facilities for the storage of these fuels. Distributors can only purchase and remove fuel from agents authorized by the ANP, subject to its specific regulations [5].

II.2 NR-20: HEALTH AND SAFETY AT WORK WITH A FUEL AND FLAMMABLES

The NR-20 issued by the Ministry of Labor and Employment (MTE) establishes minimum requirements for the management of safety and health at work against risk factors for accidents arising from extraction, production, storage, transfer, handling and handling of flammable and combustible liquids [6].

The original version of the standard was edited together with Ordinance 3214, in 1978. In 2012, it was revised and updated, and this version 15 is still valid today. NR-20 applies to all establishments, industrial or commercial, that handle or produce flammable or combustible liquids, regardless of whether it is a refinery or a simple gas station, according to the classification presented [6].

II.3 CLASSIFICATION OF FLAMMABLE AND COMBUSTIBLE

According to the definitions in NR-20, flammable liquids are liquids that have a flash point greater than or equal to 60 ºC; Flammable gases are gases that ignite with air at 20 ºC and a standard pressure of 101,3 kPa; and combustible liquids, in turn are liquids with a flash point greater than 60 ºC and less than or equal to 93 ºC [6, 7].

Flash point means the minimum temperature at which the substance (in the case of combustible or flammable NR-20) begins to release its flammable vapors. The flash point that ethyl alcohol, also known as ethanol, for example, is around 13 ºC, a low value (and for this reason it is considered flammable); on the other hand, the flash point of the wood is 150 ºC, requiring a lot of heat to generate a temperature to release gases [6, 7].

III. MATERIALS AND METHODS

III.1 COMPANY DESCRIPTION – PLACE OF STUDY

The work was carried out at a company in the oil sector in the city of Manaus, which has been operating since 2000 and has been consolidating its position as one of the largest distributors of petroleum fuels and biofuels in Brazil. As defined by the ANP, the company under study carries out the activity of distribution of liquid fuels that is of public utility and comprises the acquisition, storage, mixing, transportation, commercialization and quality control of fuels [8].

It recently underwent a process to expand its storage capacity, which went from 15.000 m^3 to 75.000 m^3, according to Regulatory Standard n° 20 (NR-20) of the Ministry of Labor is classified as a class III hazardous facility and carries out storage, transfer, handling and handling of combustible and flammable liquids [9].

III.2 STAGES OF WORK

The steps for carrying out the work are described in the flowchart shown in Figure 1.

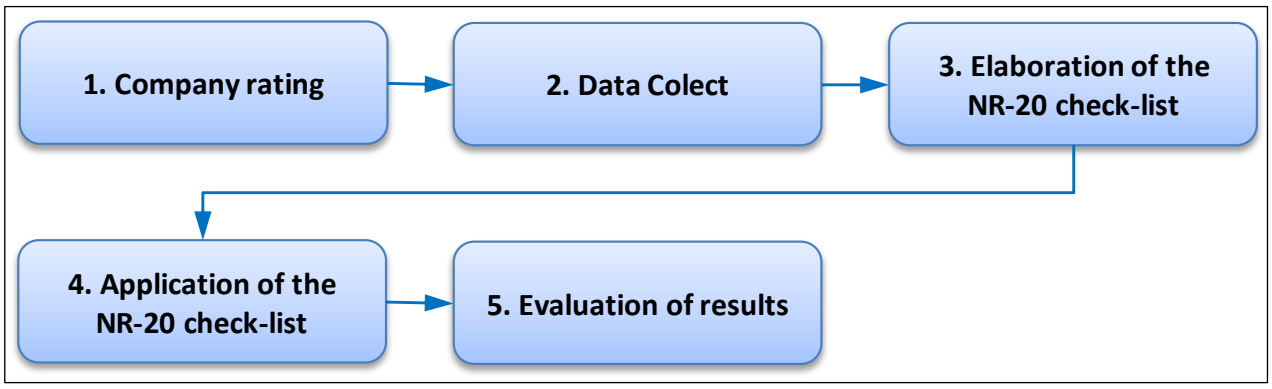

Figure 1: Methodology flowchart.
Source: Authors, (2020).

By NR-20, the company in and study carries out storage, transfer, handling and handling of flammable and combustible liquids. It is also classified as Class III Installations, according to Table 1.

The company under study is classified as “b.2 - flammable and / or combustible liquids: above 50.000 m³, since the company's characteristic activity, storage has a storage capacity of ~75.000 m³.

The data for the study were obtained from documentary research in the reports, records and forms of the Distributor in the months of August and September 2019 and tabulated in an electronic spreadsheet using Microsoft Excel software.

From the reading and study of the NR-20, a checklist (checklist) of the requirements applicable to the company under study was elaborated, and for each requirement an objective question was elaborated that related it to the item of the standard.

Table 1: Classification of Facilities according to NR-20.

Class I
a) Regarding the activity: a.1 – service stations with flammable and/or combustible liquids. a.2 – piped distribution activities of flammable gases in installations with maximum Allowable Working Pressure – PMTA limited to 18,0 kgf/cm^2.
b) Regarding storage capacity, permanently and/or transiently: b.1 – flammable gases: over 2 ton to 60 ton; b.2 – flammable and/or combustible liquids: above 10m^3 up to 5.000m^3
Class II
a) Regarding the activity: a.1 – flammable gas bottlers; a.2 – pipeline transport activities of flammable and/or combustible gases and liquids. a.3 – piped distribution of flammable gases in installations with Maximum Allowable Working Pressure PMTA above 18,0 kgf/cm^2.
b) Regarding storage capacity, permanently and/or transiently: b.1 – flammable gases: above 60 ton to 600 ton; b.2 – flammable and/or combustible liquids: above 5.000m^3 up to 50.000m^3.
Class III
a) Regarding the activity: a.1 – refineries; a.2 – natural gas processing units; a.3 – petrochemical facilities; a.4 – etanol manufacturing plants and/or alcohol manufacturing units.
b) Regarding storage capacity, permanently and/or transiently: b.1 – flammable gases: above 600 ton; b.2 – flammable and/or combustible liquids: above 50.000m^3.

Source: [6].

The work methodology used consisted of the identification and quantification of the NR-20 requirements applicable to the company, evaluation of these requirements with the existing occupational health and safety management system and elaboration of the action plan for the requirements identified as non-compliant.

During the stage of preparing the checklist, questions were asked, relating the item of the standard, in order to evaluate them with two simple answers: item conformed (C) or no-conformed (NC).

With the check list in hand, audits were carried out in the company, evaluating item by item, critically evaluating the management of safety and health at work in such a way as to allow the identification of conformed and no-conformed in each requirement. After identifying the no-conformed, actions were proposed so that the company could continue the work and obtain compliance with all the requirements of the legislation under study.

IV RESULTS AND DISCUSSIONS

With the application and evaluation of the NR-20 check-list in the company, it was observed that of the 77 items identified, 73 are Conformed (C) and 4 are No-Conformed (NC), as can be seen in Figure 2.

Analyzing the requirements identified as no-conformed during the check-list application stage, it was possible to classify them in 2 generic categories: procedure and training, as described in Figure 3.

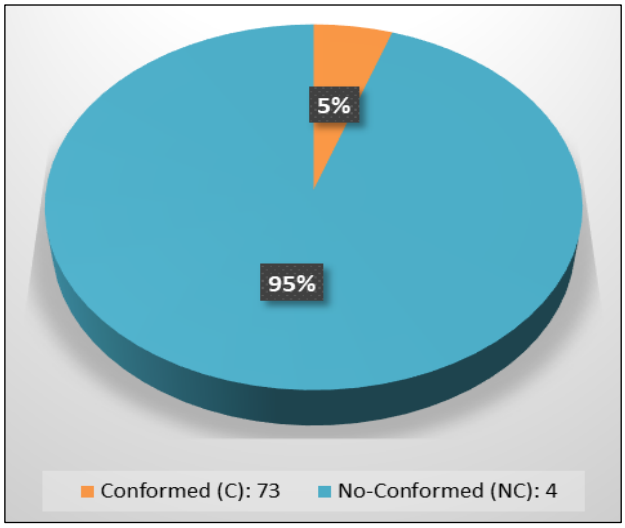

Figure 2: Evaluation of the results of applying the NR-20 check-list.
Source: Authors, (2020).

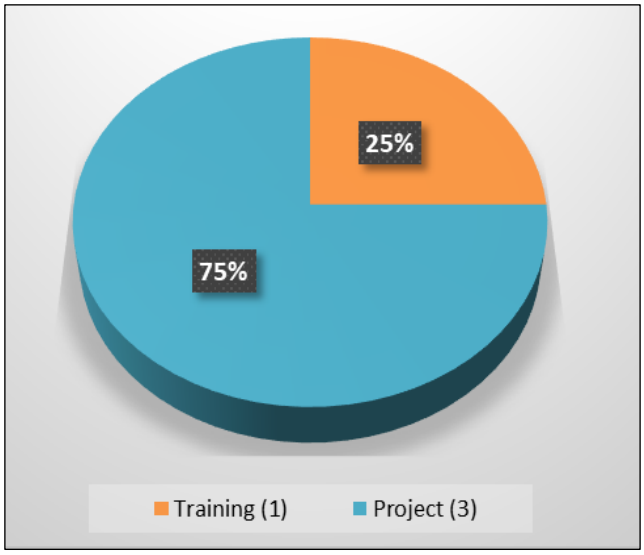

Figure 3: Classification of No-Conformed (NC).
Source: Authors, (2020).

This division aims only to facilitate the elaboration and management of the action plan, as can be seen in table 2.

Evaluating the actions proposed in table 2, it is observed that the actions inserted in the category "Projects" are the ones that demand more investments. The proposed action for item 5 is to identify and signal equipment and installations in accordance with national technical standards (ABNT and NR-26).

For item 10, it is recommended to implement the project, establish engineering measures to control fugitive emissions, emitted during the loading and unloading of fixed tanks and transport vehicles, for the elimination, minimization and/or recovery of these vapor emissions. For item 46, it is recommended to draw up a plan that includes the prevention and control of leaks, spills, fires and explosions and, in places subject to the activity of workers, the identification of the sources of fugitive emissions.

Table 2: Action plan for correction of Non-Conformities (NC).

Nº	Standard Item	Proposed Action	Category
5	20.6.3	Identify and signal equipment and installations in accordance with national technical standards (ABNT and NR-26).	Project
10	20.7.4	Implement project , establish engineering media to control fugitive emissions, emited during the loading and unloading of fixed tanks and transport vehicles, for the elimination, minimization and/or recovery of these vapor emissions.	Project
45	20.11.19	Establish and maintain an identification system that allows to know the training of each worker and the visible use of the identification means.	Training
46	20.12.1	Develop a plan that includes the prevention and control of leaks, spills, fires and explosions and, in places subject to the activity of workers, the identification of the sources of fugitive emissions.	Project

Source: Authors, (2020).

Regarding the "Training" category, there is only one proposed action item 45, in which it is recommended to establish and maintain an identification system that allows to know the training of each worker and the visible use of the identifying means.

V. CONCLUSIONS

Thus, it was concluded that of the 77 requirements identified, the company under study presented 95% Compliance. This demonstrates a good health and safety management system, as the company operates in the storage, mixing, transportation, marketing and quality control of liquid fuels.

Based on the generated non-conformities, an action plan was proposed for the company so that, when applicable, it can satisfy all the requirements of the standard under study. Compliance with current legislation, as well as national and international standards, and especially the correct management of risks associated with the activity of the enterprises are still the best ways to prevent accidents and mitigate any incidents, ensuring the safety and health of workers, as well as preservation of the environment and the company's assets.

With the development of this case study, it was possible to identify the requirements of NR-20 applicable to the company under study and to elaborate a check-list that helps, not only the local company, but also enables other branches and even other companies operating in the same market segment, an assessment to verify compliance with the legislation used.

VI. AUTHOR'S CONTRIBUTION

Conceptualization: Everaldo de Queiroz Lima, Alexandra de Lima Pereira and Mateus Queiroz Lima.
Methodology: Everaldo de Queiroz Lima.
Investigation: Everaldo de Queiroz Lima.

Discussion of results: Everaldo de Queiroz Lima, Alexandra de Lima Pereira and Mateus Queiroz Lima.
Writing – Original Draft: Everaldo de Queiroz Lima.
Writing – Review and Editing: Everaldo de Queiroz Lima, Alexandra de Lima Pereira and Mateus Queiroz Lima.
Resources: Everaldo de Queiroz Lima.
Supervision: Everaldo de Queiroz Lima.
Approval of the final text: Everaldo de Queiroz Lima, Alexandra de Lima Pereira and Mateus Queiroz Lima.

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