Journal of Engineering and Technology for Industrial Applications

ISSN 2447-0228

April 2022

Volume 08 / No 34

Editor-in-Chief: J. C. Leite

www.itegam-jetia.org

ITEGAM - JETIA ISSN 2447-0228 Online
Journal of Engineering and Technology for Industrial Applications (JETIA)

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Publication Information:
ITEGAM-JETIA (ISSN 2447-0228), (online) is published by Galileo Institute of Technology and Education of the Amazon on a every two months (February, April, June, August, October and December).

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Directory

ITEGAM - JETIA
ISSN 2447-0228 Online
Journal of Engineering and Technology for Industrial Applications (JETIA)

ITEGAM-JETIA. v.8, n.34. April of 2022. Manaus - Amazonas, Brazil. ISSN 2447-0228 (ONLINE)
https://www.itegam-jetia.org

SUMMARY

Journal of Engineering and Technology for Industrial Applications

ITEGAM-JETIA

ISSN ONLINE: 2447-0228

Manaus, v.8 n.34, p. 4-11. Mar/Apr, 2022

DOI: https://doi.org/10.5935/jetia.v8i34.798

RESEARCH ARTICLE OPEN ACCESS

HETEROGENEOUS LORAWAN DEPLOYMENT FOR APPLICATION DEPENDENT IOT NETWORKS

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ARTICLE INFO

Article History
Received: February 08th, 2022
Accepted: April 24th, 2022
Published: April 30th, 2022

Keywords:
LoRaWAN,
Heterogeneous Network,
IoT application,
Packet delivery rate,
LPWAN.

ABSTRACT

In this study, we present an application-dependent heterogeneous LoRa network. Previous studies on LoRaWAN and particularly studies that rely on the use of adaptive data rate to optimize the performance of the network are based purely on the path loss of the nodes in the network with the assumption that all nodes in the network have similar requirements in terms of data rate and latency. In a real-life full-scale deployment, this is unlikely to be the case as the current LoRaWAN deployment trend shows that practical implementations are service-based. This approach means that critical applications will suffer reliability issues since they will have to compete with non-critical services for the same resources. To address this problem, we propose a heterogeneous LoRaWAN that is capable of providing support for applications ranging from delay-tolerant to delay intolerant with improved reliability through preferential transmission parameter allocation. Our study shows that this approach can increase the probability of successful uplink transmission of the critical applications by up to 44 percent and for transmitting nodes within a 3 km radius of the gateway, heterogeneous LoRaWAN possesses a 20 percent higher uplink packet delivery rate in comparison with the homogeneous network at the cost of slightly higher energy consumption.

I. INTRODUCTION

The long-range wide area network (LoRaWAN) is a type of Low Power Wide Area Network (LPWAN) that is specifically designed for long-range, low power, low cost, and low data rate applications [1]. These important characteristics ensure that the LoRaWAN occupies a very important role in the future of the Internet of Things (IoT), where billions of battery-powered IoT devices will be required to communicate over several kilometers with minimal energy consumption [2].

However, the ALOHA-like access scheme employed in LoRaWAN pre-disposes the network to a high rate of collision which in turn leads to other problems like low packet delivery rate (PDR), high latency, and other scalability-related issues [3]. Several research efforts have been aimed at solving several of these undermining problems of LoRaWAN with the overarching goal of ensuring the reliability and integrity of LoRaWAN devices. A general assumption in most of these researches is the homogeneity of the network. In this sense, all nodes and applications in the network are assumed to have similar requirements in terms of data rate, failure tolerance, energy usage pattern, and latency.

One may be tempted to excuse this assumption for two reasons. One, LoRaWAN was initially proposed for applications like soil monitoring, weather monitoring, and several other similar applications that are insensitive to delays and packet losses. Secondly, path loss between end-devices (ED) and gateways was considered as the single most important factor in LoRaWAN design.

While this assumption simplifies both theoretical and experimental analysis of the network, it drags it further away from what would be obtainable in a full-scale real-life deployment scenario. A fundamental requirement for a truly functional Long Range (LoRa) network will be the ability to provide support for multiple applications with different requirements. The need for this kind of requirement is even further exacerbated by the current deployment pattern of LoRaWAN in which connectivity through gateways is been provided like a service similar to what is obtainable in cellular networks [4]. This approach implies that gateways must function almost like base stations and coordinate a vast number of visible EDs with different constraints all while operating within an ALOHA-like access scheme network.

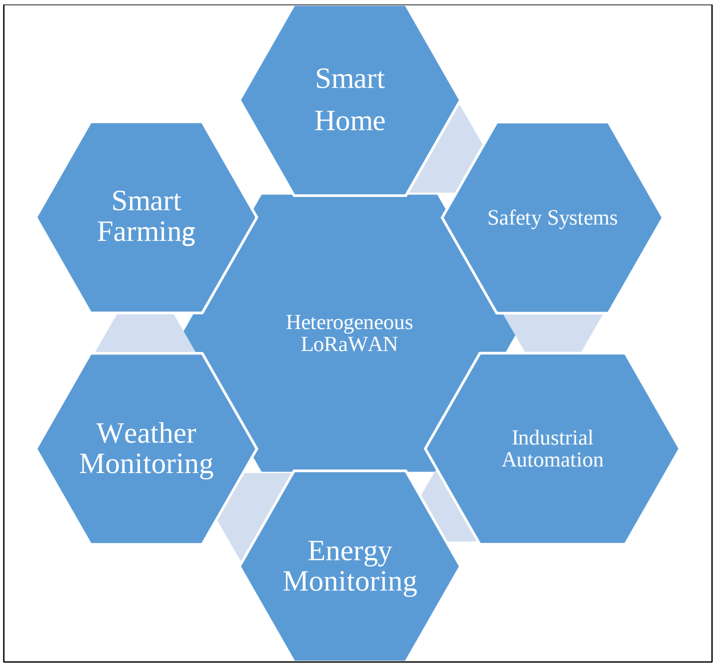

Figure 1: Heterogeneous network.
Source: Authors, (2022).

In this work, we propose a truly functional heterogeneous LoRaWAN application scenario and highlight the critical challenges such a network presents over homogeneous networks that have been the subject of most research on LoRaWAN. As shown in Figure 1, the proposed heterogeneous network runs applications that are categorized as either delay-tolerant low-reliability requiring applications (e.g., smart farming and weather monitoring), average delay tolerance, and average reliability requiring applications (such as smart home, energy monitoring, or smart grid) or delay intolerant high reliability requiring applications (such as safety systems and industrial automation applications). For the study, we assume all EDs operate within a line-of-sight environment. In other words, all transmitting nodes within the network are within the reach of the network gateway and thus have a moderate probability of successful uplink irrespective of their transmitting power or data rate.

Our experiment shows that at distances of about 3 km or less, heterogeneous LoRaWAN has about 20 percent higher uplink packet delivery rate in comparison to homogeneous network but at the cost of slightly higher energy consumption. However, the approach ensures that critical applications running on the network are guaranteed at least a 44 percent higher probability of successful transmission when compared with non-critical applications which are largely due to shorter time of air.

The rest of this paper is organized as follows: Section II provides a basic background to LoRaWAN together with published studies on wireless communication technology. In section III, we present the methodology for the study as well as the simulation parameters. In section IV, we present and discuss the results obtained from the study, and finally, in section V, we conclude the study.

II. THEORETICAL REFERENCE

II.1 BACKGROUND TO STUDY AND RELATED WORKS

IoT is one of the most rapidly expanding fields in today's world. The term is used to specifically describe the interconnection of sensors and actuators that share data over the internet [5]. As more IoT applications and services evolve, the limitations of existing technologies are becoming more and more prominent. For instance, existing wireless technologies like IEEE 802.11 wireless local area networks, IEEE 802.15.1 (Bluetooth), IEEE 803.15.3 (ZigBee), Near Field Communication (NFC), and Radio Frequency Identification (RFID) are principally for short-range communication [6]. While a few of these wireless technologies are capable of high data rate communication, their transmission range is limited to only a few meters (typically less than 100 meters) thus making them more suitable for short-ranged heavyweight applications. They are also mostly power demanding and thus can only be battery operated for only a relatively short period, usually a few weeks at most. Poor energy efficiency is the same reason, cellular networks like 2G, 3G, 4G, and LTE are considered unsuitable for most IoT applications despite their excellent transmission range [6], [7].

LPWANs on the other hand are very suitable for low data rate, energy-limited IoT applications. They are cheap, long-ranged, and can be battery-powered for several years [8]. They are currently available in several proprietary solutions like Long Range (LoRa) [9], SigFox [10], Narrowband-IoT [11], Ingenu [12], and Weightless [13].

LoRaWAN is arguably the de facto standard for the LPWAN technologies due to the open-access nature of its media access control (MAC) layer together with very extensive documentation [14]. LoRa, which is the proprietary physical (PHY) layer of the technology utilizes the direct sequence spread spectrum (DSSS) scheme to ensure a single hop, long-range communication through a gateway to a network server [15]. The gateway in LoRaWAN acts like a bridge between the LoRa node and the network server. The network server on the other hand aggregates all the uplink packets from the end devices or nodes, removes duplicates in case of multiple gateways, and routes the packets to the correct application server. The network server is also responsible for sending acknowledgment (ACK) to the end devices as a confirmation of successful receipt of uplink transmission.

ACK downlink is important in LoRaWAN because of the media access control technique adopted in the network. Specifically, the LoRaWAN MAC uses an ALOHA-like access control for the sake of simplicity [16]. This access protocol does not implement any form of collision detection or avoidance technique, hence uplinks from EDs are random and only limited by regional duty cycle restrictions [17]. This random nature LoRaWAN end devices uplink transmission presents a myriad of challenges with collision and poor packet delivery rate being the most important. Finding a suitable solution to these challenges has been the focus of several researchers in the LoRaWAN space. At the center of these different approaches in solving these problems is the use of the Adaptive Data Rate (ADR) [18]. The ADR is part of the specification of the LoRaWAN standard for optimizing the data rate and energy consumption in the LoRa network. The ADR algorithm uses the path loss and ACK signals from the network server to dynamically adjust the data rate (using the spreading factor) and transmission power of the EDs in the network. Authors in [19] and [20] carried out a comprehensive study on the agility of the ADR implementation in LoRaWAN. The challenges identified by the researchers include high convergence time of the ADR algorithm, sub-optimal convergence of the algorithm to low data rate as well as constant oscillations of nodes between different parameter combinations.

Several other authors have proposed different variations to the LoRaWAN ADR to enhance the functionality of the network, particularly in real-life deployment scenarios. For example, studies conducted by [21] proposed a slight modification to the ADR algorithm. The authors noted that the average of the SNR of end devices should be used in evaluating the link margin against the maximum SNR value proposed by the standard. In [22], the authors proposed a novel spreading factor allocation algorithm to extend the performance of LoRa. To achieve this, EXPLoRa-SF and EXPLoRa-AT algorithms were proposed. The proposed algorithms worked by dividing all end devices within the range of a particular gateway into six groups for six spreading factor assignments. However, for these two algorithms, since the six spreading factors were distributed based on the EDs distance from the gateway, there was no way of accommodating the peculiarity of the different applications the EDs may be serving. The study in [20] proposed an extension of the study carried out in [22] by proposing the inclusion of a back-off time of between two to six seconds for collision-related problems in LoRaWAN.

The ADR algorithms proposed by authors in [19]–[23] all have the limitation of only being practicable in a homogeneous LoRa network since the goal of the network is to ensure that all EDs in the network has an equal probability of successful uplink transmission. Fairness to all transmitting EDs was the central motivation behind the study conducted by [24], [25].

However, for LoRaWAN to truly reach maximum potential, there is the need to exploit its usage in a heterogeneous setting. In this sense, the network will be capable of successfully accommodating all the different evolving IoT applications leveraging the technology. Unfortunately, studies on heterogeneous LoRaWAN are limited. There is a somewhat confusing description of what constitutes a Heterogeneous LoRaWAN in literature. Authors in [26] describe a heterogeneous network as one in which individual nodes in the network selects their own LoRa configuration based on its link budget as against a homogenous network in which all nodes use the same LoRaWAN configuration. The study in [27] proposed a heterogeneous LoRa-based wireless multimedia sensor network. The network in this study was termed heterogeneous because it uses a platform that consists of a multimedia processor (Raspberry Pi 3) in addition to a low-power microprocessor used by the LoRaWAN end devices. The heterogeneity of the LoRa network proposed in [28] was based on spreading factor allocation while the one proposed in [29] was premised on the fact the network includes both ZigBee and LoRa which are two different LPWAN technology with different protocols and interfaces.

In this study, however, we define the heterogeneity of a network in terms of individual applications serviced by the network. In this sense, we assume a network with n number of independent applications where each node within the application network can take on a LoRaWAN configuration as defined within a boundary set by the requirements of the application.

III. MATERIALS AND METHODS

In highlighting the performance of a heterogeneous LoRaWAN vis-a-vis a homogeneous network, we propose the architecture shown in **Erro! Fonte de referência não encontrada.** The focus is to show the inherent challenges these networks will have to overcome in terms of packet delivery rate, energy utilization, and latency.

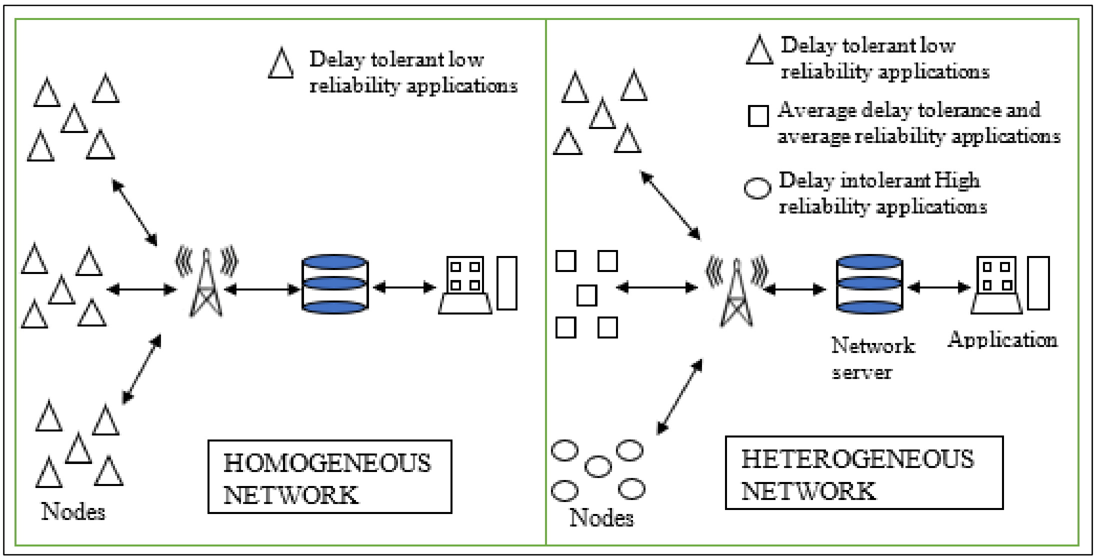

Figure 2: Homogeneous and Heterogeneous LoRaWAN setup.
Source: Authors, (2022).

For the study, we experimented with three different applications. These applications were classified as either delay-tolerant low reliability requiring applications, moderate delay tolerance moderate reliability requiring applications, and delay intolerant high-reliability applications. The delay tolerant low-reliability application is non-critical and a few seconds delay or few packet losses in the network will not have a severe impact on the application because the application environment is not sufficiently dynamic and generated data do not change too often. A good example of these is smart farming or agriculture application. At the other end are delay intolerant high-reliability applications like security and safety applications, fall detection in electronically monitored patients, industrial automation, etc. The cost of packet losses and delays in these applications can be enormous. In between the delay-tolerant and delay intolerant applications are applications like smart home and energy monitoring applications that are moderately impacted by delays and packet losses.

III.1 CHANNEL MODEL

If we denote N as the set of all end devices visible to the gateway, then the assumption is held that:

$$\text{For all node } n \,\epsilon\, \mathrm{N} = \{P_R > S\} \qquad (1)$$

This implies a network configuration where all end devices have a link budget that allows them to be within reach of the gateway irrespective of their network parameter and are only limited by the boundary set for their respective application.

S in equation (1) is the sensitivity of the gateway and P_R the received power from the end devices at the gateway which is as described by equation 2.

$$P_R\,[dBm] = P_T\,[dBm] + G_A^T[dB] + G_A^R\,[dB] - L[dB] \qquad (2)$$

Where P_T is the transmit power of the end device, G_A^T the gain of the transmitting antenna, G_A^R, the gain of the receiving antenna and L the path loss as given in Equation (3)

$$L = 69.55 + 26.16\log_{10}(f)\ \log - 13.82\log_{10}(h_b) - C_H + (44.9 - 6.55\log_{10}(h_b)).\log_{10}(d) + s \qquad (3)$$

From Equation (3), f is the frequency in MHz, h_b is the height of the gateway, d the distance between the gateway and the end device and C_H the height correction factor as described in equation (4).

$$C_H = 3.2(\ \log_{10}(11.75h_m))^2 - 4.97 \qquad (4)$$

h_m in equation (4) is the height of the end device antenna.

MATLAB-based LoRaWAN simulator [30] was employed with the Okumura-Hata model [31] implemented in the model development.

III.2 LORA PARAMETER ASSIGNMENT

To achieve the set task for the study, different data rates were assigned as shown in Table 1. Applications that are most sensitive to delays were assigned the highest data rate, while those with the least sensitivity are allocated to the lowest data rate. For the experiment, the application allotment was done in the ratio of 30:30:40. 30 percent of the end devices were delay intolerant application, another 30 percent for the average delay tolerant application while the remaining 40 percent was reserved to delay intolerant application.

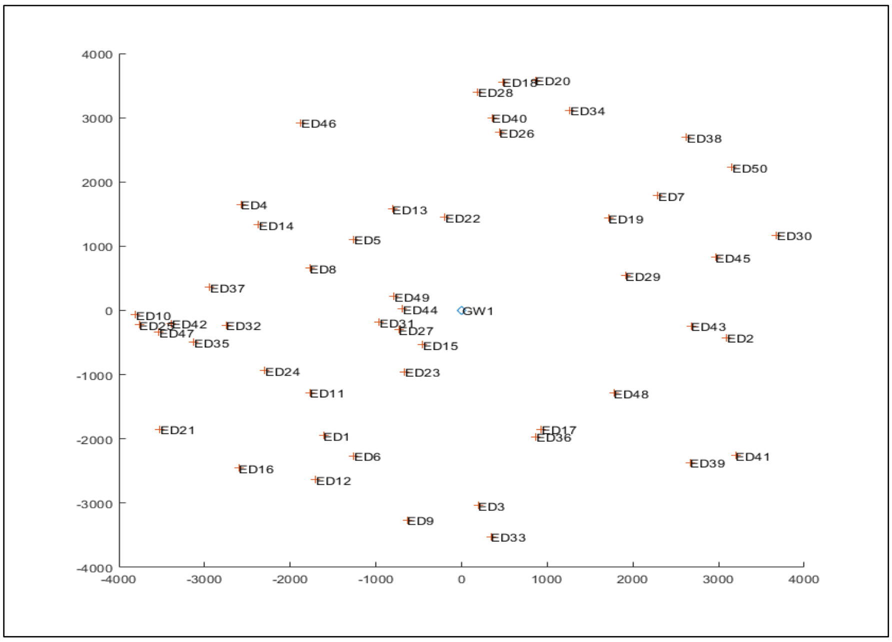

Figure 3: ED distribution around the gateway.

Source: Authors, (2022).

The end devices were randomly distributed around the gateway as could be seen in Figure 3.

Table 1: Heterogeneous Network Data Rate Allocation.

Data Rate	Spreading Factor	ApplicationApplication
DR0 – DR1	SF12 – SF11	Delay tolerant low-reliability applications
DR2 – DR3	SF10 – SF9	Average tolerance to delay and packet loss
DR4 – DR5	SF8 – SF7	Delay intolerant high-reliability application

Source: Authors, (2022).

The network was simulated with the simulation parameters shown in Table 2.

Table 2: Simulation Parameters.

S/N	Parameter	Value
1	Packet Size	20 bytes
2	Average Sending Interval	10 Seconds
3	Bandwidth	125 kHz
4	Coding Rate	4/5
5	LoRaWAN Header Size	7 bytes
6	Number of Gateway	1
7	Duty Cycle	1%
8	No of preamble	8

Source: Authors, (2022).

III.3 NETWORK EVALUATION

Finally, the network parameter for both homogeneous and heterogeneous scenarios was evaluated using the packet delivery rate, energy consumption, and latency. The packet delivery rate (PDR) and energy consumption (E) were estimated using equations (5) and (6) respectively. The latency was characterized by the time of arrival (ToA). The ToA is the time it takes the packet generated by the end device to arrive at the gateway and it is dependent on the data rate used for the transmission.

$$PDR = \frac{\sum_{n=1}^{N} d_n}{\sum_{n}^{N} T_n} \quad (5)$$

$$E = \frac{1}{N}\sum_{n=1}^{N} E_n \quad (6)$$

Where d_n is the packet successfully delivered by the end devices, T_n the number of transmitted packets and E_n the energy consumption of the end devices. The ToA was estimated using equation (7) – (11) [32]. The parameter definition for the ToA estimation is as shown in Table 3.

$$T_{sym} = \frac{2^{SF}}{BW} \quad (7)$$

$$T_{preamble} = (n_{preamble} + 4.25)T_{sym} \quad (8)$$

$$n_{payloadSym} = 8 + max\left\{ceil\left(\frac{8PL - 4SF + 28 + 16 - 20H}{4(SF - 2DE)}\right)(CR + 4), 0\right\} \quad (9)$$

$$T_{payload} = n_{payloadSym} \times T_{sym} \quad (10)$$

$$T_{packet} = T_{preamble} + T_{payload} \quad (11)$$

Table 3: Parameter definition for ToA Estimation.

ToA Parameter	Definition
T_{sym}	Symbol duration
SF	Spreading factor
BW	Bandwidth
$T_{preamble}$	Preamble duration
$n_{preamble}$	Number of preamble symbols
$n_{payloadSym}$	Number of payload symbol
$T_{payload}$	Payload duration
PL	Number of payload bytes
DE	Data rate optimization factor
H	Header enabled (H=0) or disabled (H=1)

Source: Authors, (2022).

IV. RESULTS AND DISCUSSIONS

First, we sought to understand how individual ED distances from the gateway impact the uplink packet delivery rate in both homogeneous and heterogeneous networks. The result is presented in Figure 4. The result highlights one of the major challenges heterogeneous networks may face in comparison to homogeneous networks. The result shows that homogeneous networks generally have a better uplink packet delivery rate in comparison to the heterogeneous network at distances exceeding 3 km while the heterogeneous network superior delivery rate for distances of about 3 Km or less. This result outlook is because, at short distances, the ADR algorithm converges all the EDs on the homogeneous to use the same transmission parameter thus leading to a high collision rate and less PDR. For the heterogeneous network, there is a better distribution of transmission parameters as shown in Figure 5. The energy consumption of the two networks is depicted in Figure 6. Energy consumption was found to be higher in the heterogeneous network at distances of about 4 Km or less but much less in comparison with homogeneous networks thereafter. A heterogeneous network has a better distribution of the SF thereby having better energy usage, particularly at larger distances.

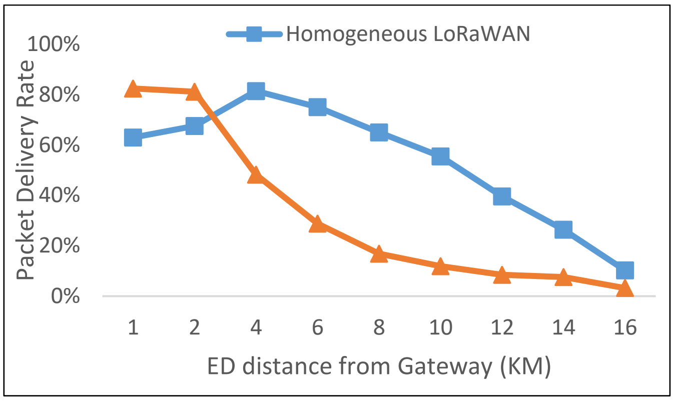

Figure 4: Uplink delivery rate variation with distance from the gateway.
Source: Authors, (2022).

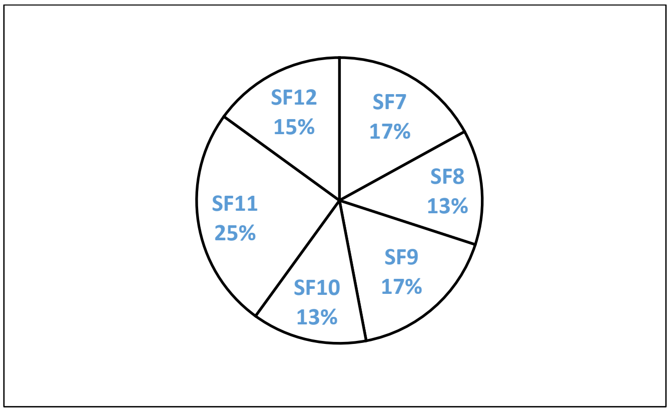

Figure 5: SF allocation for Het. Network at 2 KM.
Source: Authors, (2022).

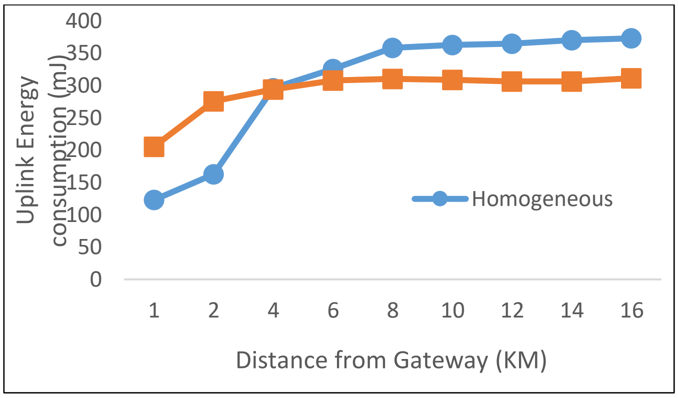

Figure 6: Uplink energy consumption with distance.
Source: Authors, (2022).

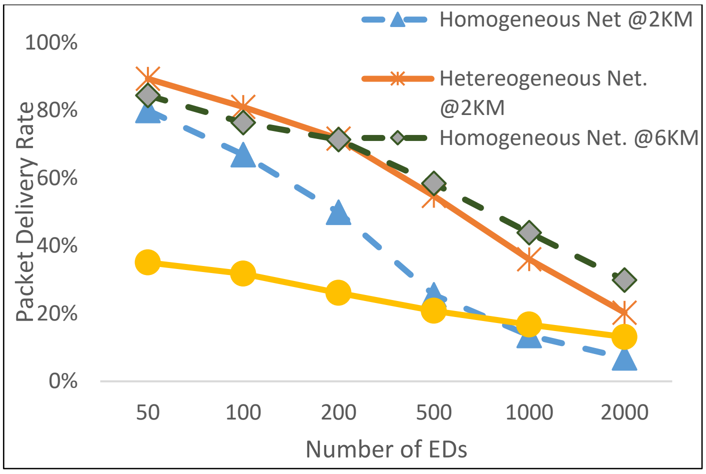

Figure 7: LoRaWAN PDR with varying number of EDs.
Source: Authors, (2022).

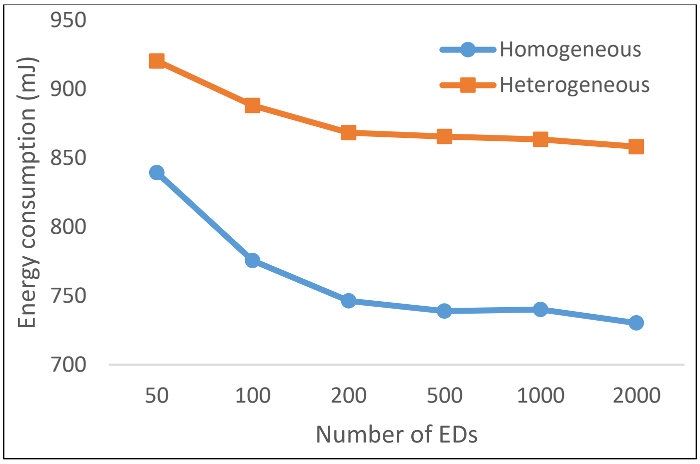

Figure 8: Energy consumption with varying number of Eds.
Source: Authors, (2022).

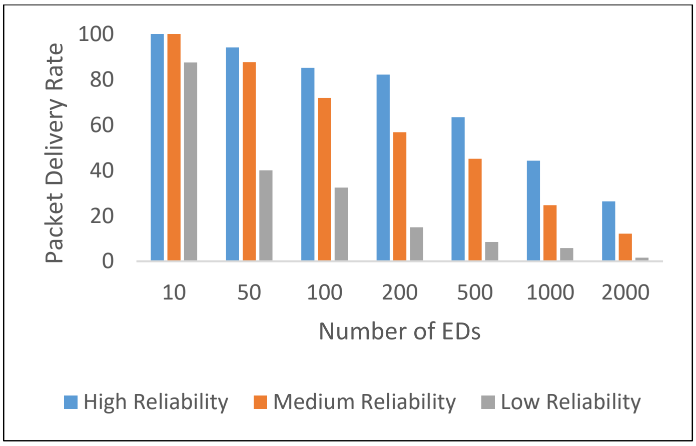

Figure 9: PDR for applications on the Heterogeneous LoRaWAN.
Source: Authors, (2022).

Figure 7 shows how the number of EDs affects the LoRaWAN uplink PDR. Generally, for both networks, the PDR expectedly reduces as the network size increases. At a distance of 2 KM, the heterogeneous network outperforms the homogeneous network due to high collision on the homogeneous network largely. However, for a distance of 6 km, the challenge of heterogeneous networks becomes glaring as it is outperformed by the homogeneous network. Energy usage at these large distances is also much higher in heterogenous LoRaWAN as shown in Figure 8.

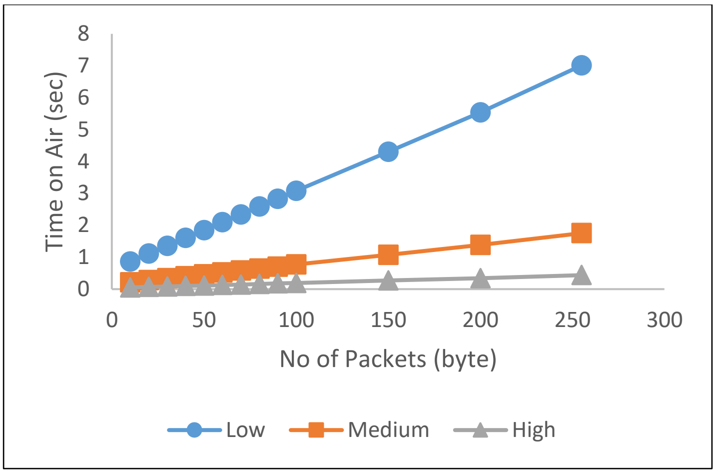

Figure 10: Time on Air for low, medium, and high reliability demanding applications.
Source: Authors, (2022).

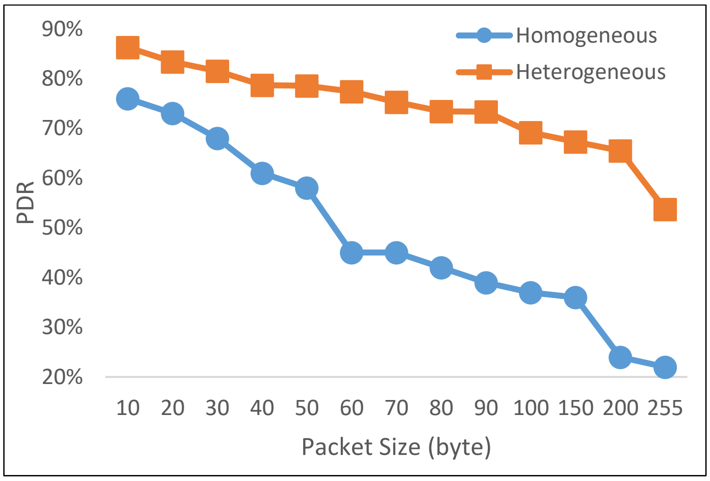

Figure 11: PDR with packet size.
Source: Authors, (2022).

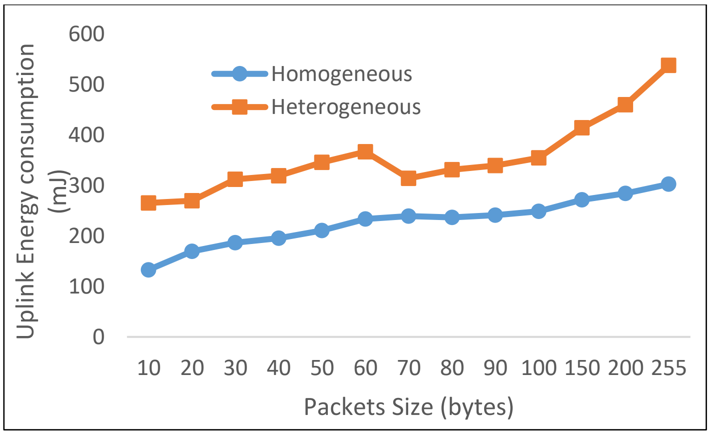

Figure 12: Energy consumption with packet size.
Source: Authors, (2022).

Figure 9 shows the PDR for each of the different applications on the Heterogeneous Network. The result shows that the critical application gets the priority by having 44 percent higher PDR in comparison to applications that require either medium reliability or low reliability which is good since there is no guarantee of better packet delivery for critical applications running on the homogeneous network. The higher PDR is directly linked to the shorter time on air as shown in Figure 10. Since the packet transmission takes much less time in critical applications, the probability of collision is greatly reduced.

The variation of uplink packet delivery rate with packet size is shown in Figure 11. Clearly, the larger the packet size, the lower the packet delivery rate. However, the performance of the heterogeneous network well outperforms that of the homogeneous network largely because of the allocation of transmission parameters for the transmission of the packets as against homogeneous network which uses the same parameter for the packets.

The energy consumption variation with packet sizes is as shown in Figure 12. The energy consumption varies proportionally with the increase in packet sizes. However, energy consumption is much higher in heterogeneous LoRaWAN than in homogeneous LoRaWAN.

V. CONCLUSIONS

In this study, we proposed a heterogeneous network and compared its performance with the homogeneous network which has been the focus of most studies on LoRaWAN. The heterogeneous network was designed to the application dependent and can consequently provide simultaneous support for applications with different requirements in terms of data rate and latency. We established that while such a system is limited in range and slightly more energy-consuming, they possess a higher probability of successful uplink since critical applications can enjoy preferential parameter allocation.

VI. AUTHOR'S CONTRIBUTION

Conceptualization: Olaide Ayodeji Agbolade, Folasade Mojisola Dahunsi and Samson Adenle Oyetunji.
Methodology: Olaide Ayodeji Agbolade and Folasade Mojisola Dahunsi.
Investigation: Olaide Ayodeji Agbolade.
Discussion of results: Olaide Ayodeji Agbolade.
Writing – Original Draft: Olaide Ayodeji Agbolade.
Writing – Review and Editing: Olaide Ayodeji Agbolade and Folasade Mojisola Dahunsi.
Resources: Olaide Ayodeji Agbolade and Samson Adenle Oyetunji.
Supervision: Folasade Mojisola Dahunsi and Samson Adenle Oyetunji.
Approval of the final text: Olaide Ayodeji Agbolade, Folasade Mojisola Dahunsi and Samson Adenle Oyetunji.

VII. ACKNOWLEDGMENTS

This research was funded by TETFund Research Fund Grant 2019 (TETFund/DR&D/CE/NRF/STI/58/VOL1).

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Journal of Engineering and Technology for Industrial Applications

ISSN ONLINE: 2447-0228

ITEGAM-JETIA

Manaus, v.8 n.34, p. 12-19. Mar/Apr, 2022

DOI: https://doi.org/10.5935/jetia.v8i34.804

RESEARCH ARTICLE OPEN ACCESS

HEAT TRANSFER ENHANCEMENT IN A P-SHAPE FINNED RADIAL HEAT SINK SUBJECTED TO NATURAL CONVECTION: THERMAL SIGNIFICANCE OF SLOT AND DIMPLES IN FIN

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ARTICLE INFO

Article History
Received: March 05th, 2022
Accepted: April 24th, 2022
Published: April 30th, 2022

Keywords:
Radial heat sink,
P-shape fin,
Slot,
Dimples,
Natural convection.

ABSTRACT

This study presents the optimum design of the radial heat sink for light-emitting diode (LED) under natural convection. A radial heat sink with a hollow circular base and a P-shape fin type incorporated with either slots or both slots and dimples was numerically investigated using the ANSYS (Fluent) commercial code, with the aim of achieving better cooling performance at a lower heat sink mass. The average temperature (T_{avg}) and mass of the HS for various model designs, namely; Type A (HS with plain fin), Type B (HS with slot) and Type C (HS with both dimples and slot) were compared to select the best configuration. The effect of heat flux ($700 \le \dot{q} \le 1900$) on average temperature of radial heat sink was investigated. It was found that for all three models, the temperature difference between the HS and the ambient air of the fluid domain linearly increased with heat flux. At $\dot{q} = 1900 W/m^2$, when compared to Type A (HS with plain fins), Type C (HS with slot and dimples) models offered the best cooling performance, followed by Type B where the mass and average temperature of the heat sink is reduced by 13.7% and 5.1%, 8.3% and 1%, respectively.

I. INTRODUCTION

Cooling through free convection is suitable, especially for small electronics components such as LEDs because it is relatively simple, less expensive and eco- friendly. LED is known for its durability, efficiency, and cost-effectiveness. Thus, LEDs replaced much extant lighting devices. Studies have revealed that more than 50% of the power required by LEDs is transformed into heat. Therefore, it is important to sufficiently cool the LED device for smooth operation and higher efficiency. Cooling of the electronics component may be active or passive, the most widely used device for passive cooling is the heat sink. To meet the demands of higher thermal performance for LED devices, the challenges of cumbersome heat sinks are always encountered. Therefore, cutting-edge technology, perhaps in the aspect of heat sink design, materials selection, mass reduction, and as such, is required to improve the heat sink's performance.

II. THEORETICAL REFERENCE

Several studies have been conducted on the cooling performance of the HS for LED devices. Costa and Lopes [1] used ANSYS (CFX) commercial codes to conduct a computational study on a radial HS having protruded fins under free convection. They revealed that the average temperature of the HS is insignificantly influenced by the thickness of the fin. Furthermore, it was pointed out that the heat sinks average temperature initially declined, and then increased with the number of fins. Jang et al. [2] numerically performed a parametric study on the arrays of pin fins at various height configurations. They observed that the HS with the tallest outermost fin yielded the optimum cooling performance. Sparrow and Vemuri [3] evaluated the heat transfer characteristics of a pin-fin heat sink for several orientations of the installation under the conditions of radiation and natural convection. They found that the vertical pin-fin provided the best cooling performance. Yildiz and Yuncu [4] demonstrated a study on the thermal performance (TP) of an annular fin mounted on a cylinder subjected to natural convection. They indicated that the highest heat transfer coefficient (HTC) is obtained at an optimum spacing between the fins. Tijani and Jaffri [5] observed the influence of perforations on pin-fin HS subjected to force convection. They concluded that the HTC is improved by 40% in a HS with perforated fins. Jaffal [6] performed both experimental and numerical studies on the TP of HS having different fin designs. He concluded that heat flux strongly influences the heat transfer rate and, more so, HS with perforated fins performed better than others. Rath et al. [7] numerically examined the thermal characteristics of radial HS consisting of longitudinal corrugated fin with three different number of cycles (one cycle, two cycles, and three cycles). They revealed that the highest value of fin effectiveness and Nusselt number was obtained in corrugated fins with three cycles, followed by two cycles and one cycle. Tehmina et al. [8] adopted a multiphase Eulerian-Lagrangian model to simulate the hydrothermal behavior of three different multiwalled carbon nanotubes (MWCNT) heat sinks with hydrofoil pin-fin, rhombus pin-fin, and triangular pin-fin, respectively. They concluded that better performance was achieved in the triangular pin-fin MWCNT heat sink as compared to others. Rahul et al. [9] numerically explored the heat transfer enhancement in HS with branched and interrupted fins. They reported that HS with branched fins yielded better performance, and they further suggested that higher performance is obtained in HS with branched fins when the symmetrically oriented secondary fins of the branched fins are far from the base of the plate. Ding et al. [10] carried out experimental and numerical studies on the thermal dissipation behaviors of vertically oriented finned tubes. They indicated that a Nusselt number of about 207% was obtained in a heat sink with finned tubes as compared to that of a convectional heat sink. Furthermore, they opined that the effects of circular fin pitch and the width of the fin were insignificant. Hithaish et al. [11] numerically analyzed the hydrothermal characteristics of heat sink with triangular pin-fin at different orientations ($30\ ^oC$ to $60\ ^oC$), height of the fin ($0.25mm$-$0.75mm$) and arrangements (alternate backward and forward). They revealed that HS with triangular pin fins in alternate forward and backward configuration had the highest value of the thermal performance index. In this study, the P-shape fin designs are proposed to enhance the thermal dissipation of the radial heat sink without altering the mass of the HS above the comparable convectional HS. Cooling performance of three different HSs (the Type A-HS with plain fin, the Type B-HS with slot, and Type C-HS with both slot and dimples) are compared.

III. METHODOLOGY

III.1 GEOMETRY DESCRIPTION

A three-dimensional HS is designed using Design Modeler of ANSYS (Fluent) software package. Fig. 1(a)-(c) shows three different designs of radial heat sink, Type A-plain, Type B-slot and Type C-slot and dimples) respectively. each of the heat sink which made of aluminum material consists of P-shape fins attached to vertically projected annular cylinder and then mounted on hollow circular base. The fins are radially arranged at an equal interval on a hollow circular base which projected horizontally. The bottom of the HS is subjected to heat flux varied from $700W/m^2$ to $1900W/m^2$, ambient temperature of the air is maintained at 300K. Fig. 2(a)-(b) illustrates the schematic diagram of the fin and computational domain. A portion of the HS containing one fin is demonstrated because of the time consumption as a result of large number of grids in the simulation. The details of the computational domain and the heat sink parameter are presented in Table 1.

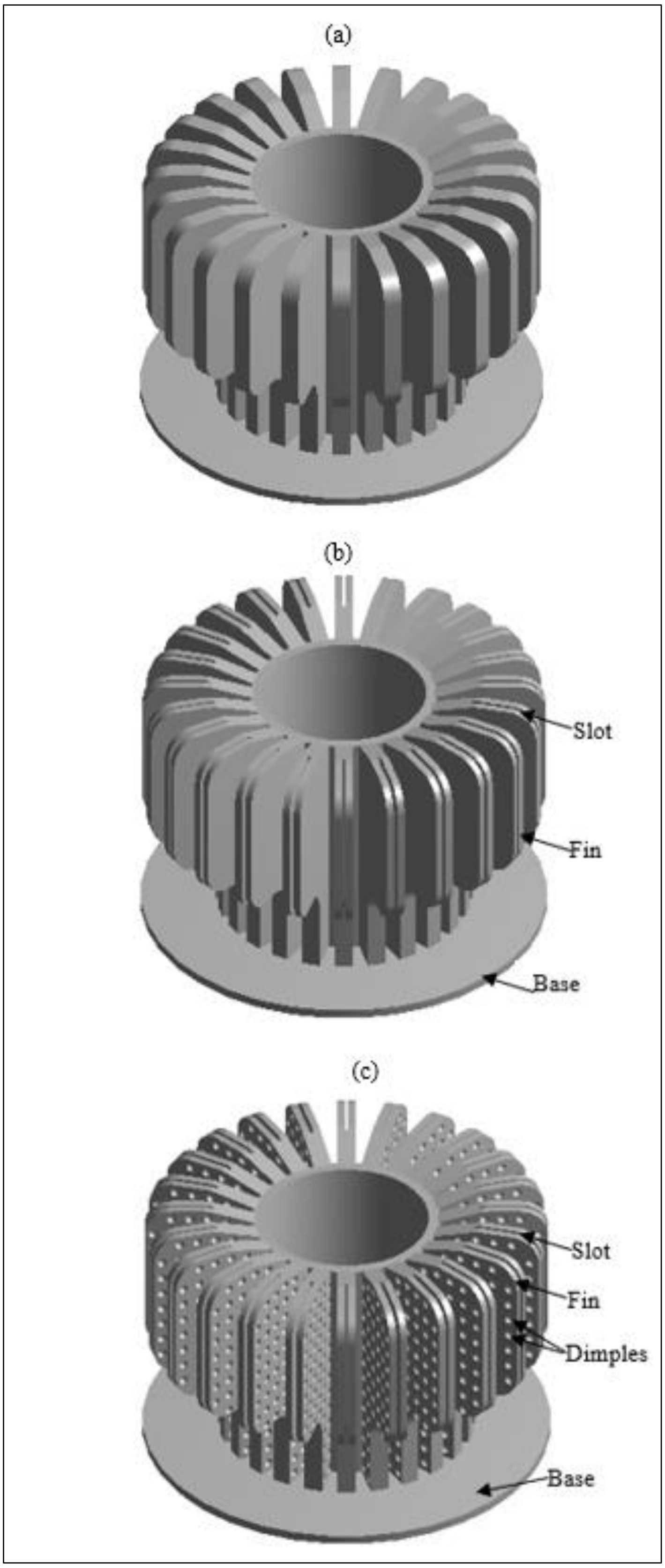

Figure 1: SS (a) Type A (Radial HS with plain fins or convectional) (b) Type B (HS with slotted fins) (c) Type C (HS with slotted and dimpled fins).
Source: Authors, (2022).

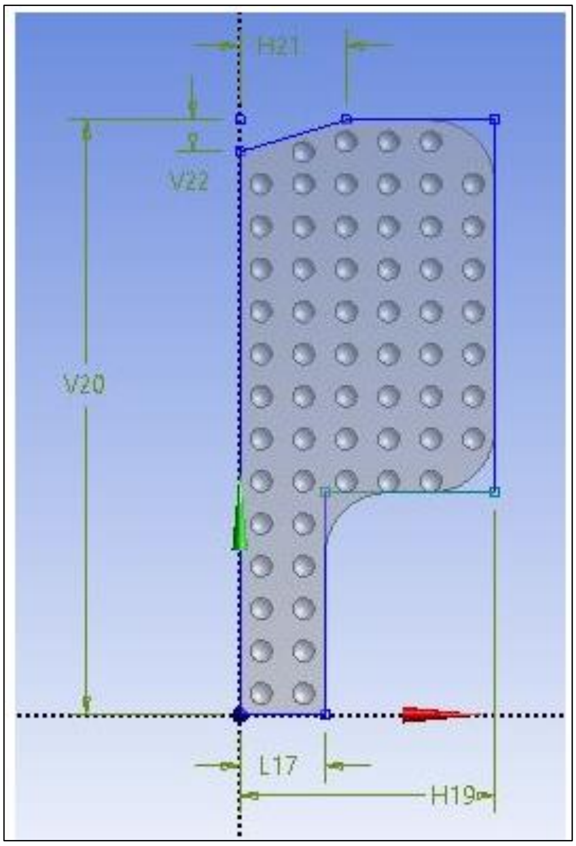

Figure: 2(a) Schemtic representation of the fin with dimples.
Source: Authors, (2022).

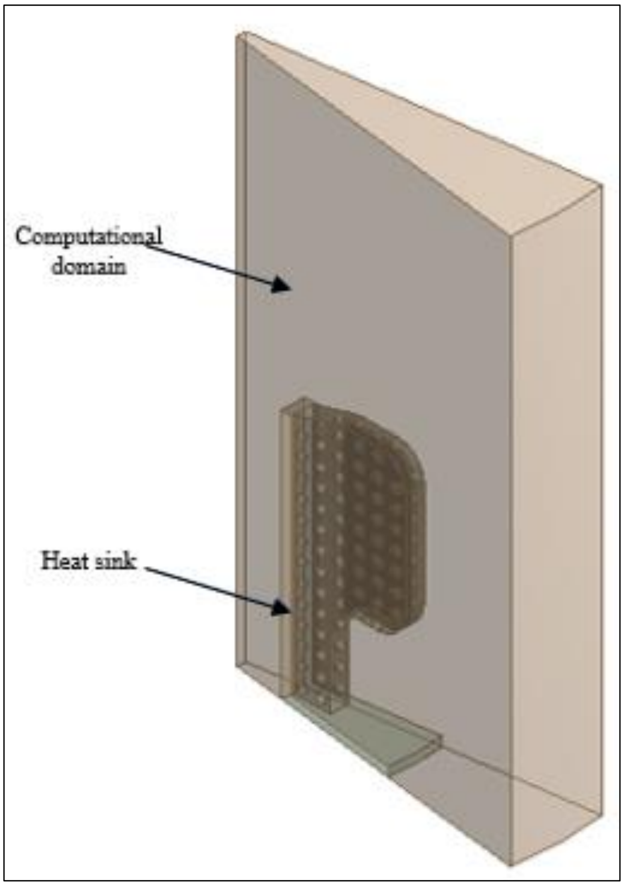

Figure: 2(b) Schemtic diagram of the computational domain and HS.
Source: Authors, (2022).

Table 1: Dimensions of the heat sink.

Item	Parameter	Value
Computational domain	Base radius (R)	37.5mm
	Height (H)	145mm
Radial Heat sink		
Circular base	Inner radius (r_i)	9mm
	Outer radius (r_0)	22.25mm
	Base thickness (t_b)	1mm
P-shape Fin	Fin thickness (t_f)	2mm
	H_{19}	12mm
	H_{21}	5mm
	L_{17}	4mm
	V_{20}	28mm
	V_{22}	1.5mm
	Fillet radius (r_f)	2.5mm
	Sphere/Dimple radius (r_D)	0.5mm
	Dimples spacing	2mm
	Slot length (L_s)	7.5mm
	Slot width (W_s)	0.2mm
	Slot height (H_s)	16mm
	Number of fins (N_f)	24

Source: Authors, (2022).

III.2 MESH GENERATION

The grids were generated using ANSYS Mesh. As depicted in Fig. 3(a)-(b), the Qua/Tri hexahedral method was assigned to the whole geometry, while the refined mesh of element size of 0.008mm and 0.009 are assigned to the HS and fluid domain respectively.

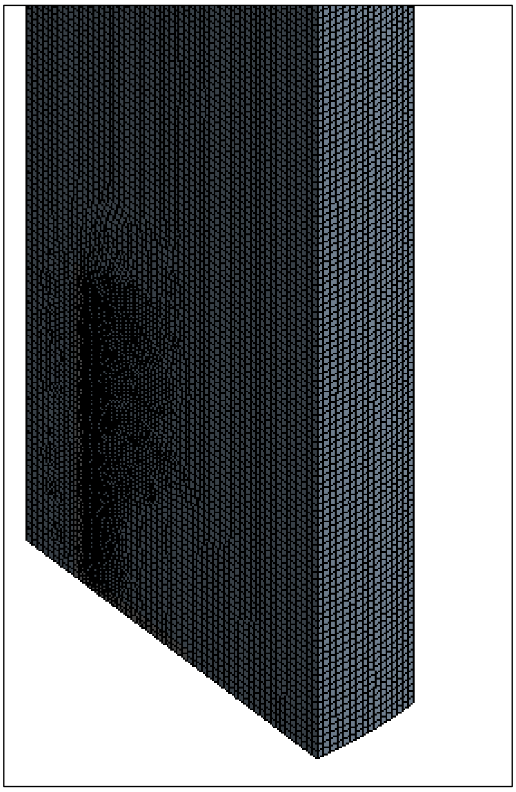

Figure: 3(a) hexahedral grids for computation domain.
Source: Authors, (2022).

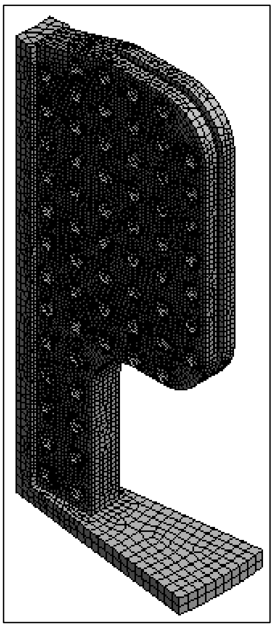

Figure: 3(b) hexahedral grids for heat sink.
Source: Authors, (2022).

III.3 PROBLEM FORMULATION

The computational simulation of natural convection is based on the assumptions stated below.

1. The flow is assumed to be steady, laminal, and three-dimensional.
2. All the properties of air do not depend on the temperature, except the density.
3. The density of the air is computed by using an ideal gas law.
4. Radiation and magnetic effects are neglected.

The governing equations are presented below;

Continuity equation

$$\nabla.(\rho v) = 0 \quad (1)$$

Momentum equation

$$\frac{D\mathbf{v}}{Dt} = -\frac{\nabla P}{\rho} + \upsilon\nabla^2\mathbf{v} - g_y \quad (2)$$

Energy equation

$$\rho C_p \frac{DT}{Dt} = \nabla.(k\nabla T) + \frac{DP}{Dt} \quad (3)$$

Ideal gas law is used to compute density of the air

$$\rho = \frac{p_{atm}}{(R/M_w)T} \quad (4)$$

M_w denotes the molecular weight of the air, which is taken as 28.966 kg/kmol.

The material properties of the heat sink and the boundary conditions adopted for this study are presented in Table 2 and Table 3, respectively.

Table 2: Boundary conditions.

Domain	Location	Hydrodynamic conditions	Thermal conditions
Fluid	Periodic	$u_i(\vec{r_i}) = u_i(\vec{r_i} + \vec{L})$	$T(\vec{r_i}) = T(\vec{r_i} + \vec{L})$
		$\nabla p(x_i) = \eta\frac{\overline{L}}{\lvert L\rvert} + \nabla p^*(x_i)$	
	Outer	*Pressure inlet/Pressure Outlet condition*	$T_{inlet} = T_{outlet,backflow=}T_\infty$
Solid	Heat sink base	$u_i = 0$	$-k_s\frac{\partial T_s}{\partial n} = \dot{q}$
	Symmetric face	$u_i = 0$	$\frac{\partial T_s}{\partial n} = 0$
Fluid-solid	Interface	$u_i = 0$	$T_{f,wall=}T_{s,wall}$ $-k_f\frac{\partial T_f}{\partial n}\lvert_{wall} + \dot{q}_{out} = -k_s\frac{\partial T_s}{\partial n}\lvert_{wall} + \dot{q}_{in}$

Source: Authors, (2022).

Table 3: Thermo-physical properties of the heat sink and the air.

Materials	***C_p*** ***($Jkg^{-1}K^{-1}$)***	***μ*** ***(Pa.s)***	***k*** ***($Wm^{-1}K^{-1}$)***	***ρ*** ***(kgm^{-3})***
Air	1005	1.834e-05	0.0242	$\frac{p_{atm}}{(R/M_w)T}$
Heat sink	871	-	136.8	2719

Source: Authors, (2022).

III.4 NUMERICAL PROCEDURE

The ANSYS (Fluent) software package was used to perform the numerical simulation, and was used to solve the continuity, Navier-Stokes equations (momentum and energy equation) taking into account the boundary conditions and assumptions stated earlier. The COUPLE Algorithm was assigned for pressure-velocity coupling, default value of under-relaxation parameter was used, the Least Square cell based was assigned for the gradient under spatial discretization and the second-order upwind scheme was used for density, momentum, and energy, whilst Body Force Weighted was set for pressure. All solver residuals were set to convergence criteria of 1×10^{-4}.

IV. RESULTS AND DISCUSSIONS

To select the best design, we compared the average temperature of all the cases while maintaining the same conditions.

IV.1 GRID SENSITIVITY STUDY

The grid sensitivity test was carried out by increasing the number of grids from 80000 to 600000. The parameters of type A profiles (heat sink with plain fin) at heat flux of $700W/m^2$ are used as reference. As illustrated in Fig. 4, 328221 grid was selected as a reference grid point from the grid independence test, because a further increase in the number of grid points beyond 328221, yielded less than 2% in the variation of average temperature of the heat sink.

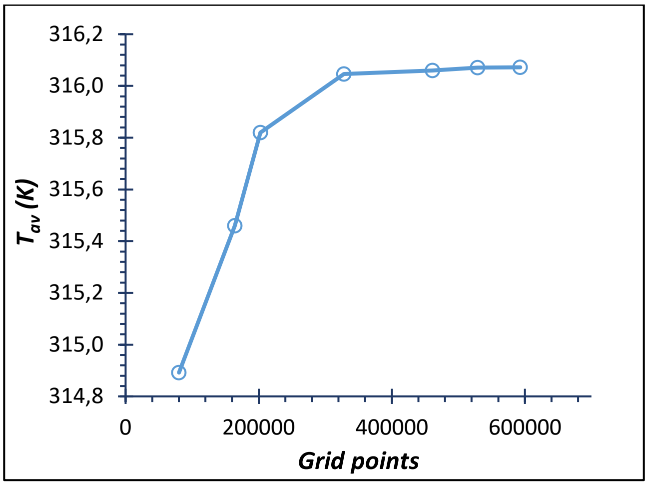

Figure 4: Average temperature of the HS at various grid points.
Source: Authors, (2022).

IV.2 MODEL VALIDATION

The difference between the average temperature (T_{avg}) of the HS and the ambient temperature of the air (T_{amb}) is presented to compare the numerical results of this study with the experimental data of Seung-Hwan et al. [12]. the geometry parameters used for validation are $N_f = 20, L_f = 55mm, t_f = 2mm, h_{fL} = 21.3mm, h_{fH} = 21.3mm, r_i = 10mm, r_o = 75mm,$ $t_b = 1.5mm$ and $200 \leq \dot{q} \leq 850$. Fig. 5 presents the comparison of the temperature difference against the heat flux for the numerical results of this work and the experimental data provided by Seung-Hwan et al. [12]. A good agreement is established between the present work and the experimental data of Seung-Hwan et al. [12].

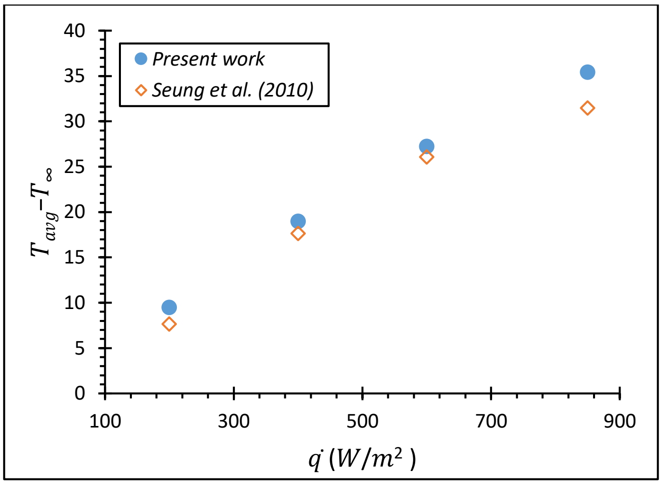

Figure 5: Comparison of temperature difference between the numerical results and experimental result.
Source: Authors, (2022).

IV.3 RESIDUALS PLOT

The residuals plot in Fig. 6 below depicts the convergence of the continuity, momentum (velocity) and energy curve for Type A heat sink model at a constant heat flux of $700W/m^2$.

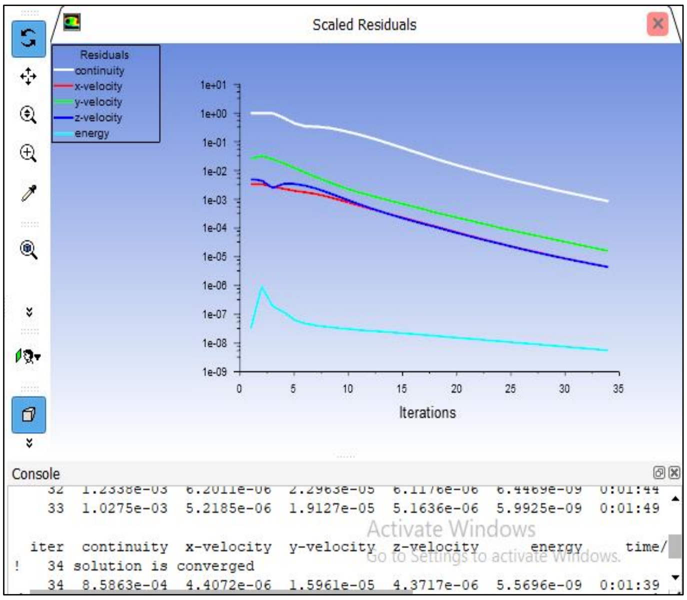

Figure 6: Residuals plot.
Source: Authors, (2022).

IV.3 EFFECT OF HEAT FLUX ($\dot{q}$)

Fig. 7 depicts the influence of heat flux applied to the base of a HS on the thermal performance of various model designs. As shown in Fig. 7, the difference between the T_{avg} of the HS and ambient air (T_{amb}) increases linearly with heat flux. At $700 \leq \dot{q} \leq 1900$, Type C (HS with slot and dimples) has lowest temperature difference, followed by Type B (HS with only slot) and Type A (plain). At $\dot{q}$ =700 W/m^2, temperature difference of 16.05K, 15.12K and 9.83K is reported in Type A (plain), Type B (HS with slot) and Type C (HS with slot and dimples) as follows. However, at $\dot{q}$ =1900 W/m^2, Type A, Type B and Type C has a temperature difference of 44.48K, 41.7K and 27.05K as followed.

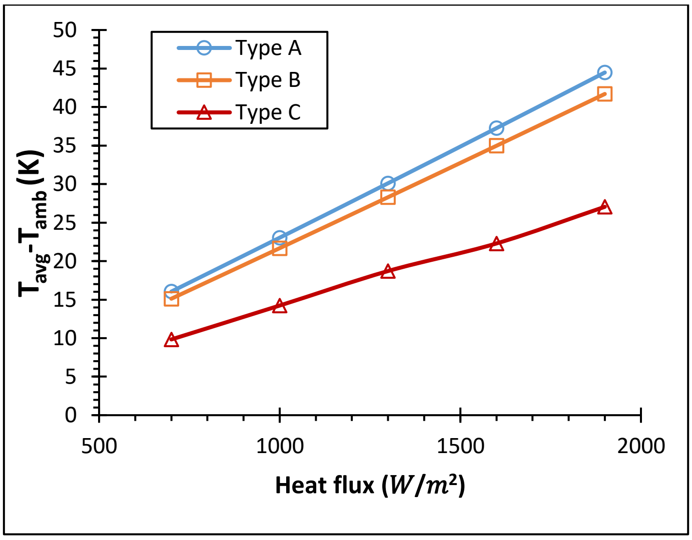

Figure 8: Comparison of temperature difference against heat flux at different model designs.
Source: Authors, (2022).

IV.4 COMPARISON OF THE TYPE A (PLAIN), TYPE B (HS WITH) AND TYPE C (HS WITH SLOT AND DIMPLES) MODEL

Table 4 compares the average temperature and mass of each of the HS designs at a constant heat flux of 1900 W/m^2. In respect to Type-A (Plain) HS design, which has the highest average temperature of 344.48K and a mass of 0.00168kg, it is observed that by incorporating a slot in the fin as we have in Type-B HS model, the average heat sink temperature and the mass are reduced by 2.78K and 8.33%, whereas total surface area increases by 29.58%. This simply means that the Type B model has a better thermal performance than the Type A model with just a plain fin, because the slot in Type B creates an additional passage or spacing in the fin which increases the cooling region or heat transfer area of the fin. However, upon the incorporation of both slots and dimples to the plain fin, as it is shown in Type C model, the T_{avg} and the mass of the HS are decreased by 17.43K and 13.69%. Among all the model designs, Type C (slot and dimples) has been seen to have the best cooling performance and lowest mass. The reason for this is that the incorporation of both slot and dimples has a greater influence on thermal performance by increasing the heat transfer area as compared to the Type B model (HS with slot) and the Type A model with a plain fin.

Table 4: Average Temperature and mass for various heat sink designs at $\dot{q}$ =1900 W/m^2.

Model	Total Area (mm^2)	Frontal Area (mm^2)	Volume (mm^3)	Mass (kg)	Temp (K)
Type A	852.87	287.56	618.31	0 .00168	344.48
Type B	1105.2	287.56	566.90	0.00154	341.70
Type C	1201.1	269.5	534.96	0.00145	327.05

Source: Authors, (2022).

IV.4 TEMPERARURE CONTOUR

Fig. 9 through Fig. 11 visualizes the heat flow between the heat sink and fluid domain in the z-x plane and the x-y plane. Heat flows in two directions, which are horizontal direction and upward direction. Heat flows in a horizontal direction when the cooled air from the fluid domain horizontally approaches the outer part of the heat sink where it becomes warmer (the temperature of the cooled air from the fluid domain gradually increases while approaching the outer part of the heat sink). It is also observed that the temperature of the air in the outer part of the HS is comparatively lower than the temperature in the inner part. Furthermore, the warmed air from the outer part of the HS enters the spaces between the fins and becomes warmer and lighter as compared to its previous state in the outer part. Due to the fact that the surrounding air in the outer part of the HS is heavier than the warmed air between the fins (which has a higher temperature), density therefore plays a greater role here by displacing the warmed air between the fins upward in a vertical direction from the inner part of the HS. However, the temperature of the HS decreases as the cooling air flows from the base to the tip of the HS (the HS which is maintained at a relatively higher temperature, is cooled by the cooling air).

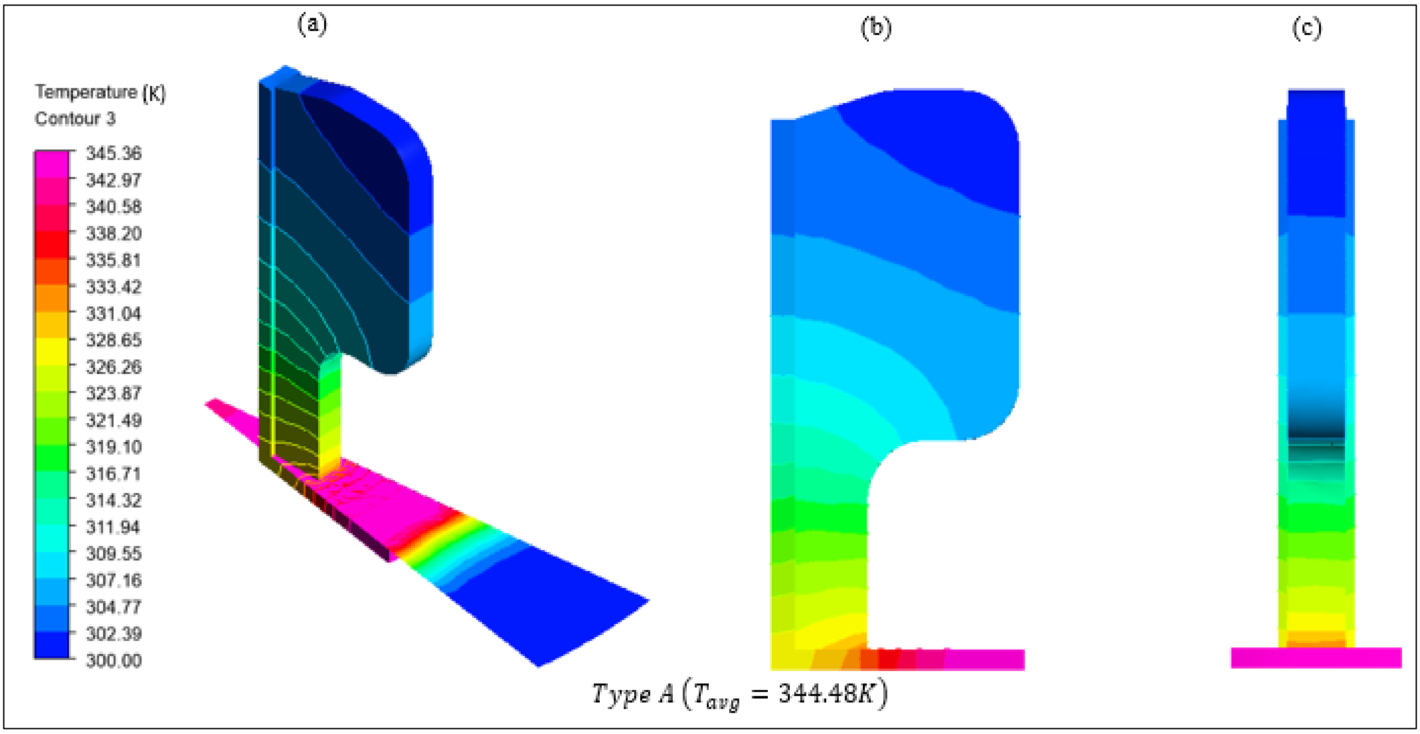

Figure 9: Temperature contour plot of the Type A radial HS at $\dot{q}$ =1900 W/m^2 for (a) 3D view of Type A (b) Side view of Type A (c) Frontal view of Type A.

Source: Authors, (2022).

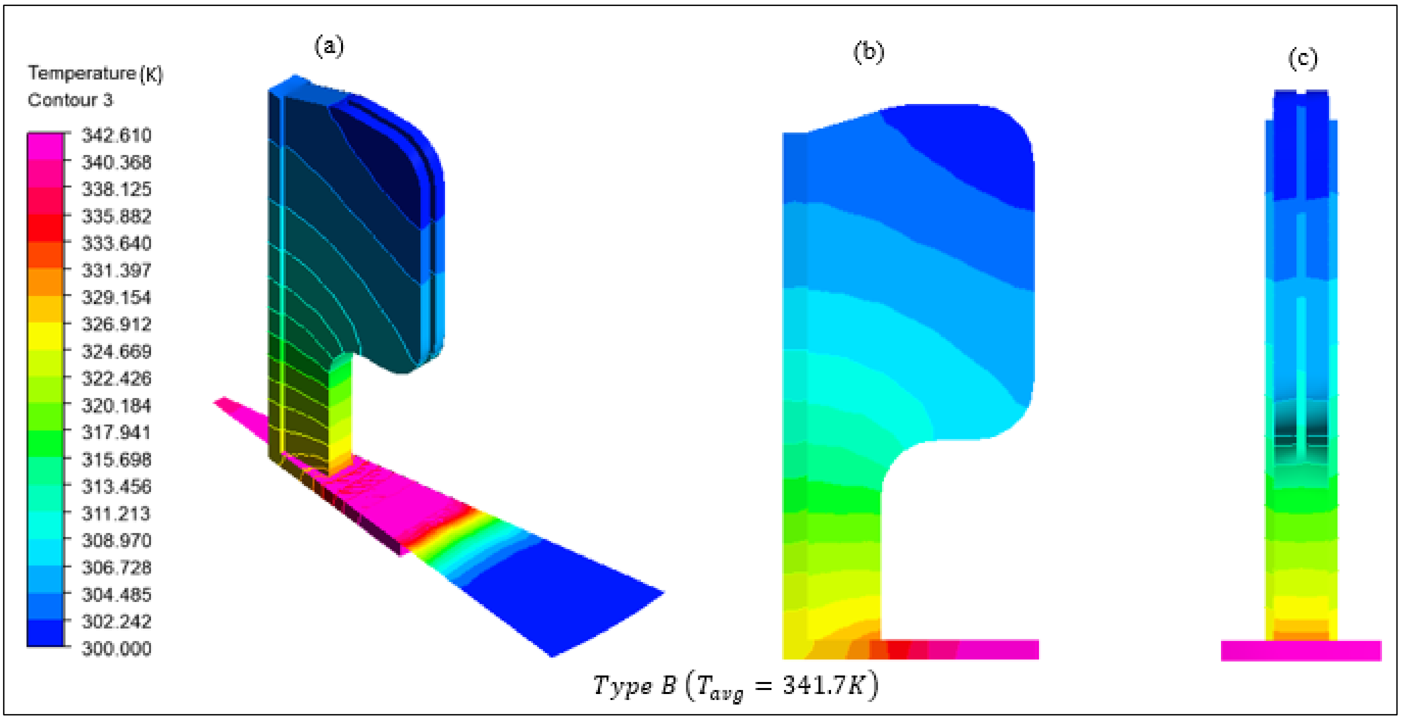

Figure 10: Temperature contour plot of the Type B radial HS at $\dot{q}$ =1900 W/m^2 for (a) 3D view of Type B (b) Side view of Type B (c) Frontal view of Type B.
Source: Authors, (2022).

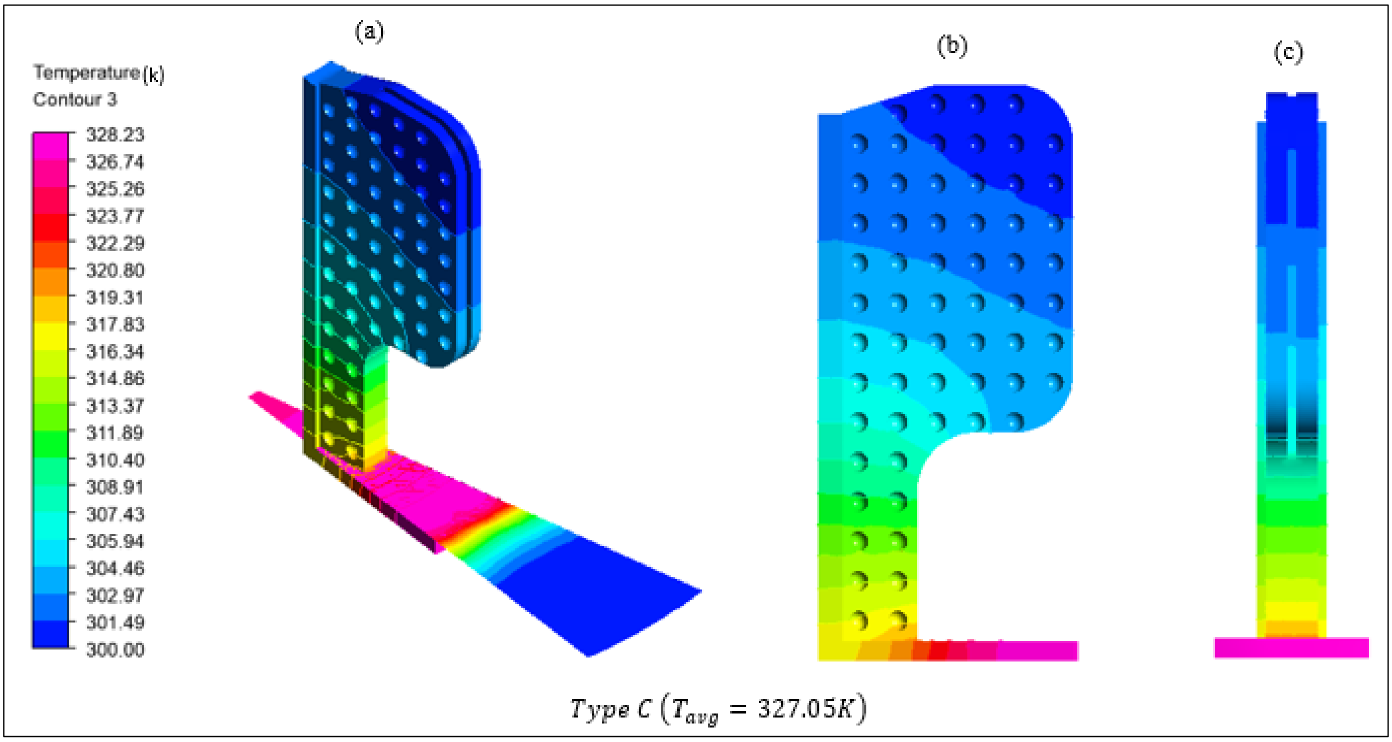

Figure 11: Temperature contour plot of the Type C radial HS at $\dot{q}$ =1900 W/m^2 for (a) 3D view of Type C (b) Side view of Type C (c) Frontal view of Type C.
Source: Authors, (2022).

V. CONCLUSIONS

Thermal analyses were conducted to maximize the performance of a P-shape finned radial HS under natural convection by using ANSYS (Fluent) software. Validation was carried out by comparing the numerical results with the available experimental data, and the agreement was satisfactory. To determine the best design for the P-shape finned heat sink, three different designs of heat sink, namely Type A (HS with plain fin), Type B (HS with slot) and Type C (HS with slot and dimples) were compared based on the T_{avg} and mass of the HS. Among all these models, Type C is the most economical and provides the best cooling performance because of its lowest average temperature and heat sink mass.

VI. AUTHOR'S CONTRIBUTION

Conceptualization: A.Ibrahim Fetuga, T. Olabode Olakoyejo, and K. Joshua Gbegudu.
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Discussion of results: A. Ibrahim Fetuga, T. Olabode Olakoyejo and O. Adekunle Adelaja.
Writing – Original Draft: A. Ibrahim Fetuga and K. Joshua Gbegudu.
Writing – Review and Editing: A. Ibrahim Fetuga, T. Olabode Olakoyejo and O. Adekunle Adelaja.
Resources: T. Olabode Olakoyejo.
Supervision: T. Olabode Olakoyejo and O. Adekunle Adelaja.
Approval of the final text: T. Olabode Olakoyejo and O. Adekunle Adelaja.

VII. ACKNOWLEDGMENTS

We appreciate the support of university of Lagos for this research.

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Journal of Engineering and Technology for Industrial Applications

ITEGAM-JETIA

Manaus, v.8 n.34, p. 20-28. Mar/Apr, 2022
DOI: https://doi.org/10.5935/jetia.v8i34.805

ISSN ONLINE: 2447-0228

RESEARCH ARTICLE OPEN ACCESS

MULTIOBJECTIVE OPTIMIZATION OF CUTTING PARAMETERS FOR FINISHING END MILLING HARDOX® 450

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ARTICLE INFO

Article History
Received: April 13th, 2022
Accepted: April 24th, 2022
Published: April 30th, 2022

Keywords:
Hardox® 450,
End milling,
Machining force,
Surface roughness,
Box-Behnken design.

ABSTRACT

Hardox® 450 is pre-hardened structural steel with high hardness and mechanical strength, designed to resist under abrasion wear, cracks, and breakages. This material provides a longer service life for crushers, buckets, and gears due to its excellent mechanical properties, which result in low machinability. Moreover, the knowledge about machining this material is limited, justifying further investigation. Thus, this study aims to evaluate the influence of cutting speed (v_c), axial depth of cut (a_p), and feed per tooth (f_z) on the machining forces and surface finish during the finishing end milling of Hardox® 450 with a CVD-coated carbide tool. The experiment was planned and analyzed through a 3-factor, 3-level Box-Behnken Design. The analysis of variance showed that a_p was the most significant parameter for all response variables considered in this study. A multiobjective optimization was carried out to determine the ideal levels of cutting parameters, considering the lowest values of static and dynamic machining forces and average and total surface roughnesses. The model suggests that the best results are achieved with v_c = 89 m/min, f_z = 0.1 mm/tooth, and a_p = 0.212 mm. Even with efficient results, the predicted and measured response variables differed slightly (mainly due to tool wear).

I. INTRODUCTION

Hardox® 450 is pre-hardened wear-resistant steel manufactured by Oxellösund SSAB (Sweden), with a 45 HRC nominal hardness, 1250 MPa specific yield strength, and 1400 MPa tensile strength. It is known for its high abrasion resistance and good structural properties [1]. Furthermore, this material has a tempered martensite microstructure due to the combination of carbon and alloy elements (Mn, Cr, Ni, Mo, B) [2]. Due to high wear resistance, ductility, and toughness, Hardox® is commonly used to increase the work-life of crushers, buckets, screens, feeders, and gears [3]. However, its high wear resistance implies low machinability, causing a high flank wear rate and, consequently, a short tool life [3, 4].

Since they are considered difficult-to-cut materials, Hardox® steels are usually processed through unconventional machining processes such as abrasive water jet (AWJ), laser, and plasma [5]. Nonetheless, this family of materials is prone to suffer microstructural changes when exposed to temperatures above 250 °C, potentially leading to the degradation of the mechanical properties, especially hardness [6]. Thus, it is recommended to use cold cutting methods such as AWJ, submerged cutting, or direct a cooling fluid spray into the cutting zone when conventional machining processes are used [5, 7]. Since milling is more broadly used and economical than most unconventional machining processes and rarely generates a heat-affected zone in the workpiece [8], some researchers decided to explore the feasibility of using this machining process in the manufacturing of Hardox® steels, some even considering the optimization of the cutting parameters. This approach is widely used to reduce cutting forces and ensure better surface finishing in machining processes.

Krolczyk et al. [9] analyzed the surface topography generated by the processing of Hardox® 400 through different machining processes. The end milling tests were performed with a 4-teeth carbide end mill cutter considering two cutting conditions:

(1) v_{f1} = 80 mm/min and n_1 = 400 rpm, (2) v_{f2} = 160 mm/min and n_2 = 250 rpm. According to the authors, the values of skewness S_{sk} of the samples indicated that the majority of the material is localized in nearby valleys, while the values of kurtosis S_{ku} specified the presence of inordinately high peaks and deep valleys in the surface texture for the sample (1) ($S_{ku} > 3$). Moreover, the polar graph indicated that the milled surface has an anisotropic periodical structure.

Among the statistical optimization techniques covered, the Taguchi method is one of the most frequently used in milling processes [10] as it allows the study of parameters with only a small number of experiments [11]. Kara [12] studied the cutting parameters through the Taguchi method for the finish end-milling of Hardox® 400 with PVD-coated carbide tools considering two different cutting speeds (60 and 120 m/min) and lubricooling conditions (dry and wet). According to ANOVA, cutting speed is the most significant factor in the roughness values (64.6%) for this study, followed by the lubricooling condition (13.3%). After validation experiments, the optimum R_a value (0.33 µm) was obtained with wet milling and v_c = 120 m/min. It is noteworthy that the DOE applied was equivalent to a 2^2 factorial DOE, which is highly efficient to find the significant influences but neglects any higher-order influence, assuming that all relationships are linear. Since the behaviors between the tested levels are linear, the results provided for experiments that use two levels always point to one of the tested conditions. Moayyedian et al. [13] used the Taguchi method to evaluate the influence of cutting parameters (feed rate v_f, spindle speed n, axial depth of cut a_p, and radial immersion of the tool a_e/d) on the surface roughness after milling Hardox® 600. The results showed that a_e/d presented the most significant influence over the surface roughness, with a contribution of 45.3%. This parameter was followed by n (21.1%), a_p (20.0%), and v_f (13.6%). After optimization, the authors performed a validation test for the optimal condition, whose surface roughness presented a 5.5% error from the result predicted by the model. They mentioned the number of selected parameters for evaluating the surface roughness as the main limitation of this study. However, the DOE used consisted of only nine runs, with confounded iterations and no replication.

Despite the excellent results of the industrial application of the Taguchi method, the information provided by this technique is frequently oriented to results. According to Nekere and Singh [14], the desired requirements are obtained by selecting the best conditions which produce a consistent performance, thus providing a systematic, simple, and efficient methodology for optimizing near optimum design parameters. However, intending to reduce the number of runs, this method often considers the influence of the control variables to be linear due to selecting two levels.

Response surface methodology (RSM) is a group of techniques for analyzing experimental data, and it is frequently used to investigate milling processes [8, 10]. This method involves modeling the response of a system through an n-dimensional surface, whose function, usually a low-order polynomial, can be used to optimize the studied process. RSM is generally used with a suitable design of experiments: CCD (Central Composite Design) and BBD (Box-Behnken Design) are the more usual DOEs. CCD involves the factorial and fractional design, obtaining a complete adjustment of the quadratic model. Although not including such effects, BBD presents the combination of factors in three levels through a reduced number of combinations [15]. BBD allows both statistical optimization and the analysis of the effect of each independent variable (factor) and their combinations on the response variable. The method is based on a combination of factors in three levels: low (-1), medium (0), and high (+1), and provides efficient estimates for first and second-order coefficients, with the advantage of being performed efficiently with fewer samples when compared with full factorial DOEs. For example, for an experiment with three input factors, the number of runs is reduced from 27 (full factorial) to 15 [16].

One of the results of RSM is the generation of regression models for the response variables as a function of the process parameters, a vital part of the optimization process. When predicting the parameters' optimization, the significance analysis of each input factor and its combinations results in ideal process parameters for the required response variable. Therefore, BBD uses the regression coefficients and the probability of significance (p-value $\leq \alpha$) to define a variance analysis (ANOVA) considering a confidence interval of $1 - \alpha$. In the ANOVA, uncertainties are associated with random and statistical errors in the process and the variables that showed p-value $> \alpha$ (low significance). Thus, as the analysis is debugged, these factors become part of the range of errors, allowing only significant values to be presented. This approach uses a reduced ANOVA that explains only the variables that have significance for the model [17]. In the case of multiobjective optimization, it is possible to contemplate the behavior and influence of all variables present in the study and determine the combination of parameters that meets the criteria expected on the machined surface [3, 16].

Due to the lack of research regarding the milling of Hardox® steels, this work presents a multiobjective optimization of the cutting parameters (v_c, f_z, a_p) in the end milling of Hardox® 450 aiming to minimize the response variables (static and dynamic forces, and surface roughness parameters) simultaneously.

II. MATERIALS AND METHODS

Table 1 presents the chemical composition of the Hardox® 450 samples according to the Manufacturer's Inspection Certificate nº EN 10 204 – 3.1 and the maximum values allowed according to SSAB [1]. Figure 1 presents the micrography of Hardox® 450 steel. Its martensitic microstructure allied with the high manganese content, which induces the work hardening, guarantees Hardox® 450 high hardness, toughness, abrasion resistance, and good weldability due to the low percentage of carbon equivalent [12].

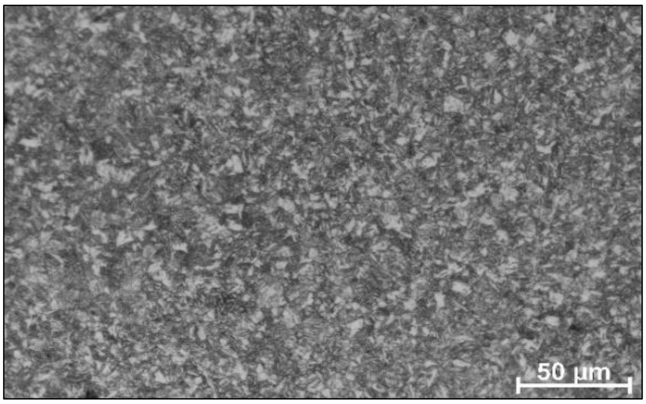

Figure 1: Micrography of Hardox 450 obtained through optical microscopy.
Source: (Courtesy of Welding and Related Techniques Laboratory, UFRGS, Brazil, 2021).

The experiments were executed on three rectangular samples with 100 x 90 x 3.5 mm, extracted from the same sheet, with holes for fixturing on the dynamometer. Six 34 mm runs (samples) were machined in each specimen. Due to the thickness of the samples, only one face was machined.

Table 1: Chemical Composition of the Workpiece (% mass).

	C	Si	Mn	P	S	Cr	Ni	Mo	B	Others
Certificated	0.177	0.170	1.29	0.011	0.001	0.25	0.05	0.02	0.0015	0.073
Normalized	0.260	0.700	1.60	0.025	0.010	1.40	1.50	0.60	0.0050	–

Source: Authors, (2022).

End-milling tests were performed in a ROMI Discovery 308 machining center using Walter Tools WKP35S CVD-TiCN/Al_2O_3 coated carbide inserts with r_ε = 0.4 mm fixed on a 2-insert Walter Tools Xtra-tec tool holder with a length of 35 mm and diameter of 20 mm. Bondmann BD-Fluid B90 oil-free bio-lubricant (1:20 dilution) was applied in abundance throughout the experiments.

The orthogonal components of the machining force (F_x, F_y, F_z) were measured with a Kistler 9129A piezoelectric dynamometer and conditioned with a Kistler 5070A charge amplifier. The force signals were acquired through a Measurement Computing PCIM-DAS 1602/16 DAQ at a 5 kS/s rate and processed digitally by the LabVIEW®9.0 software on a dedicated computer. MS Excel was used for the analysis and postprocessing of the force signals. Figure 2 illustrates the experimental setup.

For the processing data of the machining force, the tool input and tool output were neglected due to the unstable cut in this region. The resulting force (F_R) was calculated by equation 1, while the active (F_a) and passive (F_p) forces by equation 2. The data were processed to obtain the static and dynamic machining forces [18]. The static force (F_U) denotes the root mean square (RMS) value of F_R for the steady sampling interval (S = 2000) is given by equation 3, while the dynamic force (dF_U), which represents the fluctuation of the force around the static force (considering the Normal distribution with 95% confidence interval), is given by equation 4.

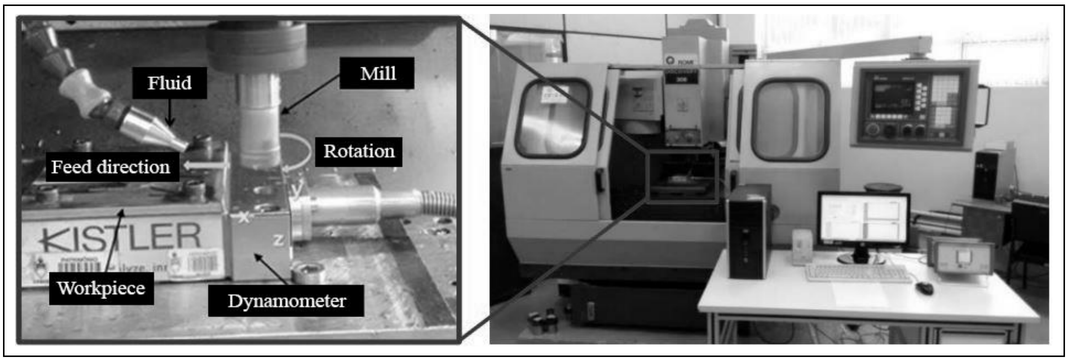

Figure 2: Experimental setup.
Source: Authors, (2022).

$$F_R = \sqrt{F_x^2 + F_y^2 + F_z^2} \quad \text{and} \quad F_R = F_U \pm dF_U \tag{1}$$

$$F_a = \sqrt{F_x^2 + F_y^2} \quad \text{and} \quad F_p = F_z \tag{2}$$

$$F_U = \sqrt{\frac{\sum_{i=1}^{S} F_{Ri}^2}{S}} \tag{3}$$

$$dF_U = 1.96\sqrt{\frac{\sum_{i=1}^{S}\left(F_{Ri} - \bar{F}_R\right)^2}{S}} \quad \text{where} \quad \bar{F}_R = \frac{\sum_{i=1}^{S} F_{Ri}}{S} \tag{4}$$

The machined surface texture (roughness profile and parameters) was evaluated with a Mitutoyo Surftest SJ-201P portable surface roughness tester. Following DIN EN ISO 4288, a sampling length of 0.8 mm and an evaluation length of 4.0 mm were used for all data acquisition. Three measurements were executed in the stable region for each run, and the mean values of the results were used for representing the average (R_a) and total (R_t) roughness values.

In this work, the influences of the main machining parameters (cutting speed v_c, feed per tooth f_z, and axial depth of cut a_p) were tested in three levels, according to Table 2. The experimental procedure followed the BBD, with 15 runs executed randomly (Table 3). The variance analysis (ANOVA) allowed the evaluation of the main effects and the contributions of each control variable (v_c, f_z, a_p) in the response variables (F_U, dF_U, R_a, R_t) in the end milling of wear-resistant steel Hardox® 450. The BBD describes the optimal levels of these input variables to achieve minimum levels simultaneously for all output variables.

Table 2: Cutting parameters and levels.

Controllable Input Factors	**Levels**		
	Low (-1)	Middle (0)	High (+1)
v_c (m/min)	60	90	120
f_z (mm/tooth)	0.08	0.10	0.12
a_p (mm)	0.2	0.4	0.6

Source: Authors, (2022).

The machined surface and tool wear images were monitored using a Dino-Lite AM 413ZT USB digital microscope with a magnification of 50x.

III. RESULTS AND DISCUSSIONS

Table 3 presents the output factors as a function of the input parameters. The input parameters were only repeated in runs 3, 8, and 14. Since all factors were evaluated at the intermediary level (0), these runs will be considered middle points. The ratio between dF_U and F_U varied between 0.21 and 0.56, indicating that the experiments occurred in a stable regimen. According to Sória [19], milling becomes unstable when $dF_U > F_U$, resulting in vibrations that could affect the quality of the machined surface.

Table 3: Response variables as a function of the controllable factors.

Run Order	Controllable Factors			Response Variables					
	v_c (m/min)	f_z (mm/tooth)	a_p (mm)	F_a (N)	F_p (N)	F_U (N)	dF_U (N)	R_a (µm)	R_t (µm)
1	60	0.10	0.20	47.1	50.5	59.8	34.2	1.73	12.3
2	90	0.12	0.60	143.9	102.3	176.6	70.9	3.40	23.8
3*	90	0.10	0.40	83.9	94.3	126.2	45.2	0.43	2.0
4	60	0.08	0.40	98.7	81.3	127.9	79.9	2.48	17.3
5	120	0.10	0.20	62.6	123.5	138.5	55.1	0.75	4.9
6	60	0.10	0.60	148.1	114.2	187.1	60.6	2.53	14.9
7	120	0.10	0.60	151.4	124.4	196.0	71.7	2.42	13.4
8*	90	0.10	0.40	102.5	125.1	161.7	47.4	0.57	3.1
9	90	0.08	0.20	46.0	78.6	91.0	53.0	0.75	4.1
10	90	0.12	0.20	70.5	118.8	138.1	50.5	0.60	4.5
11	90	0.08	0.60	147.8	158.0	216.4	51.1	1.45	8.9
12	120	0.12	0.40	113.3	160.0	196.1	50.1	0.63	3.6
13	60	0.12	0.40	129.8	118.7	175.9	53.4	1.85	10.1
14*	90	0.10	0.40	129.6	162.1	207.6	54.6	0.62	3.9
15	120	0.08	0.40	121.2	188.7	224.3	64.4	0.52	4.3

*Central level runs defined by BBD from middle points (0).
Source: Authors, (2022)

III.1 RESULTING FORCE

Figure 3 displays the static (F_U) and dynamic (dF_U) force values obtained in the experiments. An increase in F_U was observed in the middle points, probably due to the premature tool wear throughout the experiment. Another phenomenon observed is that starting from run 8, dF_U remains well-nigh constant (53 ± 5 N) until the end of the study, indicating a disturbance during material cutting, possibly related to the tool wear.

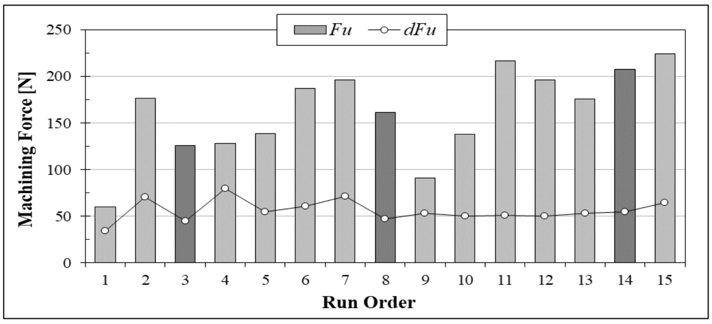

Figure 3: Static (F_U) and dynamic (dF_U) force values measured in each run.
Source: Authors, (2022).

Figure 4 presents the active and passive components of the machining force. The passive force (F_p) presented a tendency to be higher than the active force (F_a). The exceptions were runs 2, 4, 6, and 7. While runs 2, 6, and 7 correspond to cutting conditions with the highest a_p level, a high dF_U was observed in run 4, indicating significant force fluctuation. This oscillation may be associated with the difficulty of chip shearing (due to the low width of cut) and work hardening, and high R_a and R_t values are also expected [20]. Moreover, $F_p \cong 2\,F_a$ in run 5 due to the small a_p/r_ε ratio increases the passive force [19]. This fact is also observed in runs 9 and 10, where $a_p = 0.5\,r_\varepsilon$. This effect was slightly evident in run 1, possibly due to the new cutting edge combined with a low cutting speed (60 m/min).

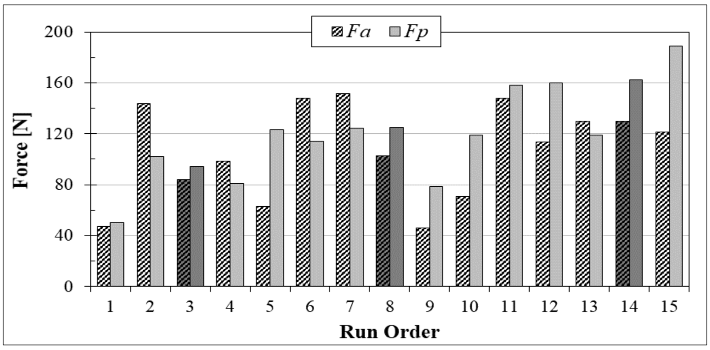

Figure 4: Active (F_a) and passive (F_p) force values measured in each run.
Source: Authors, (2022).

Figure 5 presents images of the cutting edge after runs 6, 12, and 15 to illustrate the progression of the flank wear. Despite being only a qualitative analysis of the tool wear, the increase in the force values between the middle points (runs 3, 8, and 14) and the visual examination of the insert suggests that the machining of Hardox® 450 with PK35 CVD-coated carbide inserts leads to premature tool wear. This phenomenon was unexpected: Majerik and Danisova (2010) evaluated the tool-life of coated carbide tools in rough milling of Hardox® 500 under similar conditions, finding tool lives over 120 min, much higher than the sum of all the 15 runs performed with Hardox® 450. Majerik and Barenyi (2016) estimated a tool life of 78.5 min for the end milling of Hardox® 500 with coated carbide tools with a cutting speed of 135 m/min.

III.2 AVERAGE AND TOTAL ROUGHNESS

Figure 6 presents the average roughness (R_a) and Figure 7 the total roughness (R_t) values by end milling of Hardox® 450. Both roughness parameters presented low values at the middle points and exhibited similar behaviors ($R_t \cong 6\,R_a$). The highest values of R_a and R_t were observed in the sampled machined in Run 2. This sample also presents the highest dispersion in R_a, which is related to the severe configuration of this run: f_z and a_p at the high levels and v_c at the medium level.

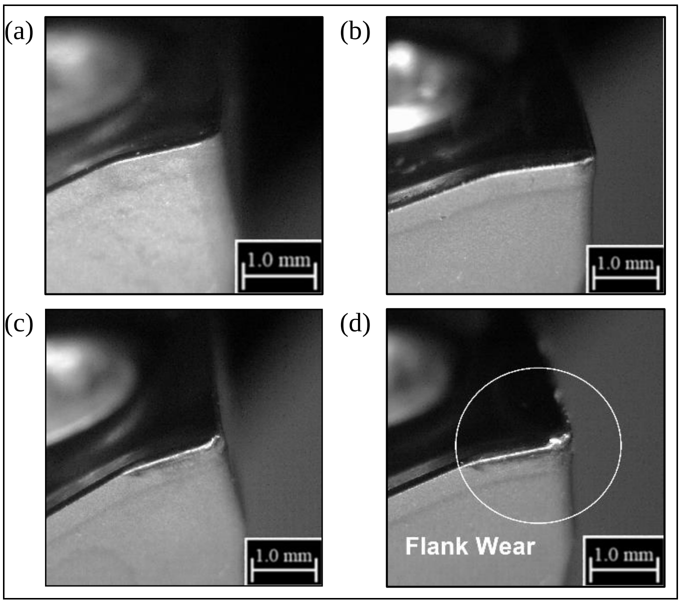

Figure 5: Tool wear monitoring throughout the experiment: (a) new tool; (b) after run 6; (c) after run 12; (d) after run 15.
Source: Authors, (2022).

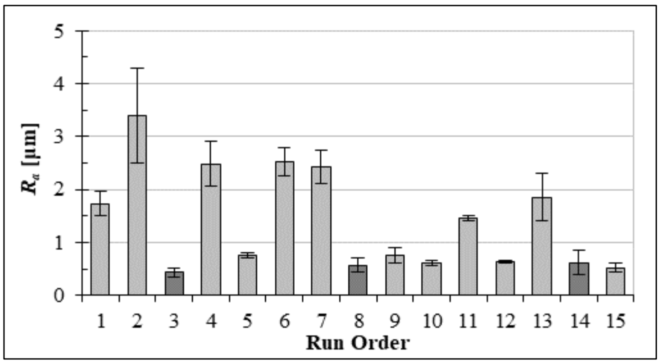

Figure 6: Average roughness R_a values of machined samples
Source: Authors, (2022).

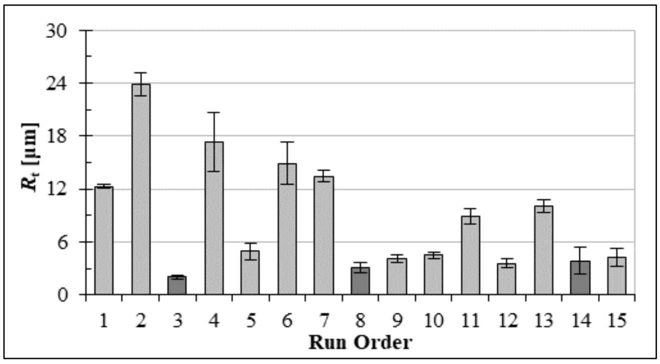

Figure 7: Total roughness R_t values of machined samples.
Source: Authors, (2022).

It is common knowledge that, in machining processes, the surface roughness is mainly affected by feed rate (or feed per tooth, for multiple cutting edges). However, significant differences were observed between runs performed with the same feed per tooth. Figure 8 illustrates the surface profiles and images of the respective surfaces machined with f_z = 0.1 mm/rev. Figure 8a presents the surface profile for run 3 (v_c = 90 m/min, a_p = 0,4 mm): this run presented the lowest roughness values in both parameters considered, and the machined surface exhibits well-defined feed-per-tooth marks produced by the cutting tool (Figure 8c). The roughness profile of sample 6 (Figure 8b) presents much higher with irregular peaks and valleys, with some discernible undulation. The image of the surface machined in this test (Figure 8d) does not present a regular pattern, indicating a possible difficulty for the chip breakage, leading to burr formation and increasing the measured roughness. According to Chinchanikar and Choudhury [22], this difficulty is related to the low v_c, and, under low f_z, lower cutting speeds tend to increase the surface roughness of the machined parts. Another possible explanation is the occurrence of unstable built-up edge (BUE); however, no adherence was identified in the periodic tool evaluations.

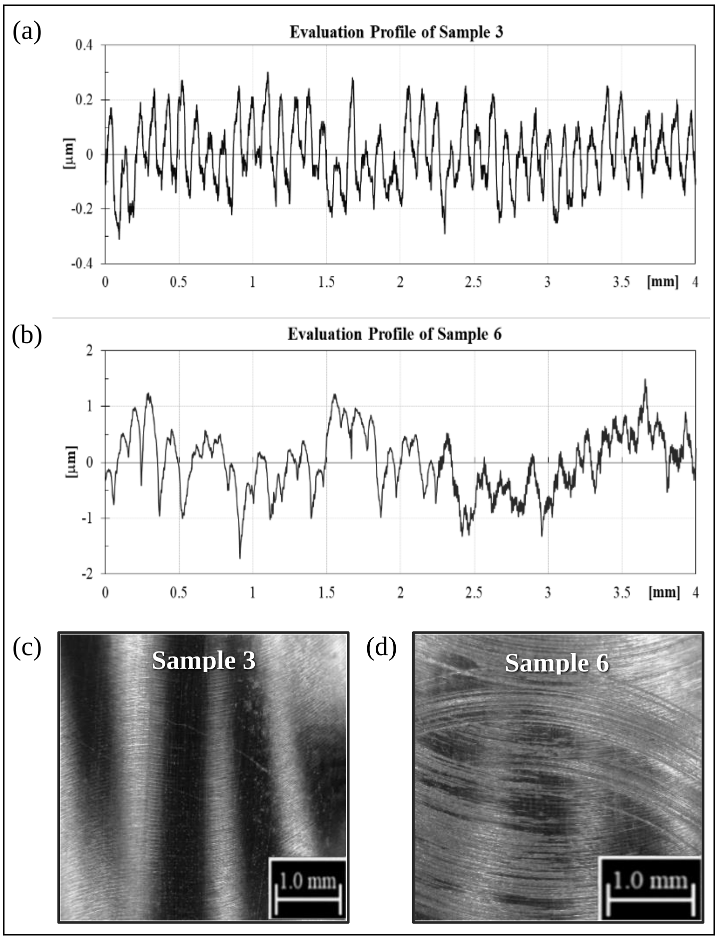

Figure 8: Roughness profiles and images of the machined surface after runs 3 and 6.
Source: Authors, (2022).

III.3 STATISTICAL ANALYSIS

Table 4 presents the reduced ANOVA of the response variables considering a 95% confidence interval. Furthermore, the effect was considered partially significant for a confidence interval between 90 and 95%. According to Montgomery and Hunger [17], one may consider that the statistical model represents well the behavior of the response variable when the coefficient of determination (R^2) is higher than 70%, which was observed for all the cases. The regression models obtained for each parameter are presented in equations 5 to 8.

Table 4: Reduced ANOVA of the main effects.

Factor	F_U [N]		dF_U [N]		R_a [µm]		R_t [µm]	
	p-value	Cont. (%)	p-value	Cont. (%)	p-value	Cont. (%)	p-value	Cont. (%)
v_c	0.016	17.3	-	-	0.034	17.7	0.079	17.5
a_p	0.001	48.1	0.005	38.0	0.010	34.6	0.042	27.0
v_c^2	–	–	0.125	6.50	0.091	7.20	0.208	5.50
a_p^2	0.097	7.0	0.026	19.7	0.040	16.0	0.092	15.7
f_z x a_p	0.100	6.8	0.158	6.76	0.100	8.60	0.173	9.14
R^2	72.4%		70.9%		89.4%		81.9%	

Source: Authors, (2022).

$$F_U = 174.9 + 24.77\, v_c + 41.27\, a_p - 0.1\, v_c^2 - 23.0\, a_p^2 - 21.9\, f_z \times a_p \quad (5)$$

$$dF_U = 45.4 + 2.22\, v_c + 8.27\, a_p + 5.63\, v_c^2 + 8.74\, a_p^2 + 4.94\, f_z \times a_p \quad (6)$$

$$R_a = 0.701 - 0.534\, v_c + 0.746\, a_p + 0.549\, v_c^2 + 0.729\, a_p^2 + 0.525\, f_z \times a_p \quad (7)$$

$$R_t = 4.47 - 3.55\, v_c + 4.40\, a_p + 3.25\, v_c^2 + 4.75\, a_p^2 + 3.63\, f_z \times a_p \quad (8)$$

The linear effect of the axial depth of cut (a_p) presented the most significant influence for all the response variables evaluated. The quadratic effect (a_p^2) was significant for the dynamic force (dF_U) and R_a and partially significant for the static force (F_U). The linear effect of the cutting speed (v_c) also presented a significant contribution to F_U, partially significant for R_t, while v_c^2 had a partially significant influence over dF_U, R_a, and R_t. The only interaction effect that showed some degree of influence (i.e., partially significant) on the response variables was f_z x a_p.

Figure 9 presents contour plots for the static (F_U) and dynamic (dF_U) forces as a function of f_z x v_c for the three tested levels of a_p (most significant parameter). Distinct behaviors were observed for F_U and dF_U with the increase of a_p: for $a_p \leq r_\varepsilon$ (Figures 9a and 9b), F_U increases with v_c and f_z. This behavior is related to the increased cross-section of the cut with higher feed rates that directly affect F_U. However, for $a_p = 1.5\, r_\varepsilon$ (Figure 9c), F_U increases with higher cutting speeds and decreases with higher levels of feed per tooth. In this case, there is a strong influence of f_z on the generated chip: the combination of thin chips with high a_p hampers material shearing, leading the chip to be crushed instead of sheared. As a result of the characteristics of the Hardox® 450, this heightens work hardening, leading to higher machining forces.

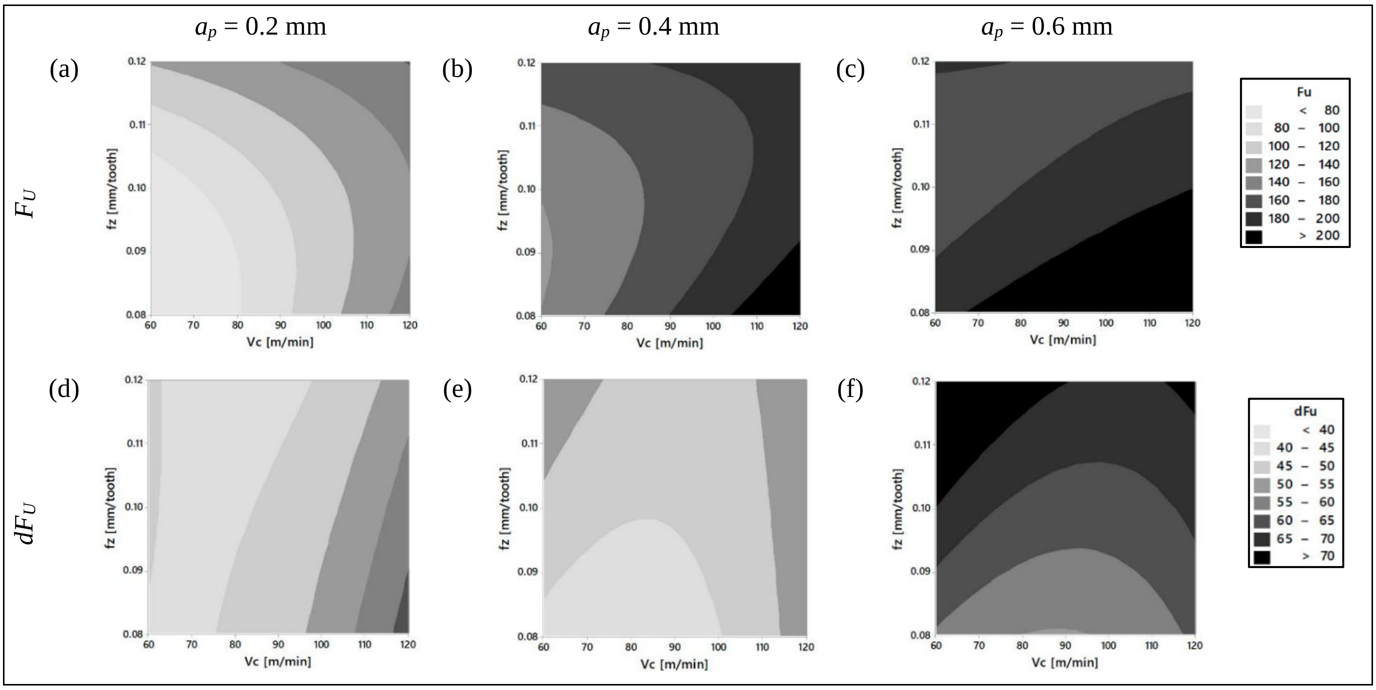

Figure 9: Contour plots of F_U and dF_U for a_p= 0.2 mm; 0.4 mm; 0.6 mm.

Source: Authors, (2022).

Feed per tooth presented a low influence on the dynamic force for a_p = 0.2 mm (Figure 9d). For $a_p \geq r_\varepsilon$ (Figures 9e and 9f), the influence of the quadratic effect of the cutting speed is evident, with the v_c x f_z contour lines following parabolic-like curves. The analysis of the contour plots indicates more severe regions (higher dF_U) as f_z increases and v_c departs from 90 m/min. This effect may reveal possible instability regions at the extremes (60 and 120 m/min) with $a_p \geq 0.4$ mm [19].

According to Table 4, the linear effect of a_p has the most significant influence on R_a and R_t, followed by the linear effect of

v_c. Except for v_c for R_t, the quadratic effects of v_c and a_p and the interaction f_z x a_p showed significant influence on R_a and R_t for a confidence interval of 90% or higher. The contour plots in Figure 10 confirm these results, where the behaviors of R_a and R_t curves are very similar for each level of a_p. The regions with lower roughness values are dislocated for different levels of a_p. For $a_p = 0.5\ r_\varepsilon$ (Figures 10a and 10d), the combination of low v_c and f_z produces higher R_a and R_t values due to the difficult chip cutting and subsequent burr formation on the machined surface [22]. Consequently, a better surface finish is achieved with higher values of v_c and f_z, with the low roughness region located in the upper limit of the studied domain. For $a_p \geq r_\varepsilon$ (0.4 e 0.6 mm), the plot behaviors are similar and, as expected, the roughness values increase with the growth of f_z and with the decrease of v_c [19]; however, the center of the low roughness region has been dislocated to the lower tested value of the feed per tooth.

The analysis of the surface roughness of the samples machined in the middle points (runs 3, 8, and 14) indicates a slight increase of R_a and R_t mean values throughout the experiment. However, the dispersions of the roughness values increased significantly during the experiment, indicating a stronger influence of the tool wear over these dispersions.

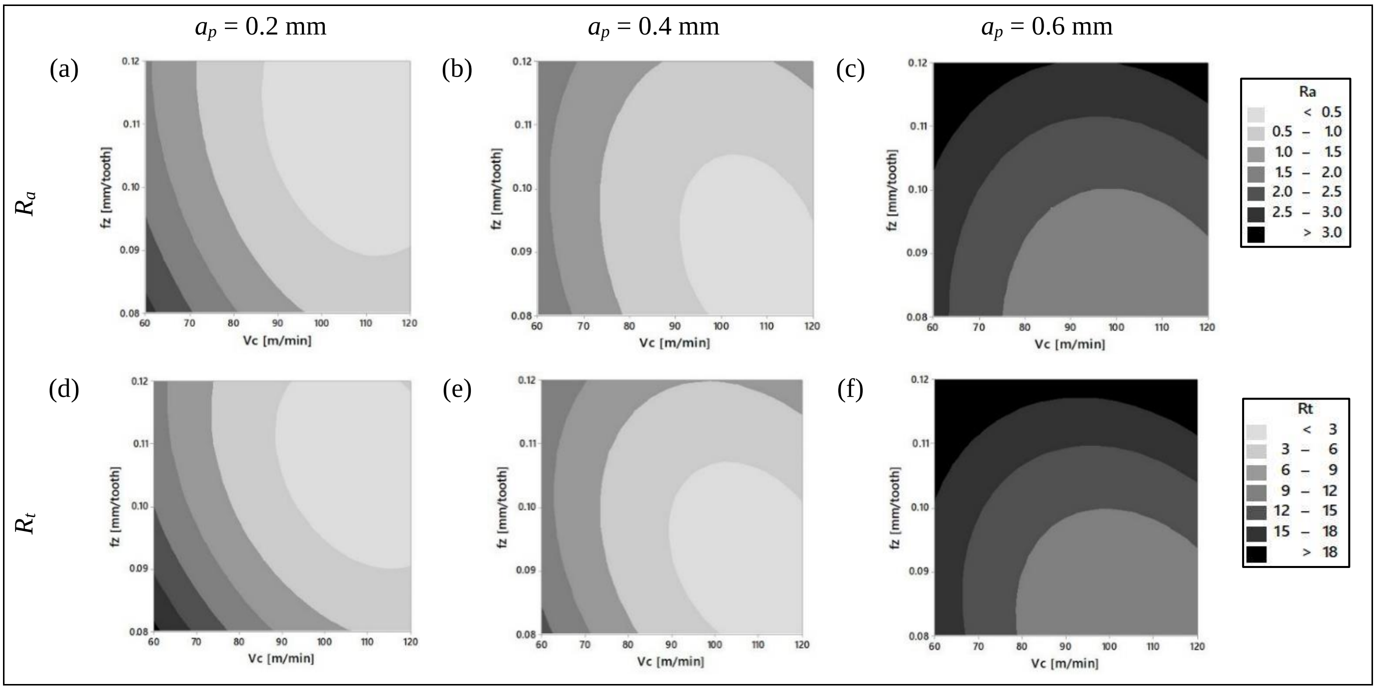

Figure 10: Contour plots of R_a and R_t for a_p= 0.2 mm; 0.4 mm; 0.6 mm.
Source: Authors, (2022).

III.4. MULTIOBJECTIVE OPTIMIZATION OF CUTTING PARAMETERS

Figure 11 illustrates the characteristic curves of each controllable input factor (v_c, f_z, a_p) on the response variables (F_U, dF_U, R_a, R_t). The optimized input variables are indicated through vertical lines, and the predictions of response values are presented utilizing the dashed horizontal line. It is observed that a_p is the only parameter whose value chosen for the optimization is on the vicinities of the lower level (0.212 mm), while the choice of the values of v_c and f_z approached the average tested values (89.1 m/min and 0.103 mm/tooth respectively). The behavior of R_a and R_t was similar for all variables, indicating the same optimization points. The same does not apply in terms of the comparison between F_U and dF_U. The result of "composite desirability" (D) presented a suitable value, considering that it seeks to optimize four simultaneous parameters. In contrast, the "individual desirabilities" (d) of the roughness parameters were close to the ideal (d = 1), and the forces presented acceptable values [15].

The results of the validation test are presented in Table 5. The validation test returned a lower static force and a higher dynamic force when compared to the values predicted by equations 3 and 4. These differences were expected since the models presented determination coefficients in the boundaries of the acceptable ($R^2 \cong 70\%$) due to disturbances that reduced the cutting stability and tool wear, affecting the force values.

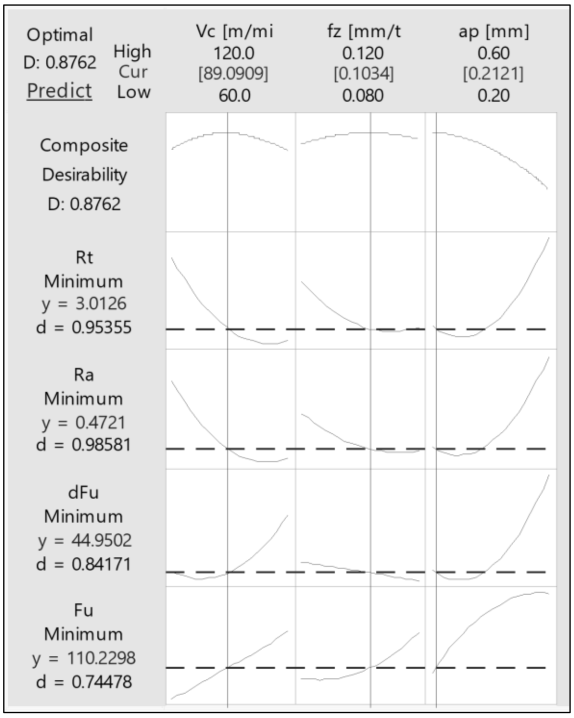

Figure 11: Characteristic curves of controllable factors.
Source: Authors, (2022).

Table 5: Validation of multiobjective optimization.

	F_U [N]	dF_U [N]	R_a [µm]	R_t [µm]
Predicted	110	45	0.47	3.01
Measured	96	65	0.57	4.24

Source: Authors, (2022).

The roughness values predicted by equations 5 and 6 were lower than the validation results. Equation 5 presented a good prediction for R_a, considering diverse factors like vibration and tool wear could affect the measured values [16]. Although the difference between the predicted and measured R_t values is high, this parameter is the most sensitive to texture variations since it comprises the maximum peak-to-valley height in the evaluation length of the roughness profile.

The multiobjective optimization reached output values considerably low relating to those obtained previously. The different behaviors observed can still be considered efficient in the combined minimization of response variables.

IV. CONCLUSIONS

Multiobjective optimization of cutting parameters (cutting speed v_c, axial depth of cut a_p, and feed per tooth f_z) was performed for the end milling of wear-resistant steel Hardox® 450 using CVD-coated carbide tools. Static and dynamic machining forces (F_U and dF_U) and average and total roughness values (R_a and R_t) were analyzed, leading to the following conclusions:

- The lowest F_U value was registered on the first run (new insert) with the lowest v_c and a_p levels and the intermediate f_z level.
- A tendency of increasing F_U values throughout the experiment was observed in the analysis of the middle points (runs 3, 8, and 14). F_U presented steady growth by the replications of this condition due to tool wear. This effect was observed on a smaller scale for dF_U.
- For a 95% confidence interval, the reduced ANOVA indicated a statistically significant influence of the linear effects of v_c and a_p on F_U, while dF_U was only significantly influenced by a_p (linear and quadratic effects).
- The surface roughness parameters R_a and R_t did not seem to have been strongly affected by the tool wear. However, the increasing dispersion of the values measured along the middle-point replications suggests that the tool wear somehow influences the surface finish of the machined parts.
- The reduced ANOVA also showed a significant influence of a_p on R_a and R_t for a 95% confidence interval. Both v_c and the quadratic effect of a_p significantly influenced R_a.
- According to the multiobjective optimization, best results (minimum levels of all response variables) are obtained with a_p close to the lowest tested level (0.212 mm), while v_c and f_z must be kept close to the medium applied levels (89.1 m/min and 0.103 mm/tooth).
- Differences between the predicted and measured values during validation can be attributed to noncontrollable input factors, such as tool wear; however, both forces and roughness values were considerably low throughout the experiment.
- A more in-deep study on the influence of tool wear over the response variables is recommended since it may increase the force components and cause vibrations; detailed investigations regarding chip formation in the end milling of Hardox® 450 are also suggested.

V. AUTHOR'S CONTRIBUTION

Conceptualization: Émerson S. Passari and André J. Souza.
Methodology: Émerson S. Passari and André J. Souza.
Investigation: Émerson S. Passari and André J. Souza.
Discussion of results: Émerson S. Passari, Heraldo J. Amorim and André J. Souza.
Writing – Original Draft: Émerson S. Passari.
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: Émerson S. Passari, Heraldo J. Amorim and André J. Souza.

VI. ACKNOWLEDGMENTS

The authors thank SSAB/SC Co. for donating the Hardox® 450 steel plate, Walter Tools for coated carbide inserts, Bondmann Chemical Industry for cutting fluid, and Coordenação de Aperfeiçoamento de Pessoal de Nível Superior – Capes (Grant No. 495511/2020-00) for the graduate scholarship.

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Journal of Engineering and Technology for Industrial Applications

ITEGAM-JETIA

ISSN ONLINE: 2447-0228

Manaus, v.8 n.34, p. 29-38. Mar/Apr, 2022

DOI: https://doi.org/10.5935/jetia.v8i34.807

RESEARCH ARTICLE OPEN ACCESS

BIBLIOMETRIC REVIEW OF FACILITIES MANAGEMENT AND ITS IMPACT ON ORGANIZATIONAL EFFECTIVENESS

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ARTICLE INFO

Article History
Received: April 16th, 2022
Accepted: April 24th, 2022
Published: April 30th, 2022

Keywords:
Organizational Effectiveness,
Bibliometric,
Facility Management,
AEC.

ABSTRACT

Facilities management (FM) has been adjudged to be critical in all industries both at developed and underdeveloped countries. As such, available literatures seem to agree to the fact that the importance of Facility Management to both service organization competitiveness and manufacturing can never be underestimated. But the knowledge of how FM impact on the organizational effectiveness remains unsearched. Till now, few literatures are available that examined what impact does facilities Management has on organizational effectiveness, how does the FM affect the effectiveness of an organization. Recently in Architecture, Engineering and Construction (AEC) research, bibliometric is becoming more prominent as a quantitative study that examines many characteristics of literature on a particular topic. It aids in the discovery of new information about a phenomenon under inquiry. The use of bibliometrics approaches in a variety of disciplines has resulted in an explosion of bibliometrics and associated literature. To this end, this paper therefore attempts to examine the impact of Facility Management on organization effectiveness using bibliometric approach. Through co-occurrences analysis, of word, author, journal, institution, and country analysis. A total of 309 bibliographic records from the Scopus core collection databases were selected and analyzed. The findings showed that facility Management facilities management has a significant impact on organizational effectiveness, and effective asset management has a significant impact on organizational growth. Moreover, most publication on facility Management came from UK and US than China, Australia and Norway. This study highlighted trends in contributors to highly-cited Facility management development research.

I. INTRODUCTION

Companies have been obliged to look at all measures of decreasing costs and preserving a market edge due to fierce competition, fluctuating trading circumstances, high energy costs, and other economic factors [1]. Facilities management has been established on all five continents as a result of these circumstances, despite its reputation as a poor related of the property and building professions [2]. Property management, financial management, change management, human resource management, contract management, health and safety in buildings, engineering services, maintenance, domestic services, and utilities supplies are all topics covered by this subject [3]. Facilities management, according to the Centre for Facilities Management (2010), is the process through which an organization offers and maintains support services in a high-quality environment to meet strategic needs. It's also known as "the process through which an organization guarantees that its buildings, systems, and services support core operations and procedures while also contributing to the achievement of strategic objectives under changing conditions" [4].

Facility management encompasses the administration of built assets as well as the controlling services required for an organization's successful business operations. It should not just attempt to reduce the operating costs of a developed facility, but also to increase the facility's efficiency [5]. The physical environment has a significant impact on an organization's ability to operate successfully and efficiently; by altering it, an organization's intended efficiency can be reached [6] . To assess the success of facility management, it is required to first gain a thorough awareness of the facility's existing state and then hypothesize improvements in facility management procedures in order to attain the desired results. Poor facility management, according to [7], can lead to insufficient facilities to sustain functioning, excess facilities that aren't contributing to the organization's mission, cost inefficiencies, inadequacy, and facility unavailability for future demands. A solid facility management strategy, on the other hand, provides critical support for the organization's mission, as well as the realization of future facility requirements, increased cost efficiency, and the ability to predict the outcomes of present management decisions.

The Center for Facilities Management (CFM, 2010) emphasizes the importance of focusing resources on satisfying user demands in order to support people's vital role in businesses and works to continuously enhance quality, decrease risks, and assure value for money. Facilities management lays out a company's response to critical concerns such space allocation and charging, environmental control and protection, and direct and contract labor. Facilities management is important in all industries in industrialized, developing, and underdeveloped countries. Facility management is critical to an organization's growth and survival, especially in today's fast-paced culture [8]. The ability of management to guarantee that there is working equipment, lands and buildings, infrastructure, fixtures, and other items is critical to the organization's performance and survival.

Companies have lost their efficacy and production, according to [9], due to poor facility management. He went on to say that a negative attitude toward facilities management makes it difficult for businesses to operate. According to him, facilities management causes management to operate at a lower capacity. Maintaining a good level of facility should be one of the tasks of any good organization's management to ensure efficiency and productivity. However, research have indicated that the majority of businesses have failed in the area of facility management. Companies have a weak maintenance culture, according to statistics. This has contributed to certain business failures and limited business profit.

According to [10], the culture of management and maintenance in Nigeria has gone down the drain, affecting nearly all aspects of our social and economic lives. When facilities are not effectively managed and maintained, it can lead to a variety of defects, which can cause annoyance and disruption to those who use them. Several studies conducted by researchers have demonstrated a link between facilities management and organizational success; for example, [11] discovered a link between facilities management and effective corporate operations. Similarly, research by [12] found that good facility management increased production. Despite these results and recommendations, businesses continue to struggle to successfully manage their facilities, resulting in losses. The paper is organized as follows: the introduction section discusses the historic background and function of Facility Management, Secondly, Literature review on the measurement and performance concept of FM, is described; thirdly, the methodology used is discussed; and finally, conclusion was drawing from the analysis and review.

II. LITERATURE REVIEW

II.1 REVIEW RATIONALE AND OBJECTIVES

The literature review reveals the established and generally accepted facts of the situation being studied, and enables one to identify and understand the theories or models, which have been used by previous researchers in the field. The literature review assists the researcher in identifying an unsolved problem in the field being studied, which will become the focus of the research study. The review of the literature included an in-depth examination of the material relating to Facility Management and it impact on construction in general. The main purpose and outcome of this was to identify theoretical gaps in the literature which pointed to potential research topics. Although the area of Facility Management is not new, but the constructs of Facility Management are neither well-established nor standardized across and even within Facility Management discipline. There is, therefore, an abundance of areas that require further investigation. This study aims to review the facility management and it impact on the organizational effectiveness.

II.2 HISTORICAL PERSPECTIVE TO FM

The origins of FM can be traced back to the scientific management era and the expansion of office administration that followed. The trend toward better property management is projected to continue as buildings, their contents, and organizations grow more sophisticated. Several organizations, some of which are based on ideas from more traditional professional fields, have attempted to define the scope of the FM's employment. There are many different definitions of FM, and there is no consensus on what FM entails.According to the US Library of Congress, "the practice of integrating the physical workplace with the people and work of the organization combines the principles of business administration, architecture, and the behavioral and engineering sciences." Because this idea is so broad, it is insufficient as a primary foundation for constructing a facility management model. Nonetheless, it suggests that there are at least three fundamental characteristics of the facilities management role that apply to all cases [13] ;(1) It is a support function for an organization's principal business; (2) it focuses on the interaction between the physical workplace and people; and (3) it needs a multi-skilled approach.

FM is defined as "the process by which an organization provides and maintains a quality working environment and delivers quality support services to meet the organization's objectives at the lowest cost," according to the University of Strathclyde's Centre for [14] . The term "working environment" refers to all systems and services that support a company's operations, meaning that FM is primarily demand-driven and should be closely linked to the company's strategic planning. At the heart of FM is the effectiveness of procedures that ensure that non-core activities provide good value for money and how facilities are adjusted to meet company needs [14].

According to [15] recognition of the role of facilities management in business performance has gradually developed over a period of profound change in the public sector and corporate world. Corporate competitiveness strategies – core business, customer responsiveness, and continuous quality improvement –

have necessitated a massive rethinking of all operations and reorganization. Under pressure to rationalize the business, cut costs, and increase flexibility, new techniques to managing the facilities that support the business have emerged. The growth of professional qualifications and focused education and training are supplementing respect for individuals with exceptional skills and abilities in coordinating varied activities and making things happen. Professional and corporate interests in the sector are presently supported by a single professional organisation in the United Kingdom. Packages of contracted services are coordinated within the context of management control to ensure that they meet user needs in terms of quality, cost, and time. The market is currently befuddled, with an increasing number of consultants presenting often contradictory claims. New service partnerships, on the other hand, promise more productive interactions that benefit users, clients, and suppliers alike. The facilities management industry is maturing.

The task of ensuring facilities management's future as a respectable discipline, profession, and corporate service is huge. In times of uncertainty and profound cultural change in the professions, industries that have traditionally served business demands will retain control over how challenges are identified. In order to elevate the role and status of facilities managers, the new professional bodies will define boundaries and enhance qualifying standards to exclude. The services and solutions that the market delivers under the banner of facilities management will be shaped by powerful industrial forces.

In the face of conservatism, defensive hostility, skepticism, and bigotry, the movement need strong and educated leadership. The design of an open profession for the future century must be carefully considered, as must the use of modern communications to develop networks that mirror the "virtual company." These frameworks should take into account the portfolio manager's replacement of the career professional. The facilities management movement can be defined as a conviction in the ability to enhance methods by which workplaces can be managed in order to motivate people to give their best, to support their effectiveness, and, ultimately, to contribute to economic growth and organizational success. A solid program of education and research dedicated to understanding and expanding the discipline, generating and sharing a common knowledge base, and identifying and codifying best practice must be the foundation for the future. We must establish a venue for informed debate as well as the exchange and validation of experience.

Facilities management (FM) is a broad word that refers to a variety of tasks involved in the efficient management of constructed assets. Facilities management, according to Alexander, is the process through which an organization provides and maintains support services in a high-quality environment to meet strategic needs [16]. The International Facility Management Association (IFMA) describes facilities management as a multidisciplinary profession that integrates people, place, procedures, and technology to assure the built environment's functionality [17] As a result, facility management is a broad phrase that encompasses a variety of property and user-related responsibilities that can be combined for the benefit of the business and its personnel as a whole [5]. It entails the overall management of all services that support the organization's core business [5]. Facilities management services, for example, include real estate management, financial management, change management, human resources management, health and safety management, contract management, as well as building and engineering services, domestic services, and utility supply [18] . Sustainability is the most recent value-added service in the realm of facility management [19].

II.3 FOUR MAIN FUNCTIONS OF FM

These are referred to as four pillars of FM by [20 and they include: **People, Processes, Building and Technology**. Speaking to the four main pillar of FM according to [20] It has do with People, Process, Building and Technology. **For People**, FM manager provides a conducing environment for workers to work and they act as a bridge between the workers and the employees. The see to good working environment, creating space for new workers, whenever there is accommodation issue, FM comes to provide and ensure workers are settled. "*Facility managers serve as a bridge between the workplace and the employees working within it. Whenever issues of accommodation, safety, or comfort arise, it's up to the facility manager to solve them*" [20].

For process, [20] went further to say that an organization cannot run effectively without the process. Processes are to be in place to ensure orderliness and moderation. Process ensures that there is order in doing thing. Order creates a system of expectation [20] **For Building** aspect of the FM function, this is where FM derives her name; it entails keeping the physical structure in good shape and bringing improvement in the existing structure. This is one of the robust aspects of Facility management. It is worthy of note to state that, Facility management goes beyond just maintaining physical asset but making sure the same asset serves the expectation of the users (that is keeping the structure in shape, maintaining and keeping it up to date so that the user will enjoy using it).*"It involves not only tending the building, but cultivating partnerships, future planning, and asset management" and "Facilities are the second largest expense behind the workforce—it's the job of a facility manager to turn the workplace into a competitive advantage, instead of a cost center. It's about ensuring facilities meet the needs of the people using them"* [20].

For Technology: We mean technology integration. Gone are the days when anyone we say I do not need technology. We are the world of technology or in the era of global use of technology. Technology cuts across virtually all section of industries. The use of technology is becoming inevitable for any business to thrive. For facility managers too, they are expected to embrace technology for the delivery of their duty."*Identifying and implementing the right technology is the chief responsibility of a facility manager*" [20]

II.4 PERFORMANCE EVALUATION AND MEASUREMENT CONCEPT IN FM

The necessity of measurement has long been emphasized. It's a topic that's gotten a lot of attention in recent years, and the adages "you can't manage what you can't measure" and "what gets measured gets done" are all too prevalent in management books. [21] demonstrate the importance of measurement in enabling good planning and control, change management, communication, continuous improvement, resource allocation, motivation, and long-term focus, deeming it a "legitimate management instrument." As a result, measuring is now widely used to aid in the dissemination of fundamental values within organizations. Although there is a lot of literature on performance assessment, relatively little of it gives solid evidence that the concepts work in the real world, particularly in fields like FM. According to a recent assessment of FM literature, there is a trend toward performance measurement, particularly for strategic development. Furthermore, the FM organization creates a conducive environment for performance measurement research. According to a review of FM literature, performance measurement in FM will be seen in two ways. The first is as a "key success factor" in the strategic planning process, and the second is as a learning process within the FM company. The latter refers to a process in which an FM organization aligns itself with its environment by gathering information, either from the marketplace or via scientific knowledge generation, and applying it to organizational development processes.

II.5 WHY PERFORMANCE MEASUREMENT?

The identification of KPIs and the implementation of performance measurement of a portfolio of buildings, according to [7], focuses on assessing overall performance toward an organization's objective. Furthermore, performance measurement considers the buildings or facilities owned, their current state, extra facilities required to meet organizational goals, concerns to be addressed, and the outcomes of investment or no-investment decisions. As a result, the goal of performance measurement is to understand the effects of management decisions on portfolio success and failure, as well as to suggest changes [7]. According to [22], the facility management unit's capacity to make basic judgments, as well as its ability to create a convincing case for its recommendations, is harmed when it lacks reliable and comparable data on building performance and costs.

Performance measuring aims, according to [23], include determining the extent to which a facility caters to its residents and detecting key concerns affecting its performance negatively. Performance measurement is critical, according to [24] Kincaid (1994), especially for comparisons and developing development methods. Furthermore, it must focus not only on expenses, but also on issues that affect the organization's physical environment. One of the primary reasons for performing performance assessment, according to [25], is to drive performance improvement decision-making techniques by looking into the past, present, and future. Furthermore, one of the driving reasons behind performance measurement is assessing an organization's growth, recognizing the current state of an organization's facilities, making future plans, and producing blueprints to carry out those plans. According [26], quick feedback regarding the building's condition is critical for consistent and continuous improvement in building performance.

According to [5] and [26b] building performance is related not only to the building's functional excellence, but also to the building's contribution to the organization's goals. As a result, buildings assist businesses in achieving their long-term business and other objectives. Facility managers, according to [27], must assess facilities in detail in order to make appropriate management decisions. Building evaluations could take the form of a comprehensive performance evaluation that takes into account architectural and technical characteristics, or a predictive evaluation that links buildings to organizations by detecting performance issues [27]. [28] underlines the relevance of facility performance measurement in evaluating strategies in terms of results and allowing management teams to identify critical issues impacting the organization as well as concerns relating to specific operations.

Sustainable and green construction practices are frequently promoted by facility managers [19]. Sustainable development is described by the World Commission on Environment and Development, also known as the Brundtland Commission, as development that fulfills current demands without jeopardizing future generations' ability to meet their own. Sustainable or "green" construction is a subset of sustainable development that adheres to the three pillars of sustainable development: economic, social, and environmental advantages. "An outcome of a design that focuses on increasing the efficiency of resource use energy, water, and materials while reducing building impacts on human health and the environment during the building's lifecycle, through better sitting, design, construction, operation, maintenance, and removal," according to the definition of green building [29]. Furthermore, a sustainable building "uses a careful integrated design strategy that minimizes energy use, maximizes daylight, has a high degree of indoor air quality and thermal comfort, conserves water, reuses materials and uses materials with recycled content, minimizes site disruptions, and generally provides a high degree of occupant comfort," according to [30] As a result, there is little doubt that integrating sustainability and green construction techniques to buildings will benefit an organization in terms of increased financial returns, improved community standing, increased productivity, and less negative environmental effects [31].

[32] provides a long-term perspective from the early beginnings of facility management to present integration and standardization in his article. A assessment of facility management progress and competency reviews by significant professional associations are presented in order to offer a road ahead for integration in a simplified manner with global potential for impacts. With facility management having matured over the last four to five decades, it's essential to make a stronger link between research findings and their implementation in practice. Focusing on core competencies rather than minute variances in practice will benefit the sector as a whole by giving senior executives a greater grasp of the value facility professionals bring. The importance of sharing best practices around the world is also emphasized. Focus is a significant issue for more advancement and connectedness of research into practice in the facility management sector, according to additional synergy from an investigation of global skills. The author makes suggestions for facility management's further progress and professionalization.

III. RESEARCH METHODOLOGY

The research approach used is similar to [33] notion of discovery through literature, which stresses the development of new knowledge through the use of bibliographic information found in peer-reviewed papers, conference proceedings, and other forms of valid literature. This method is gaining popularity and is being employed in a growing number of research investigations [34-36]. An exhaustive literature search was conducted, which included published books, articles in peer-reviewed journals and conference proceedings, federal facility assessment reports, and presentations at facility management seminars.

III.1 SEARCH STRATEGY

First search TITLE-ABS-KEY ("FACILITY MANAGEMENT" OR "ORGANIZATIONAL EFFECTIVENESS") = **8445.**

Second search TITLE-ABS-KEY ("FACILITY MANAGEMENT" OR "ORGANIZATIONAL EFFECTIVENESS") AND (LIMIT-TO (PUBSTAGE, "final")) AND (LIMIT-TO (OA, "all")) AND (LIMIT-TO (DOCTYPE, "ar") OR LIMIT-TO (DOCTYPE, "cp")) AND (LIMIT-TO (SUBJAREA, "ENGI")) AND (LIMIT-TO (LANGUAGE, "English")) AND (LIMIT-TO (SRCTYPE, "j") OR LIMIT-TO (SRCTYPE, "p")) = **447.**

Third search: TITLE-ABS-KEY ("FACILITY MANAGEMENT" OR "ORGANIZATIONAL EFFECTIVENESS") AND (LIMIT-TO (PUBSTAGE, "final")) AND (LIMIT-TO (OA, "all")) AND (LIMIT-TO (DOCTYPE, "ar") OR LIMIT-TO (DOCTYPE, "cp")) AND (LIMIT-TO (SUBJAREA, "ENGI")) AND (LIMIT-TO (LANGUAGE, "English")) AND (LIMIT-TO (SRCTYPE, "j") OR LIMIT-TO (SRCTYPE, "p")) AND (EXCLUDE (DOCTYPE, "cp")) AND (EXCLUDE (LANGUAGE, "Japanese")) AND (EXCLUDE (SRCTYPE, "p"))=**309.**

After First Search,

THE SECOND SEARCH limit the search to Facility Management in Open Access Journal, Engineering as subject area, articles in English language, publish journal, conference papers which return: TITLE-ABS-KEY ("FACILITY MANAGEMENT" OR "ORGANIZATIONAL EFFECTIVENESS") AND (LIMIT-TO (PUBSTAGE, "final")) AND (LIMIT-TO (OA, "all")) AND (LIMIT-TO (DOCTYPE, "ar") OR LIMIT-TO (DOCTYPE, "cp")) AND (LIMIT-TO (SUBJAREA, "ENGI")) AND (LIMIT-TO (LANGUAGE, "English")) AND (LIMIT-TO (SRCTYPE, "j") OR LIMIT-TO (SRCTYPE, "p")) AND (EXCLUDE (DOCTYPE, "cp")) AND (EXCLUDE (LANGUAGE, "Japanese")) AND (EXCLUDE (SRCTYPE, "p")).

III.2 METHODOLOGICAL REVIEW USING VOSVIEWER

Accordingly, a database topic search was done using the "Scopus" electronic publications repository which is considered as one of the largest databases which provide online access to more than 74 million records in over 21,000 peer-reviewed journals. As one of the most popular and comprehensive databases, Scopus yielded the highest number of documents for the keywords search in this study. Using several databases for bibliometric analysis was not feasible due to overlapping of the results and complexity in comparatively analysing bibliometric networks. Hence, the Scopus was selected as the optimal database from which to draw a representative and adequate set of relevant papers for bibliometric analysis. Keywords used to search the relevant papers for this review are: "Facility Management" OR "Organizational Effectiveness". The aforementioned keywords combination was used to access the most suitable papers for the study. To ensure the quality of the review, the researchers considered only the published articles in journal papers, proceedings papers, and book chapters. While other publication categories such as reviews, editorial material, and book reviews were excluded. Accordingly, the initial or first search returned: **8445** results, and after exclusion, analysis was based on **(n= 309)** published papers that were identified.

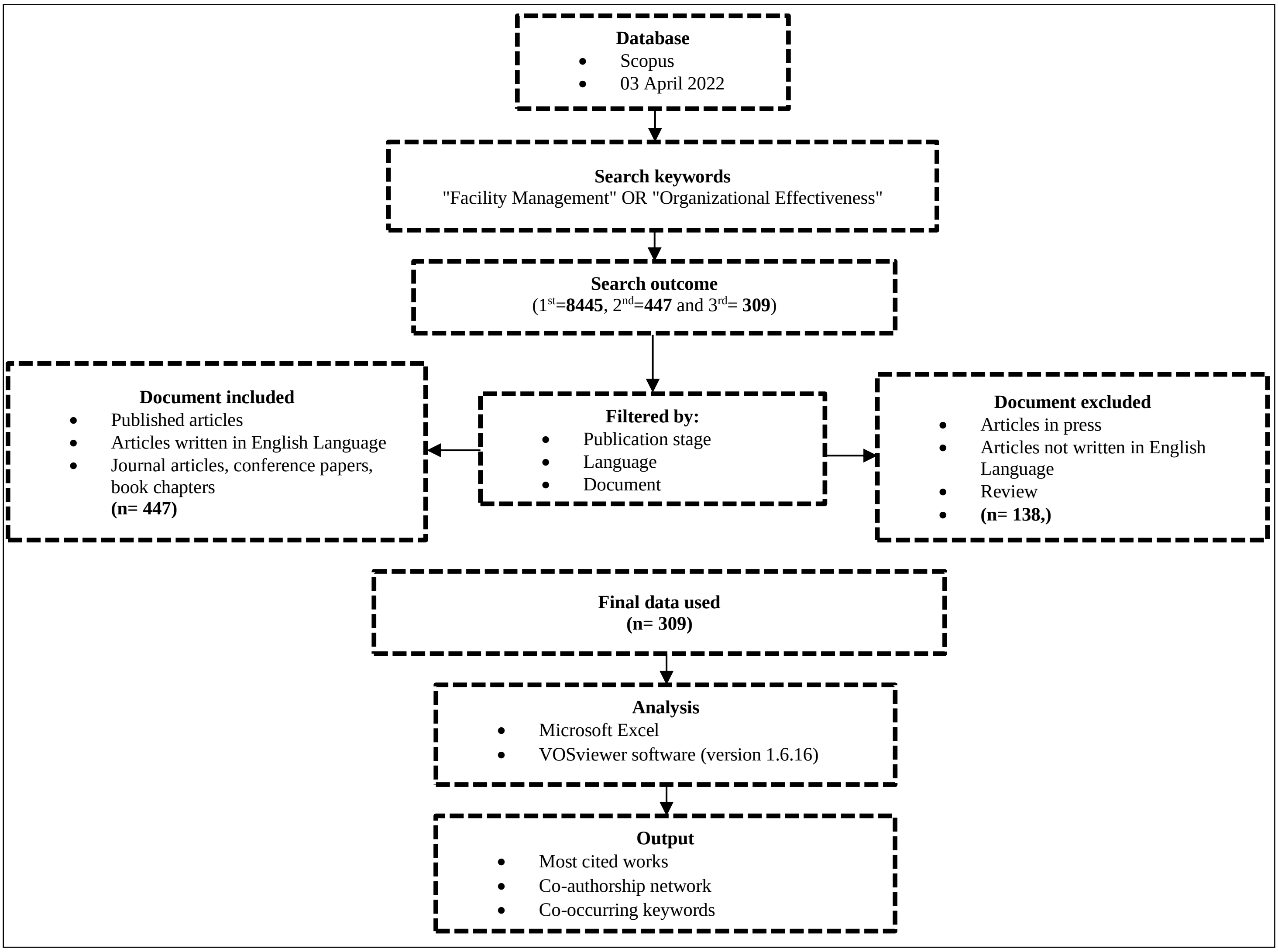

Figure 1: Search flow chat process.
Source: Authors, (2022).

Subsequently, the bibliometric analysis was conducted with the aid of "VOS Viewer" software package which is popular amongst researchers and freely available to download and use, hence widely tried and tested with many available guidelines. VOS viewer is powerful enough, user friendly and provides enough dimensions for the intended bibliometric analysis. Hence, this software package was selected for the study. All the identified **(n= 309)** papers were utilised for the review under the "full counting" approach. "Fractional counting" approach was not used due to the complexity of handling fractional values when counting the papers under the journals and geographical locations. According to the focus of the review, the authors limited the bibliometric analysis variables to keywords, journals and geographical distributions while excluding the more narrowed authorship and organisational level analysis approaches. Next, a comprehensive methodological review was done by selecting the most relevant papers which are directly related to each objective from the search were considered. Wherein, the researchers examined the full text of the **(n= 309)** downloaded papers to identify the best matching studies.

Correspondingly, 309 specific papers were identified for the study. Even though initially identified 309 papers fulfilled the criteria for keywords search, some studies do not fall within the exclusion criteria and this was deselected in the methodological review. Further, some of the papers have not directly addressed the objectives aims. Hence, the authors specifically applied the aforementioned two conditional criteria to select the most suitable papers and identified 309 papers to carry out the methodological review. These papers were categorised into different knowledge categories as the first step of analysis. Each of these papers was then analysed to specifically identify data collection and analysis techniques, network visualisation methods, statistical and software platforms used by researchers.

V. DISCUSSION AND ANALYSIS

V.1 PUBLICATION PER YEAR

Table 1: Publication per year.

Year	Document
1990-1995	2
1996-2001	6
2002-2007	13
2008-2013	31
2014-2019	143
2020-2022	114

Source: Authors, (2022).

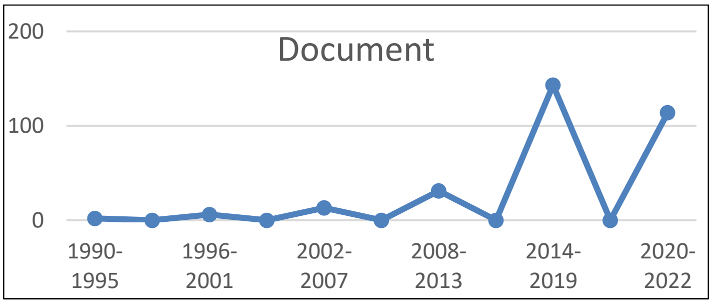

Figure 1: Publication per year.
Source: Authors, (2022).

V.2 PUBLICATION PER CITATION

Evaluating the publication and citation per country in this study is important, this reviews the country showing more interest in this area of study. Total number of 12 countries were involved. The inclusion criteria were set at 10 minimum document and 10 minimum citations, wherein, 12 countries fall within this threshold. Here, the interest was to determine the number of citations received from each country. It will be interesting to note that, only UK and USA retained their position in order of ranking. Citation shows the impact of a particular publication. Some countries that have large number of documents may not receive as much as citation as some that have less publication. In this case, United Kingdom and USA has the highest number of documents with corresponding citation respectively. As can be seen from the table 2 below, Hong kong has just 18 documents but with 461 citations, meanwhile China has 22 documents but with 364 citations which is less than HK. The same can be witnessed in the remaining as depicted in the table.

Table 2: Document by Citation.

Document by Citation	Citation	Number
United Kingdom	1973	80
United States of America	548	36
Hong Kong	461	18
Australia	364	21
China	233	22
South Korea	266	17
Italy	266	17
Norway	143	21
Spain	105	12
Denmark	65	10
Netherlands	50	14
Malaysia	34	16

Source: Authors, (2022).

V.3 PUBLICATION PER COUNTRY

Evaluating the publication and citation per country in this study is important, this reviews the country showing more interest in this area of study. Total number of 12 countries were involved. The inclusion criteria were set at 5 minimum documents wherein, 12 countries fall within this threshold. United Kingdom has the highest number of documents which is 80, followed by USA with 36 documents, China has 22 documents, Australia and Norway has 21 each, Hongkong has 18 documents while South Korea and Italy has 21 documents each and Denmark has the least minimum number of documents. This can be seen from the table 3 and Figure 2 below.

Table 3: Document by Country or Territory.

Sno	Document by Country	Number
1	United Kingdom	80
2	United States of America	36
3	China	22
4	Australia	21
5	Norway	21
6	Hong Kong	18
7	South Korea	17
8	Italy	17
9	Malaysia	16
10	Netherlands	14
11	Spain	12
12	Denmark	10

Source: Authors, (2022).

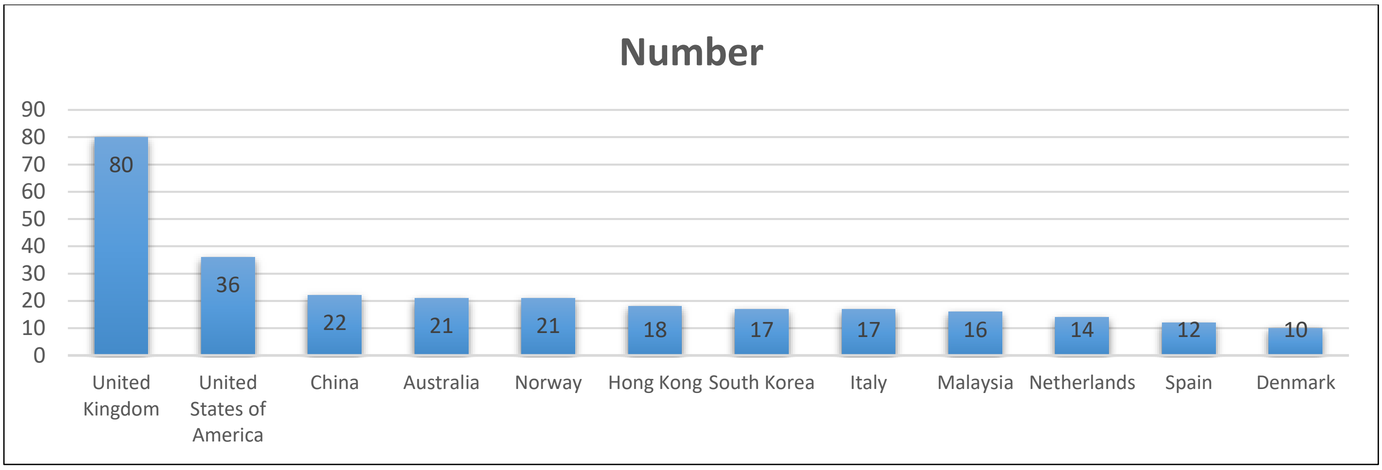

Figure 2: Document by Country or Territory.
Source: Authors, (2022).

V.4 CITATION PER SOURCE

The number of papers taken from each source title was counted. The 309 retrieved papers were published in 12 distinct journals, book chapter and conference proceedings. Only those sources having at least 5 published publications as appear in the Figure 3. IEEE access has 44 citations, the Journal of Automation in Construction topped the list with 672 citations followed by Journal of facilities with 668 citations. This is followed by Journal of Building (253 citations), Journal of Built environment project and Asset (211 citations). While Advances in Civil Engineering has 156 citations, Building and Environment has (148 citations), and Journal of Building Engineering has (21 citations).

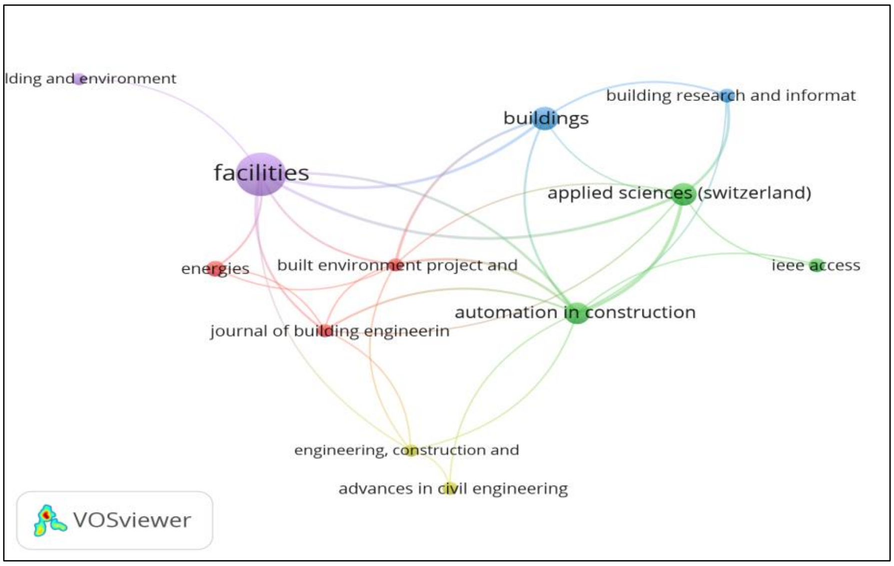

Figure 3: Citation per source.
Source: Authors, (2022).

Table 4: Citation Per Source.

Item	Article Source Type	Citation
1	Automation in Construction	672
2	Facilities	668
3	Building	253
4	Built Environment project and Asset	211
5	Advances in Civil Engineering	156
6	Building and Environment	148
7	Applied Sciences (Switzerland)	90
8	Engineering, Construction and Architecture	85
9	Building and Research Information	57
10	IEEE Access	44
11	Energies	35
12	Journal of Building Engineering	21

Source: Authors, (2022).

V.5 MOST CITED AUTHOR AND PUBLICATION

Evaluating the most cited authors from the total numbers of authors involved in this study is crucial, this will enable us to know the working strength of the other authors, minimum citation criteria was set at 3, where in 10 authors falls within this category as seen in Figure 4. Analyzing the retrieved papers to see the most referenced documents and their areas of specialization was important to completely grasp the understanding of researches in the domain of facility management. From the analysis of most cited published works, the study revealed that Dawood and Kassem are the most cited authors with 186 citations each, followed by 138 citations received from Wang and Haugent, has the least citation of 34 as depicted below.

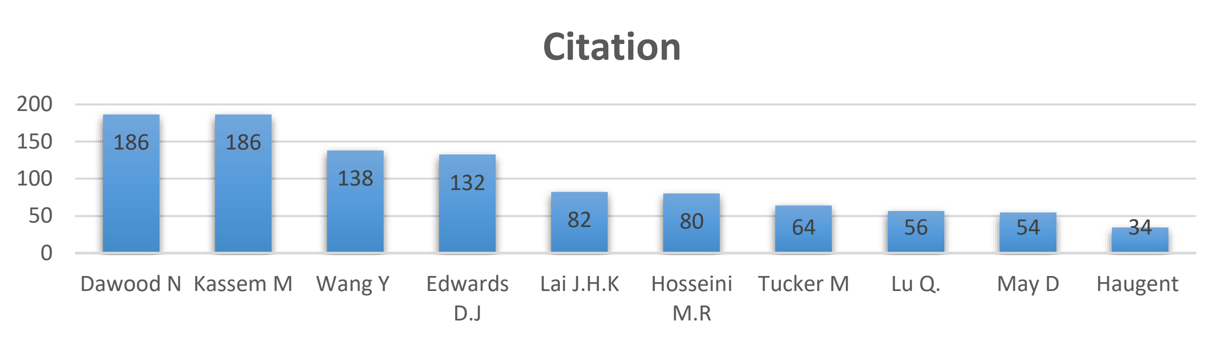

Figure 4: Citation per source.
Source: Authors, (2022).

Table 5: Most Cited Author.

Item	Most Cited Author	Citation
1	Dawood N	186
2	Kassem M	186
3	Wang Y	138
4	Edwards D.J	132
5	Lai J.H.K	82
6	Hosseini M.R	80
7	Tucker M	64
8	Lu Q.	56
9	May D	54
10	Haugent	34

Source: Authors, (2022).

V.6 CO-OCCURRENCE KEYWORDS

The detailed information of the journal publications was then imported in to VOSVIEWER for further analysis. Keyword co-occurrence networks embody the development of Facility Management over time and displays important themes of the field. Figure 5 and 6 show the overall keyword co-occurrence network (Network and Overlay Visualization). Different nodes in the map represent identified keywords that were used to summarize the nature and core of each publication. Links between nodes express relationships of co-occurrence, meaning two different keywords are used together in the same publication. The color of nodes and lines represents different years, and the size of the nodes shows the frequency of keyword co-occurrence. Out of the 2047 keywords, only 30 meet the threshold**.** The network visualisation map for the 30 co-occurring keywords and their 4 separate clusters is shown in Figure 5 and 6 The terms "Facility management" and "Office building" are at the heart of it, and all other keywords are linked to these. Cluster 1 has 9 items or co-occurrence keywords, Cluster 2 has 9 items, cluster 3 has 7 items, for cluster 4 and only 5 items.

Figure 5 and 6 below show the keywords that occurred most frequently. First, the frequency of “facilities management” was the highest, which was determined by the theme of this study. Other keywords in the cluster are “Building Information Modelling, Decision Making, Digital Twin, Facility Management and Internet of Things, Asset Management, Information Management, Information Theory, Life Cycle and Maintenance, Buildings, Energy Efficiency, Energy Utilization, Intelligent Buildings, Office Buildings, Sustainability, and Sustainable development, Architectural Design, construction Industry, Design Methodology, Frequency Modulation, Project Management and Survey, Operation and Maintenance, Decision making, Stages, Organization effectiveness, Human Resource Management, Air conditioning, Data transfer, Integration, Semantic, etc.” **Facility Management and Facilities Management.**

Information is critically important for supporting efficient and effective building maintenance and day-to-day operations. However, the FM sector continues to struggle with information management. Stakeholders waste a huge amount of money looking for, validating, and/or recreating facility information that should be readily available [37].

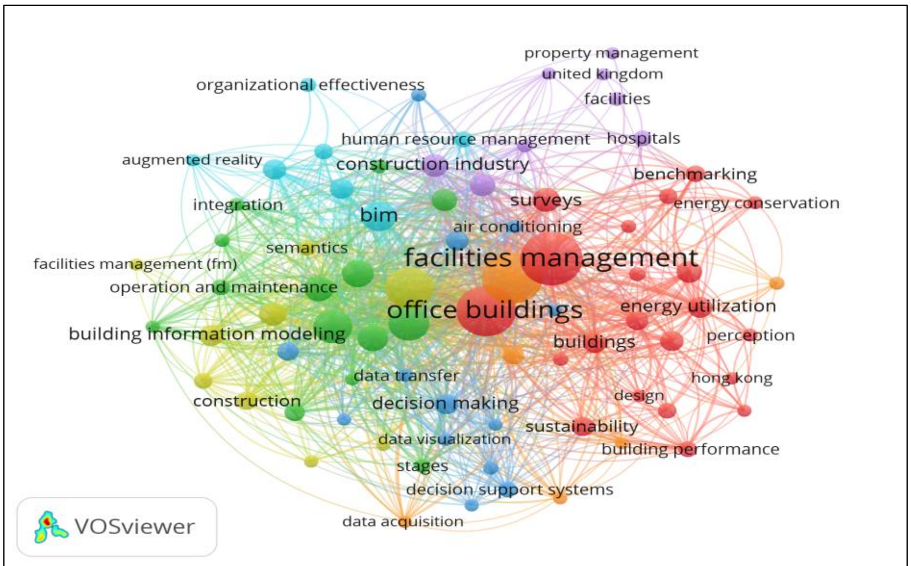

Figure 5: Network Visualization.
Source: Authors, (2022).

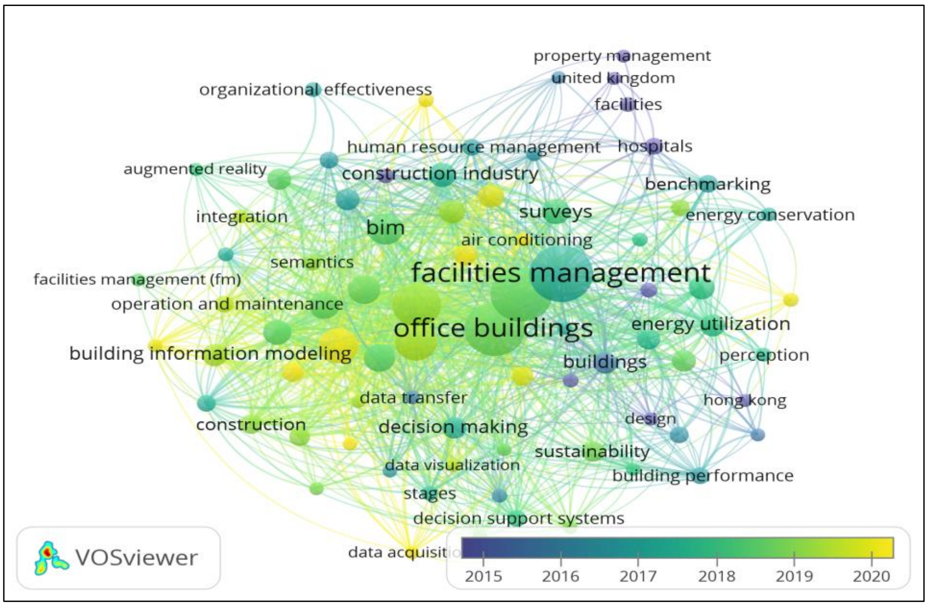

Figure 6: Overlay Visualization.
Source: Authors, (2022).

VI. CONCLUSIONS

Facilities Management research has gotten a lot of attention throughout the world, and with new technologies from allied sectors in the construction business, efforts and research will continue to try to innovate and improve global construction practice in service delivery. This research looked at the bibliometric data from relevant published journals on Facilities Management and how it affects organizational effectiveness studies around the world. The papers came from a variety of nations and were exported from Scopus' core collection of indexed research documents. Yearly publication, publication by document source, publication by citation. The analysis looked at frequency analyses, co-authorship, and co-occurrence among the authors, publication sources, organizations, and countries/locations.

According to the findings of the literature review, there is a need to increase communication between in-house departments and outsourced providers and the Facility Function. facilities management has a significant impact on organizational effectiveness, and effective asset management has a significant impact on organizational growth, which is consistent with [38] assertion that facilities management encompasses the concepts of cost-effectiveness, productivity improvement, efficiency, and employee quality of life. Moreover, some research studies have demonstrated a link between facilities management and organizational effectiveness; for example, [11] discovered a link between facilities management and effective business operations. Similarly, research by [12] found that good facility management increased productivity. Also, the result of the analysis carried out on VOSVIEWERS found that, in terms of overall productivity and contribution among authors, Dawood, N, Kassem M., Wang Y., Edward D.J, Lai J.H.K, Hosseini M.R and Tucker M, Lu Q., May D.H and Haugent as the top ten lead and most cited authors in the field. Meanwhile, the bulk of journal articles on sustainable procurement development came from the United Kingdom, United States, Hong Kong, Australia, China, South Korea, Italy, Norway, Spain, Denmark, Netherlands and Malaysia according to the distribution of the publications.

VII. AUTHOR'S CONTRIBUTION

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Discussion of results: Dr. Reuben A. OKEREKE, Nneka M. IHEKWEME and Kazeem O. OLADAPO.
Writing – Original Draft: Dr. Reuben A. OKEREKE, Nneka M. IHEKWEME and Soji D. ADETOLA.
Writing – Review and Editing: Dr.Reuben A. OKEREKE, Nneka M. IHEKWEME and Kazeem O. OLADAPO.
Resources: Dr. Reuben A. OKEREKE, Nneka M. IHEKWEME and Soji D. ADETOLA.
Supervision: Dr. Reuben A. OKEREKE, Nneka M. IHEKWEME and Kazeem O. OLADAPO.
Approval of the final text: Dr. Reuben A. OKEREKE, Nneka M. IHEKWEME, Soji D. ADETOLA and Kazeem O. OLADAPO.

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Journal of Engineering and Technology for Industrial Applications

ITEGAM-JETIA

ISSN ONLINE: 2447-0228

Manaus, v.8 n.34, p. 39-43. Mar/Apr, 2022

DOI: https://doi.org/10.5935/jetia.v8i34.808

RESEARCH ARTICLE OPEN ACCESS

INFRASTRUCTURAL DEVELOPMENT IN YEWA SOUTH LOCAL GOVERNMENT AREA IN OGUN STATE, NIGERIA

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ARTICLE INFO

Article History
Received: February 28th, 2022
Accepted: April 24th, 2022
Published: April 30th, 2022

Keywords:
Community participation,
Infrastructure development,
Government,
Management,
Planning.

ABSTRACT

This research assessed community involvement in infrastructure development in Ogun State's Yewa South Local Government Area. For countries with poor economies, providing public infrastructure is a difficult endeavour due to the enormous resources needed. The Federal Government of Nigeria has been tackling the slow pace of infrastructural development in the country. Nigeria's inability to adequately manage its resources has resulted in numerous setbacks in the development and management of the country's public infrastructure. A systematic random sampling was adopted for the study and a total number of 195 people were interviewed, and from the result it was established that there is a positive relationship between community participation, sustainability, access and utilisation of public infrastructure. Infrastructural development has a strong relationship to economical growth and the well-being of the poor in any developing society. Similarly, involving the community in infrastructure planning aids in mobilizing sufficient resources from the federal government and the community for the implementation of essential projects. Community participation also help to ensure sustainability of the projects implemented. It was concluded that mass orientation or drive in community participation, and effective resource management must be intensified in order to enhance rapid growth in development of public infrastructure.

I. INTRODUCTION

I.1 BACKGROUND OF THE STUDY

Infrastructural development is a critical component of government investing in physical and social infrastructure [1]. The establishment of key foundational services to boost economic growth and quality of life is the goal of any nation's infrastructure development [2]. Social and Physical infrastructures are the two types of infrastructure. Social housing programs, health services, education are examples of social infrastructure, while roads, telecommunications and power are examples of physical infrastructure. The lack of infrastructure facilities makes socio-economic development impossible, resulting in high pricing for services and products. The presence of power, education, road, medical facilities, employment opportunities and drinkable water supply, among other things, is usually a sign of infrastructure development [3]. Disaster risk reduction has been recognized by several global bodies on sustainability development and disaster risk reduction. Community participation is the direct involvement of people of a host community in projects to solve their own problems using the mechanism of dialogue and collaboration. Involving people in the community in projects management engenders a sense of shared responsibility and accountability towards the project. The main goal of this research is to evaluate community involvement in infrastructure development in the Yewa South Local Government Area of Ogun State, Nigeria, with the following objectives: investigate the distribution of rural infrastructure in the study area; assess the level of community participation in infrastructure development; assess the influences of community participation on infrastructure sustainability; and evaluate the obstacles of community involvement in the development of infrastructure.

II. LITERATURE REVIEW

Infrastructure is an integral part of economic and social development process [4]. The rising need for infrastructure among local populations has helped pave the way for a variety of infrastructure providers, including private organizations, community efforts, and the conventional provider, the government. In most countries, infrastructure delivery is essentially the duty of the government. In Nigeria, for example, infrastructure supply is the role and obligation of the government at the three levels (federal, state, and local government authorities) through established governmental entities. However, as a result of the government's failure to provide adequate funding, the private sector is increasingly making progress due to rapid urbanisation [5]. The majority of Nigerians lack the required infrastructural facilities to promote various business operations and socio-economic development. The relationship between economic and infrastructure development is a must-have factor for raising living standards [6]. In another perspective, according to World Bank, the correlation between a country's Gross Domestic Product (GDP) and its high level of urbanization further establishes the linkage between economic and infrastructure development [7]. The factors contributing to Nigeria's current infrastructure deficit include; poor maintenance culture, rise in population, poor governance, inadequate funding, corruption and economic sabotage. The two categories of critical public infrastructures are known as hard and soft infrastructures. The hard infrastructure refers to the enormous physical networks required for modern advanced nations to function, whereas the soft infrastructure pertains to all of the institutional facilities and frameworks required to maintain a country's economic, social, health, and cultural standards [8].

Infrastructure can be described as the conglomeration of all amenities that enable a town to operate better. It can still be thought of as a collection of social and economic services that contribute to the creation of a conducive environment for growth in the economy and better living standards [9]. Infrastructure supports and provides for essential human capabilities. Infrastructure, at its most basic level, provides people with necessary services such as water and energy, as well as protecting them from risks such as floods. People can also use infrastructure to access other services like healthcare and education, as well as partake in the economy by accessing markets and traveling to work. Infrastructure supports critical manufacturing components such as energy, water, and access to market [10]. Infrastructure facilities can also be preserved to aid economic development. Adequate infrastructure minimizes manufacturing costs, which has an impact on output profitability and the total number of employees [11]. The quality of rural infrastructure, as well as its presence or absence, has an impact on citizen wellbeing, which in turn has an influence on the city's economic ability to function effectively [12]. The influence in city infrastructure is connected to the infrastructural arrangement of the urban infrastructure delivering services, rather than to actual resource constraints [13]. Users of infrastructure must have the basic right to self-help enhancement, improved security of tenure, organization and technical assistance, an atmosphere favorable to permissive and supporting legislation, and a stronger representation in the road network project in order to participate successfully. Several variables, including time-bound project management requirements, lack of secure tenure rights, rigid planning methods, absence of feasible models, and unseemly technical standards, limit the potential reward of community involvement in the management of city road infrastructure development [14].

Furthermore, the absence of a clear organizational structure, functions, and roles for local authorities that permit both infrastructure development and community participation in decision-making is a contributory issue. Obviously, for genuine community participation, the ultimate decision must be taken by people at the grassroots level [15].

The goal of community involvement is to improve capacity and skills development as well as modalities for stimulating the consciousness and individual interest of the people in communities, by promoting and provoking their population interest in their own project to enhance development. One of the essential elements of a strong community is community participation [16]. Community participation in the local development process is a vital component and a definite approach to accelerate the socio-economic transformation of Nigeria's rural areas, as evidenced in various policy studies [17] [18]. The fact remains that many poverty-reduction efforts fail because they were supply-driven and top-down, ignoring community participation and management of development projects [19].

The importance of citizen participation in community development cannot be overstated. It is self-evident that community participation can be beneficial when the community has been involved in the process in general. As a result, finding effective solutions to foster the relationship between community participation and infrastructure development is critical and essential. Thus, the focus of this research on the assessment of community participation in infrastructural development at the Yewa South Local Government Area in Ogun State, Nigeria.

III. MATERIALS AND METHODS

This study is a cross-sectional study with data collected using a multi-stage sampling technique. The whole local government community was sampled and questionnaires were distributed. A total number of one hundred and ninety five (195) questionnaires were administered. The data were analysed using statistical tools and the results were presented. Yewa South Local Government Area is located at the west of Ogun State, Nigeria. Its Headquarter is in the town of Ilaro at 60531 00 N 300110011 in the north of the Area. It spans 629kkm2 and has a population of 168,850 (2006 Censor). The area is made up of 10 wards; Ilaro I, Ilaro II, Ilaro III, Idogo, Owode 1, Owode II, Iwoye, Oke Odan, Ilobi/Erinja and Ajilete. The locals speak the Egun and Yewa dialects of Yoruba Language.

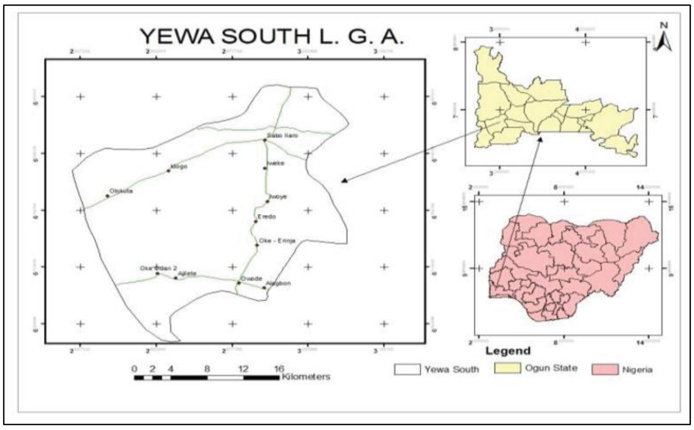

Figure 1: Map of Yewa South Local Government.
Source: [20].

III.1 SOURCE OF DATA

The primary data source was used in the study. The data was gathered via the use of questionnaires as the study's primary research tool. The total of 195 responders were administered.

III.2 METHOD OF DATA ANALYSIS

A simple correlation and recreation was used to evaluate the significance differences which may emerge across levels of community involvement in sustainable rural infrastructure in the study area. For data analysis, the SPSS program (Statistical Package for Social Sciences) was employed.

IV. RESULTS AND DISCUSSIONS

Table 1: The study of the spread and socio-economic characteristics of the respondent.

Traits	Ilaro	Idogo	Iwoye	owode	Oke odan	Ajilete	Ilobi/ irinja	Total	%
Gender									
Male	35	15	12	23	14	12	10	121	62.05
Female	25	6	6	17	8	6	5	73	37.43
No Response						1		1	0.52
Age Group									
0-20	-	2-	4-	5	2	-	4	17	8.71
21-30	7	8	6	7	6	8	7	49	25.12
31-40	15	14	25	23	10	8	6	101	51.79
41-50	3	2	-	9	-	3	2	19	9.74
Above 50	3	3	1	-	-	2		9	4.6
Marital status									
Single	14	8	12	15	6	7	8	70	35.89
Married	23	17	8	10	8	10	2	78	40.0
Widow	2	2	5	2	-	2	-	13	6.66
Divorced	2	3	6	2	6	4	2	25	12.82
No Response	2	2	1	1	1	1	1	9	4.61
Occupation									
Farming	5	10	6	7	7	9	9	53	27.17
Civil servant	13	12	6	8	10	12	8	69	35.38
Artisan	4	5	6	6	6	7	2	30	15.38
Trading	6	4	3	5	2	3	2	25	12.82
Others	2	3	2	2	2	-	2	13	6.66
No Response	2	-	2	-	1		-	5	2.56

Source: Authors, (2020).

From Table 1, it can be seen that only 8.71 percent of local residents are under the age of 20; 25.0 percent of respondents are between the ages of 21 and 30, 51.79 percent are between the ages of 31 and 40, and 9.74 percent are between the ages of 41 and 50. The fact that most respondents fall between the ages of 21 to 30 (25%) and 31 to 40 (51.79%) basically states the active age group's full participation in this community participation survey. Notwithstanding, all respondents, regardless of age group, had a good attitude toward community participation, despite the fact that 35.89 percent of the overall sample was single and 40 percent was married.

The respondents' degree of awareness was influenced by the overall level of education of the people of which 35.38 percent were civil servants. This explains the large proportion of respondents who had studied up to tertiary level of education. The fact that even though 15.38 percent and 27.17 percent of the respondents were artisan and farmer, respectively, confirms the general spread of the data analysed.

Table 2: Assessment of the level acceptance and participation by the entire community.

Level of participation	Strongly agree	Agree	Neutral	Disagree	Strongly	Total
Assume control	90	44	20	26	15	195
Delegation of authority	85	35	19	33	23	195
Joint plan	65	47	23	27	33	195
Piece of advice	78	34	24	34	25	195
Consultation	76	30	26	36	27	195
Enlightenment	58	27	28	37	45	195
Non participation	54	34	38	23	46	195

Source: Authors, (2020).

IV.1 MODEL SUMMARY

Table 3: Relationship between community participation and sustainable infrastructural development.

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.979[a]	.958	.958	.317

Source: Authors, (2020).

The result in Table 3 shows that there is a substantial positive connection between participation and sustainability of infrastructure development in Yewa South Local Government with correlation coefficient of 0.979, and it is noted that about 95.8% variation in sustainability of infrastructural development can be attributed to community participation.

Table 4: Relative statistical coefficient validating the significance of the study.

Model		Unstandardized Coefficients		Standardized Coefficients	T	Sig.
		B	Std. Error	Beta		
1	(Constant)	-.065	.059		-1.094	.276
	PAT	.149	.002	.979	66.423	.000

Source: Authors, (2020).

The coefficient table in Table 4.0 shows that for every unit increase in community participation, there is 14.9% unit increase in sustainability of infrastructural development. The t-value is 66.423 and p-value of 0.000; indicating that the test is significant, hence we can conclude that community participation have significant positive effect on sustainability of infrastructural development.

Table 5: Analysis of variance for the relationships.

Model		Sum of Squares	Df	Mean Square	F	Sig.
1	Regression	442.615	1	442.615	4412.021	.000[b]
	Residual	19.261	192	.100		
	Total	461.876	193			

Source: Authors, (2020).

Table 5 confirmed the adequacy of the test carried out in Table 2; with F-value of 4412.021 and the p-value 0.000, hence it can be concluded that the test is adequate in relating sustainability of infrastructural development, community participation and distribution of project.

V. CONCLUSIONS

Provision of rural infrastructure has become an agenda in every successive government in Nigeria. This study has shown that if communities are effectively mobilised and encourage to be part of the decision process of proposed project meant for the communities, there is a link between provision of such rural infrastructural projects, economical growth and development. Therefore, Government must mobilize and create the needed awareness about how community participation can be encouraged in other to achieve targeted goals of the annual budgets and rolling plans of government's or party's ingredients for manifestos implementation. This approaches when properly implemented with intensive efforts and enhanced community participation in infrastructure development, the rural communities would be positively transformed.

VI. RECOMMENDATIONS

There is urgent need to actively involve the communities in rural infrastructural development planning and execution. It is evident that community-led or sponsored projects could be managed efficiently, and sustainability of such project will be guaranteed by the community. Capacity building of people and developmental capacities of the rural areas can be improved, if the people of the community are allowed to participate during the planning stage by the project developer. They must be made to know that they own the projects and are responsible for their sustainability; then, the life spans of the projects will be remarkably increased, benefiting both the government and the people.

VII. AUTHOR'S CONTRIBUTION

Conceptualization: Wahab Afolabi Ajibola and Gbenga Wasiu Ibrahim.
Methodology: Wahab Afolabi Ajibola and Gbenga Wasiu Ibrahim.
Investigation: Wahab Afolabi Ajibola and Gbenga Wasiu Ibrahim.
Discussion of results: Wahab Afolabi Ajibola and Gbenga Wasiu Ibrahim.
Writing – Original Draft: Wahab Afolabi Ajibola.
Writing – Review and Editing: Wahab Afolabi Ajibola and Gbenga Wasiu Ibrahim.
Resources: Wahab Afolabi Ajibola and Gbenga Wasiu Ibrahim.
Supervision: Wahab Afolabi Ajibola and Gbenga Wasiu Ibrahim.
Approval of the final text: Wahab Afolabi Ajibola and Gbenga Wasiu Ibrahim.

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