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RESEARCH ARTICLE OPEN ACCESS

THE IMPACT OF NANO ADDITIVES IN CORN OIL BIODIESEL USED IN COMBUSTION ENGINES ON THE ENVIRONMENT: AN EXPERIMENTAL APPROACH

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ABSTRACT

Biodiesel was made in this experiment by transesterifying corn oil. The engine's performance and emissions from fossil fuels were evaluated by adjusting the fuel mixture proportions. This investigation examined various parameters, including hydrocarbon emissions, CO, NOx emissions, brake power, mechanical efficiency, brake thermal efficiency, and indicated thermal efficiency. It had a 5.2-kilowatt diesel engine. Making biodiesel is possible by disposing of corn oil. Biodiesel is a product of blending 20% corn oil with diesel. The methyl ester of corn oil satisfied the criteria set by ASTM for fuel. Through the application of different loads to a single-cylinder four-stroke diesel engine, the experimental findings were derived. Although indicated thermal efficiency declined, the B20 blend with 100 ppm titanium oxide nanoparticles led to improvements in brake power, mean effective pressure, mechanical efficiency, and brake thermal efficiency. While the addition of TiO2 nanoparticles to B20 decreased HC and CO emissions, it increased NOx emissions. The BD20+100ppm TiO2 sample provided the most favourable outcomes, all things considered.

I. INTRODUCTION

With the increasing need for renewable energy, biodiesel has shown great promise as a replacement for fossil fuels in many burners, including ICEs, stoves, and more [1]. Policies promoting the production and extensive use of first-generation biodiesel within national borders are likely responsible for the increasing popularity of this biofuel in numerous countries. The promotion of oil palm cultivation in certain countries serves as a strategy to produce biodiesel, potentially addressing energy needs for power generation [2]. It is important to note that first-generation biofuels present several disadvantages, including significant water usage in their production, which could jeopardize food supplies, as well as competition with crops intended for human consumption [3]. This starts a conversation about how well these resources can provide food and energy, which is important for developing new tactics in certain nations. In light of these challenges, there is a growing emphasis on developing innovative solutions and materials. The primary goal of these projects is to develop biofuels for the second, third, and fourth generations using resources other than food crops [4]. The creation of biodiesel from non-food sources and its use has sparked a range of opinions about the feasibility of using these resources for both food and fuel production. This necessitates a thorough assessment of this aspect during the legislative process across different countries. Scholars globally have carried out numerous comprehensive studies regarding the efficiency of internal combustion engines [5]. The biodiesel production from non-edible vegetable oils has undergone a thorough online examination, highlighting the fuel's characteristics and efficiency [6]. Scientists have looked at several plant oils as potential sources of raw materials, including those that are taken from tobacco, cotton, jojoba, rubber, flax, jatropha, and many more plants. Biodiesel is becoming more popular as a fuel for electric generators, thus several governments have encouraged the production of oil palms to fulfil this need [7]. In 2012, the Philippines was the first nation to initiate the production of biodiesel derived from olive oil. First-generation biofuels present various drawbacks, such as competition with food crops and significant water consumption during production. Research revealed that corn oil might be used to make biodiesel in a manner compliant with international environmental standards and recommendations [8]. Researchers have created a combined catalytic approach for biodiesel production using a composite membrane and sodium methoxide. Their findings indicate that under optimal conditions, a transesterification conversion rate of 98.1% can be reached. A lot of research has gone into determining if biodiesel can be used as a viable fuel for I.C. engines in the last several years. A lot of recent studies have also looked at how efficient these engines are for transportation purposes [9].

II. MATERIALS AND METHOD

II.1 BIODIESEL PRODUCTION

The Food and Agriculture Organization (FAO) states that the first stage is to cook corn to extract its oil, which should yield around 10 liters of oil. An acidity assay is then conducted using a portion of this oil. The acid number of a triglyceride reflects its free fatty acid content, indicating its level of acidity. Potassium hydroxide is essential for titration in this process, while the acidity is measured using the acid number index [10]. An acidity value of 5 or below is considered acceptable for processing, as biodiesel production requires an acidity index not exceeding 5. If the acidity is higher, the oil is less suitable for biodiesel production and is better suited for other uses. In an Erlenmeyer flask, a 5 gramme sample was combined with 50 milliliters of neutralized ethyl alcohol and a few drops of phenolphthalein at 50 degrees Celsius to determine acidity. The solution was then titrated using a 0.1N potassium hydroxide solution [11]. The transesterification process is illustrated in Figure 1.

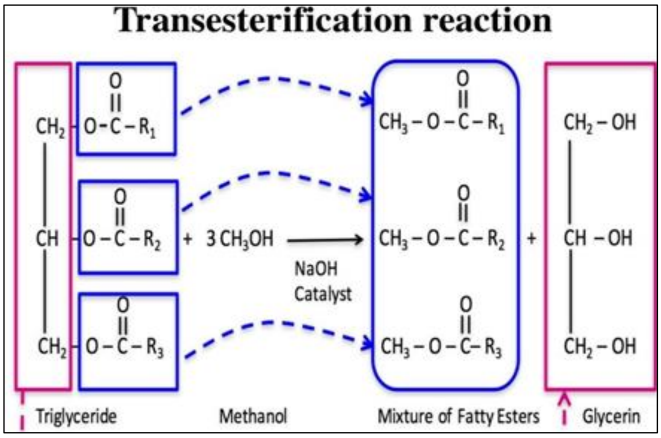

Figure 1: Transesterification process.
Source: Authors, (2024).

Using the transesterification method, renewable lipids like animal and vegetable oils may be transformed into long-chain fatty acid monoalkyl esters. This method is also applicable to animal fats and is integral to biodiesel production. In a specific experiment, 10 liters of used cooking oil were placed in a designated disposal container. Methanol, at a concentration of 20% (v/v), was then added in a volume approximately equal to that of the oil. The amount of catalyst required was calculated based on the acid number of the oil, with 8 grams of potassium hydroxide (KOH) used in the reaction [12]. After mixing the catalyst with methanol to create methoxide, this mixture was combined with the oil and agitated for about two hours at temperatures between 50 and 60 degrees Celsius. The glycerin byproduct was separated through decantation, and the biodiesel underwent three to four washes with water at concentrations of 20 to 30% (v/v), depending on the volume produced. Finally, the biodiesel was dried and filtered as part of the subsequent steps [13].

Table 1: Fuel blends properties.

	Diesel	BD 20	BD20+25 ppm TiO_2	BD20+ 50ppm TiO_2	BD20+ 75ppm TiO_2	BD20+100 ppm TiO_2
Density (kg/m^3)	815	820	826.5	833	839.5	846
Viscosity (mm^2/s)	3.1	3.2	3.3	3.4	3.5	3.6
Calorific Value (MJ/kg)	44	42.8	43.45	43.95	44.25	45
Cetane Number	52	55.6	56.05	56.5	56.95	57.4
Flash Point °C	204	194.8	195.3	196	196.7	197.4
Fire Point °C	59	129.8	130.45	131.1	131.88	132.67

Source: Authors, (2024).

II.2 FUEL SAMPLES

A magnetic stirrer was utilized to achieve a homogeneous mixture of 20% biodiesel and 80% diesel, resulting in the B20 corn oil methyl ester formulation for subsequent analysis. Following this, titanium oxide (TiO_2) nanoparticles were evenly distributed in the B20 fuel samples using an ultrasonicator [14]. The nanoparticles were added in quantities of 25, 50, 75, and 100 milligrams. The performance of these fuel blends was assessed using the ASTM D 6751 standard, which is widely recognized for evaluating fuel properties [15]. The properties of the fuel blends are detailed in Table 1.

II.3EXPERIMENTAL SET-UP

An engine with one cylinder, four strokes, compression ignition, and either a water-cooled or water-injected cooling system was used throughout the testing. For the record, the trials used an engine of the Kirloskar TV1 type. The over valves of this engine were operated by pushrods. To conduct the experimental investigation, the engine in issue was put to work. Under extreme conditions of utmost effort and a constant rotational speed of 1500 rpm, the engine is capable of producing 5.2 kW of output power. This is the maximum amount of electricity it can generate. Per the manufacturer's requirements, the timing was set at 23 degrees before the top dead center (TDC), and the fuel injection pressure was kept at 210 bar. Throughout the process, the coolant's temperature remained constant at 80 degrees Celsius. This was made possible by a system that constantly recirculated the coolant via the water jackets that were placed within the cylinder. The pressure inside the engine's cylinders was measured using a piezoelectric sensor that was flush mounted on the vehicle's cylinder head. As an aftermarket accessory, an eddy current dynamometer was installed to measure the torque output of the engine. The experimental setup is shown in a more condensed form in Figure 2, which contains an illustration of the schematic design.

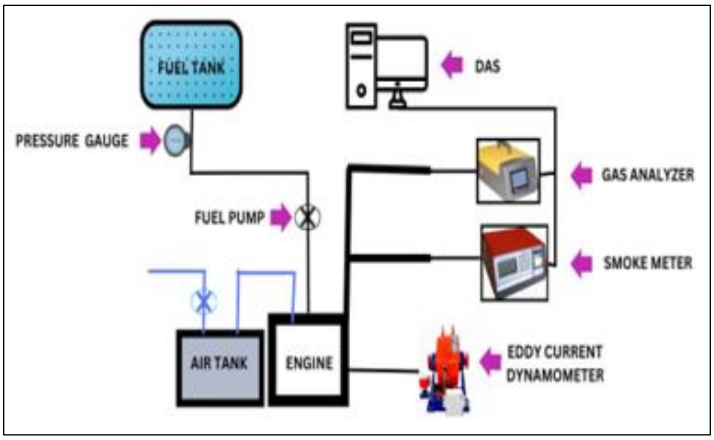

Figure 2: Experimental set-up.
Source: Authors, (2024).

III. RESULTS AND DISCUSSIONS

III.1 BRAKE POWER

Figure 3 demonstrates that the values of the engine's brake power are, for the most part, the same regardless of the load group or the kind of mixture. Displaying an almost linear upward tendency in conjunction with a rising trend as the load rises. The data shown in the picture demonstrate that the variety of gasoline used has no impact on the brake power output of the engine [16]. As the load increases the brake power also increases and the maximum value is found to be for BD20+100ppm TiO_2.

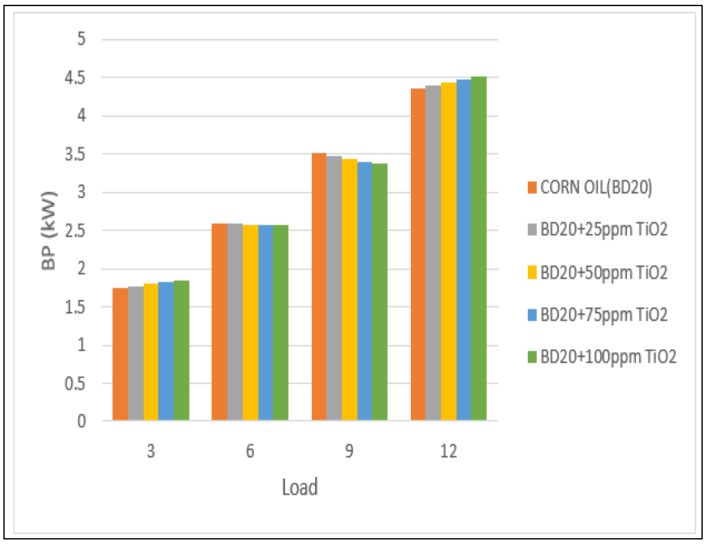

Figure 3: Brake Power varies with increase in load.
Source: Authors, (2024).

III.2 BRAKE MEAN EFFECTIVE PRESSURE

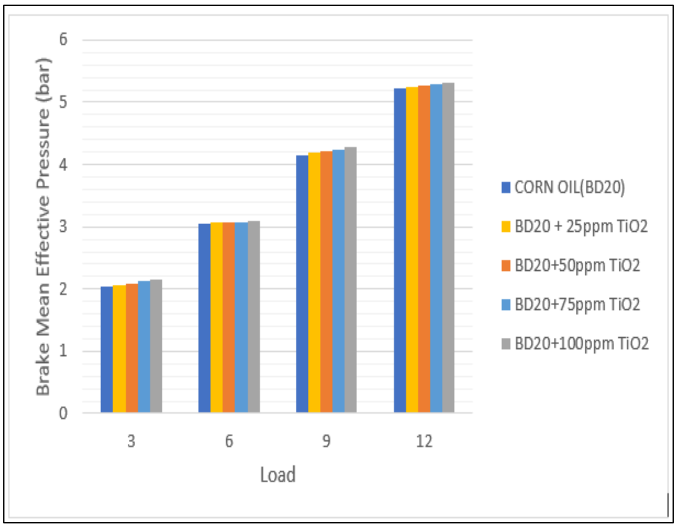

Figure 4: Brake Mean Effective Pressure varies with increase in load.
Source: Authors, (2024).

Figure 4 demonstrates that the values of the engine's brake mean effective pressure are, for the most part, the same regardless of the load group or the kind of mixture. Displaying an almost linear upward tendency in conjunction with a rising trend as the load rises [17]. The data shown in the picture demonstrate that the variety of gasoline used has no impact on the brake power output of the engine [18]. As the load increases the brake mean effective power also increases and the maximum value is found to be for BD20+100ppm TiO_2.

III.2 MECHANICAL EFFICIENCY

Figure 5 demonstrates that the values of the engine's mechanical efficiency are, for the most part, the same regardless of the load group or the kind of mixture. Displaying an almost linear upward tendency in conjunction with a rising trend as the load rises. The data shown in the picture demonstrate that the variety of gasoline used has no impact on the brake power output of the engine [19]. As the load increases the mechanical efficiency also increases and the maximum value is found to be for BD20+100ppm TiO_2.

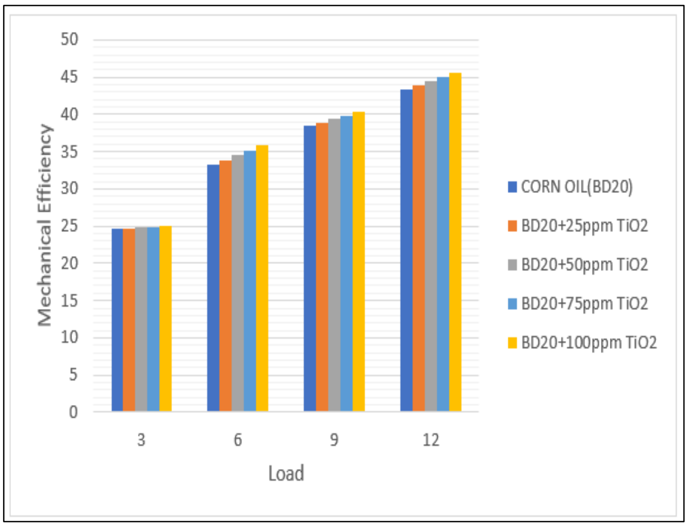

Figure 5: Mechanical Efficiency varying with an increase in load.
Source: Authors, (2024).

III.3 BRAKE THERMAL EFFICIENCY

Figure 6 demonstrates that the values of the engine's brake thermal efficiency are, for the most part, the same regardless of the load group or the kind of mixture. Displaying an almost linear upward tendency in conjunction with a rising trend as the load rises [20]. The data shown in the picture demonstrate that the variety of gasoline used has no impact on the brake power output of the engine [21]. As the load increases the brake thermal efficiency also increases and the maximum value is found to be for BD20+100ppm TiO_2.

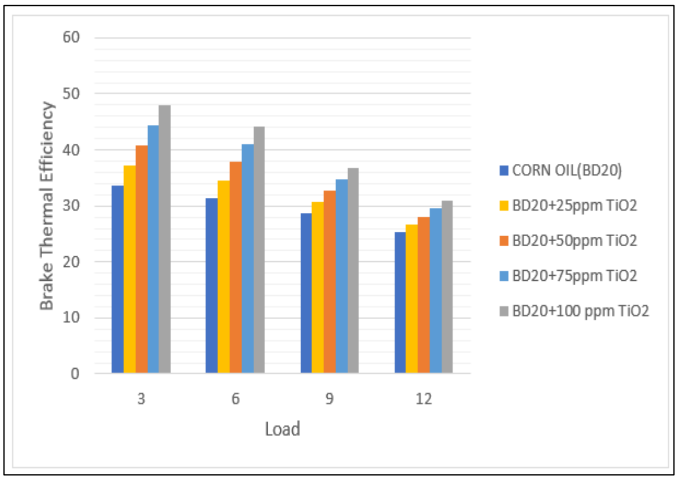

Figure 6: Brake Thermal Efficiency varies with increase in load.
Source: Authors, (2024).

III.4 INDICATED THERMAL EFFICIENCY

Figure 7 demonstrates that the values of the engine's indicated thermal efficiency are, for the most part, the same regardless of the load group or the kind of mixture. Displaying an almost linear downward tendency in conjunction with a rising trend as the load rises. The data shown in the picture demonstrate that the variety of gasoline used has no impact on the brake power output of the engine [22]. As the load increases the indicated thermal efficiency decreases and the minimum value is found to be for BD20+100ppm TiO_2.

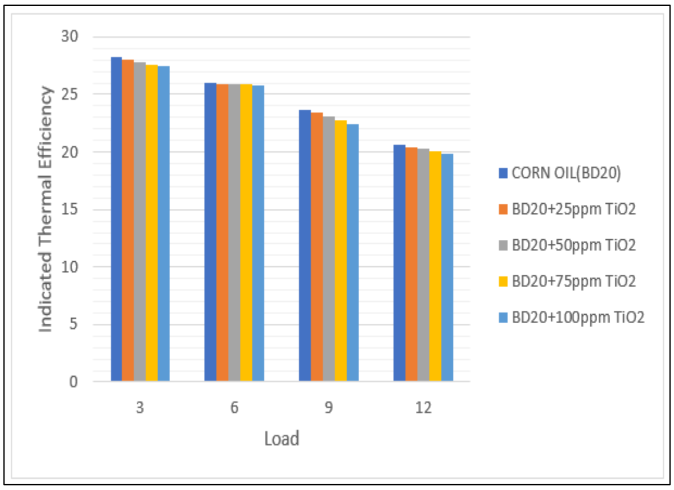

Figure 7: Indicated Thermal Efficiency varying with an increase in load.
Source: Authors, (2024).

III.5 UHC EMISSION TEST

Figure 8 shows that both under low-load and high-load situations, the amounts of UHC (unburnt hydrocarbons) emitted increase, eventually reaching maximum power. Unburnt Hydrocarbon (UHC) emissions are concentrated and rise as a result of the restricted oxygen supply, according to theory. This means the fuel is richer than the fuel-air mixture ratio would indicate. All combinations exhibit a consistent reduction in UHC emission over the operating range, as shown in Figure 4. Plus, compared to the B20 mixture, the emissions from the B20+100ppm TiO_2 combination are significantly lower [23].

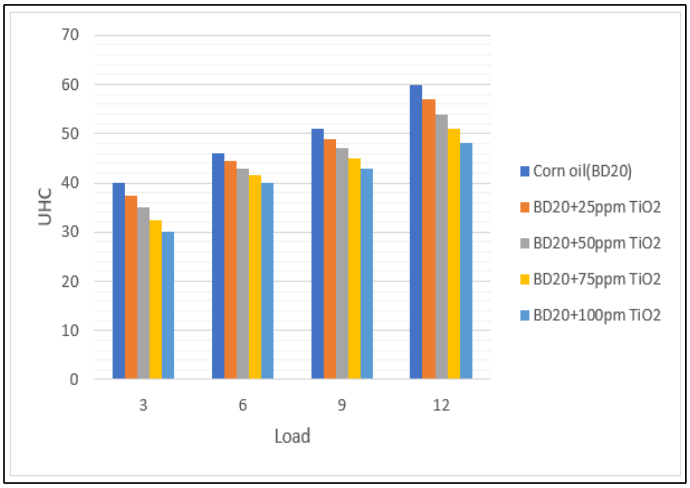

Figure 8: UHC varying with an increase in load.
Source: Authors, (2024).

III.6 CO EMISSION TEST

Carbon monoxide (CO) emissions are positively correlated with increases in all loads, according to the data presented in Figure 9. The data shown above shows a considerable drop of around 20 percent to 25 percent in total CO emissions when using gasoline combined with maize oil biodiesel [18]. Figure 9 illustrates the observed CO emissions corresponding to different loads imposed on the engine using B20 fuel. Carbon monoxide (CO) concentrations, including those in the B20 mix, tend to be highest in the ambient air [24]. One possible strategy to reduce emissions of greenhouse gases is to utilize a B20 biodiesel mix with 100 ppm of TiO_2.

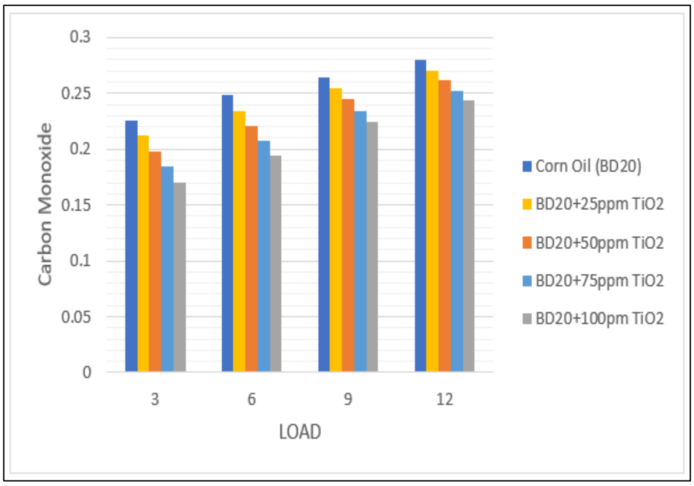

Figure 9: CO varying with an increase in load.
Source: Authors, (2024).

III.7 NOX EMISSION TEST

Figure 10 shows that when all loads increase, there is a clear positive link between NOx emissions and those increases. The data shown above shows that there is a significant rise in total NOx emissions when fuel combined with waste cooking oil biodiesel is used. Different loads applied to the engine using B20 gasoline resulted in NOx emissions, as shown in Figure 10. It shows that NOx emissions are rising for all blends over the whole operating range. In addition, compared to the B20 mixture, the combination incorporating 100ppm TiO_2 shows greater emissions [25].

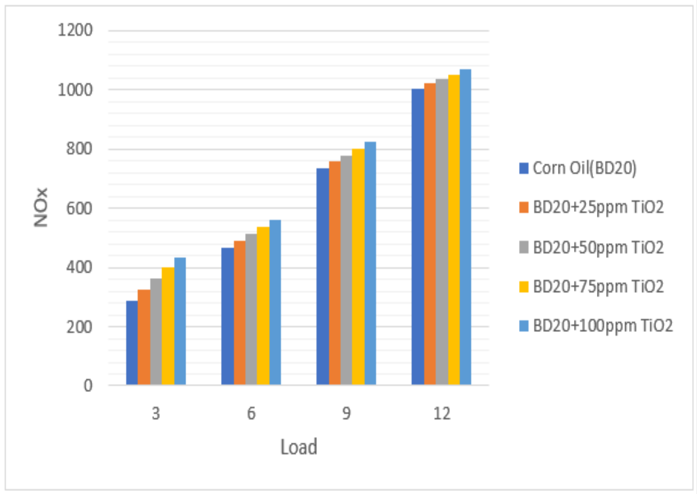

Figure 10: NOx varying with an increase in load.
Source: Authors, (2024).

IV. CONCLUSION

As engine load increases, there is a tendency for brake power, brake mean effective pressure, mechanical efficiency, and brake thermal efficiency to rise, particularly when using B20 fuel with 100 ppm TiO_2 nanoparticles. However, this trend is accompanied by a decrease in indicated thermal efficiency, as shown by the trend line. The use of all fuel types shows a decrease in the values of Carbon monoxide and hydrocarbons as the load increases and the value of NOx increases with an increase in the load and the minimum and maximum values for all of them are found to be for B20+100ppm TiO_2. In summary, the BD20 fuel with 100 ppm TiO_2 demonstrated the most favourable results.

Data availability statement

The document includes the evidence that supports the findings of this study.

V. AUTHOR'S CONTRIBUTION

Conceptualization: Raviteja Surakasi, K.Ch. Sekhar and M Jayakrishna.
Methodology: Raviteja Surakasi and K.Ch. Sekhar.
Investigation: Raviteja Surakasi and K.Ch. Sekhar.
Discussion of results: Raviteja Surakasi, K.Ch. Sekhar and M Jayakrishna.
Writing – Original Draft: Raviteja Surakasi.
Writing – Review and Editing: Raviteja Surakasi and K.Ch. Sekhar.
Resources: K.Ch. Sekhar.
Supervision: K.Ch. Sekhar and M Jayakrishna.
Approval of the final text: Raviteja Surakasi, K.Ch. Sekhar and M Jayakrishna.

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