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Analyzing the Emission Characteristics of a Catalytic Converter using a Nano-ZnO Coating

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Abstract. Due to the ever-growing challenge of pollutants emitted by vehicles, protection of the environment from the pollutants has become a focus of attention. The rising volume of traffic on our nation's roadways now poses a severe danger to the environment due to hazardous emissions, and the refueling availability and low maintenance of petrol fuel vehicles have prompted many to choose for petrol vehicles. Numerous experts have used a variety of strategies to decrease the amount of emissions produced by vehicles, but this sector still has a great deal of room for advancement. The objective of this work is to compare the emission characteristics of a four-stroke petrol engine with and without a nano zinc oxide (nano-ZnO) encased catalytic converter. The findings indicated that the nano-ZnO coated catalytic converter aided in reducing the CO, CO₂, HC and NO_x emissions by 41.3%, 71.4%, 48.2%, and 46.7%, respectively

Keywords: catalytic converter; nano-ZnO; engine emission; petrol engine; nano-coating.

1. Introduction

A catalytic converter (CC) is an automotive pollution control unit that facilitates a redox process to transform hazardous emissions and particles in exhaust system of a combustion engine to less harmful gases [1, 2]. Catalytic converters have been typically employed with gasoline and diesel engines, which includes slender burning engines, paraffin warmers and burners [3,4].

Currently, automobile catalytic converters are utilized to scale back the pollutants produced by automobiles. Catalytic converters have been adopted as a result of the majority of nations adopting legislation limiting engine emissions such as carbon monoxide (CO), hydrocarbons (HC), and nitrogen oxides (NO_x). These pollutants are extremely damaging to human health and the environment since they are produced during the burning fuels of gasoline engines [5, 6]. CO and HC emissions, when combined with hemoglobin in the circulation, contribute to the decrease of active oxygen that causes



suffocation. Oxides of nitrogen (NO_x) are a component of ocean acidification and air pollutants, as well as being irritant to the face and eyes [7, 8].

The 3 way catalytic converting devices are a cutting-edge technology for treating the exhaust of gasoline-powered automobiles that dramatically reduces CO , CO_2 , HC , and NO_x emissions into the environment [9, 10]. In terms of catalytic material, the 2 most often accessible substances on the market are metal based and ceramic based substrates [11, 12]. At the moment, the monolithic substance is the most often used configuration for the majority of uses requiring high circulation and minimized pressure losses. Despite the reason that extended ceramic monolithic substances are the most often utilized base medium, owing to their relatively inexpensive production costs [13, 14]. Metal foil monolithic platforms are gaining popularity. Both of these surfaces have a poor permeability, which renders them unsuitable for use as a catalytic reaction. To circumvent this, the walls of the channel are coated with a thin coating of a porous substance. This is known as the washing overcoat layer. A popular washing overcoat material is aluminium oxide, which has a higher total surface per gram of coating [15, 16]. Catalysts for vehicle applications are often accessible as monolithic ceramics such as cobalt ferrite and zeolites or as metallic substrates. The supplemental catalytic materials utilized are mg based substances with a hexagonal shaped structure that offers a significant topological contact area and is covered with aluminium oxide based wash overcoat. This washing coat is aimed at increasing the active surface and serves as an endorsement for valuable metals, primarily palladium (Pd), platinum (Pt), and rhodium (Rh), which aid in the catalyzed redox reactions of engine exhaust emissions from internal combustion engines to far more benign gases such as moisture, CO_2 , and oxides of nitrogen. Titanium based and ruthenium oxides are utilized in the covering because they have the potential to store air, which increases catalytic performance [17, 18]. Aluminium is a common active addition to substances and a component of air supported engine fuels [19, 20].

Dey and Dhal [21] presented a technique for reducing CO concentrations in automotive emissions by utilising a CuO based catalyst-coated catalytic converter. The findings were shown that by employing appropriate catalysts on the exterior of a converter, the quantity of air contaminants from vehicles may be reduced. In another paper, the authors discussed the progress made in the production, analysis, and use of nanomaterials in several fields. They stated that nanomaterials have emerged as a latest solution, which is capable of effectively addressing a variety of contemporary issues, one of which is carbon emissions and its regulation. Nanocrystals outperform other large substances in terms of effective area, which is critical for lowering car exhaust pollution levels [22].

A few researches have shown that the vehicle emission levels from a metal-sprayed gasoline engine operating on fuel blends. They established via extensive experiments that copper (Cu) may be quite beneficial in reducing dangerous vehicle emissions amounts. Because Cu is inexpensive and readily accessible, it is a suitable material for regulating the levels of tailpipe pollutants released by vehicles using IC engines [23, 24]. The biodiesel based fuel was used to perform an investigation to test automotive exhaust pollution. This was obvious from the test findings that if any means of decreasing vehicle emissions levels is utilized, it will produce in a healthier, greener environment [25]. In this study, a typical catalytic converter was coated with ZnO nanoparticles and its efficacy in regulating the emission characteristics of a gasoline engine was evaluated.

2. Materials and Methods

2.1. Fabrication of nano-Zno coated catalytic converter

Catalytic converter design encompasses the process and components necessary for the catalytic converter's assembly. In practice, the converter's design is a critical function. The converter device is the most effective method of reducing emissions from gasoline engines in order to comply with pollution requirements. A catalyst converter is a component that transforms dangerous emissions to

less harmful ones. The location of the converting device is also critical for design purposes. As a result, the converter is positioned amid the tailpipe and the silencer. This section discusses various criteria to consider while designing a catalytic converter system. The internal pipes are joined carefully with the cross plates and the exterior cylinders were covered and joined with the interior tube arrangement. The schematic of the nano-ZnO coated catalytic converter is presented in Figure 1.

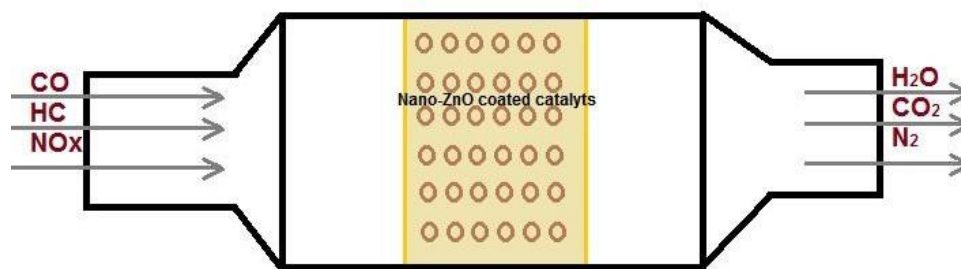


Figure 1. Schematic of nano-coated catalytic converter.

Nano zinc oxide (ZnO) slurry was used for the surface modification of the converter, which was baked to a temperature range employing an acetylene flame torch [26]. A converter's plating could be thought of as a little processing industry, where hazardous chemicals are transformed to less harmful gases [27, 28]. The 10 mg of salt are diluted in 500 ml of treated water. Metal pipes of various thicknesses are submerged in the slurry and processed using an acetylene flame torch.

2.2. Experimental

The relevant investigational data were collected using a single-cylinder, four-stroke, Birla Yamaha petrol engine with a peak power rating of 4000 Watts at 1600 rpm. The exhaust gas analyzer was employed to assess the content of the CO, HC, CO₂ and NO_x of the engine exhaust pipe, which was equipped with the non-dispersive IR sensor for carbon based pollutants, and an electrochemical sensor for the oxygen based pollutants [29, 30]. The accuracy of the analyzer was reported as 0.02% with the response time of 15 seconds. The emission level of the engine test rig for different brake power was observed in two cases namely, without any catalytic converter (without CC) and with nano-coated catalytic converter (with CC). The obtained results are deliberated in the subsequent divisions.

3. Results and Discussion

3.1. Emission level of Carbon monoxide (CO)

Carbon monoxide (CO) emissions are caused by inadequate air inward into the IC engine combustion chamber. CO is a transparent, unscented, and toxic gas that is produced at extremely low temperatures. Figure 2 illustrates the fluctuation in CO level in the exhaust with varied loads for two cases namely, without CC and with CC. CO emission increments radically as load increases. This is because of reduced air suction at the higher speeds of petrol engine. However, the data achieved are less for the engine equipped with the nano-ZnO coated CC comparing to those found for the engine without any CC. At all load circumstances, the engine with nano coated CC exhibits a considerable reduction in emissions, which is comparatively less than other kind of catalytic converters reported in the existing

literature. The nano-coated catalytic converter reduced CO emissions by 41.3% at the full load condition.

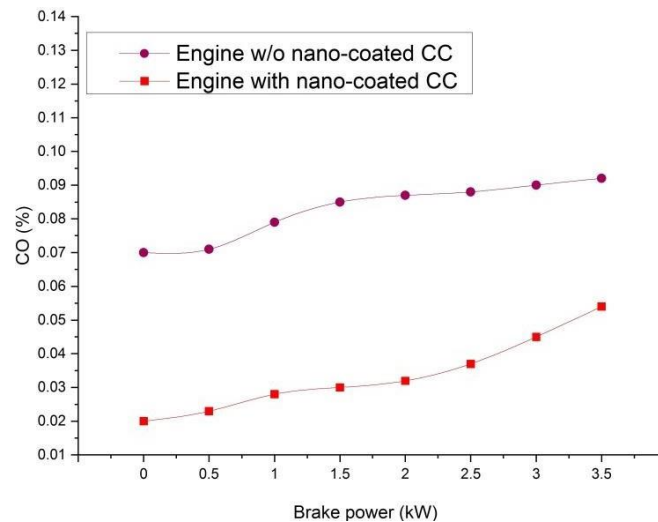


Figure 2. CO emission with respect to brake power

3.2. Emission level of Hydro Carbon (HC)

Increased hydrocarbon emissions exacerbate existing ecological problems. HC is one of the most pernicious greenhouse gas emissions. Increased HC emissions can end-up in ozone depletion that causes climate change. The data obtained from a petrol engine equipped with a nano-ZnO-coated CC under identical load settings were much lower than those obtained from an engine without a converter. In Figure 3, the values are plotted and presented. Even under high load circumstances, the nano-coated CC considerably reduced HC emissions. At the full load condition, the nano-coated catalytic converter reduced HC emissions by 79.4%.

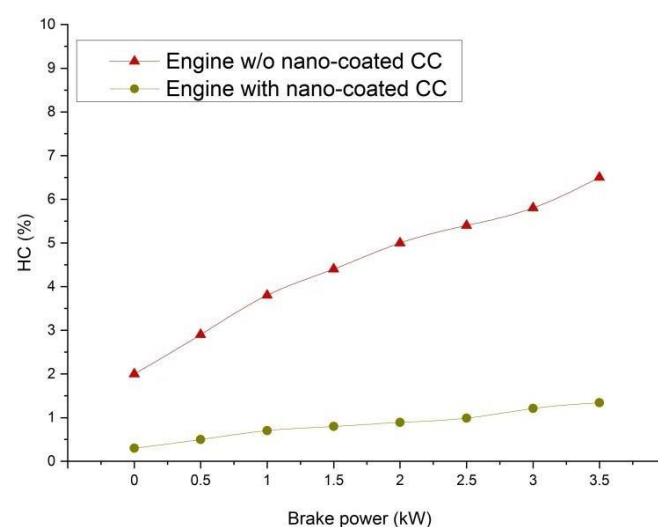


Figure 3. HC emission with respect to brake power.

3.3. Emission level of Carbon dioxide (CO_2)

The release of carbon emissions contributes to global warming. Carbon dioxide (CO_2) accounts for 70% of global greenhouse gas emissions, whereas methane accounts for 20% and nitrogen oxides accounts for 9%. Carbon emissions are thus the primary contributor to climate change. CO_2 is produced inexorably when fossil fuels such as gasoline, diesel, and petroleum gases are burnt. CO_2 emissions have grown considerably over the previous five decades and continue to grow at a rate of over 5% every year. As seen in Figure 4, the data collected are lesser for the engine with the nano-coated CC comparing to the engine without CC. At no load, a considerable reduction in emitting levels is noted for the engine with the converter, where the emission level is higher for the engine without CC. The emission of CO_2 incremented with the brake power, however, the emission level is noted to less with the catalytic converter with nano-ZnO coating. During the full load, the nano-coated catalytic converter reduced HC emissions by 48.2%.

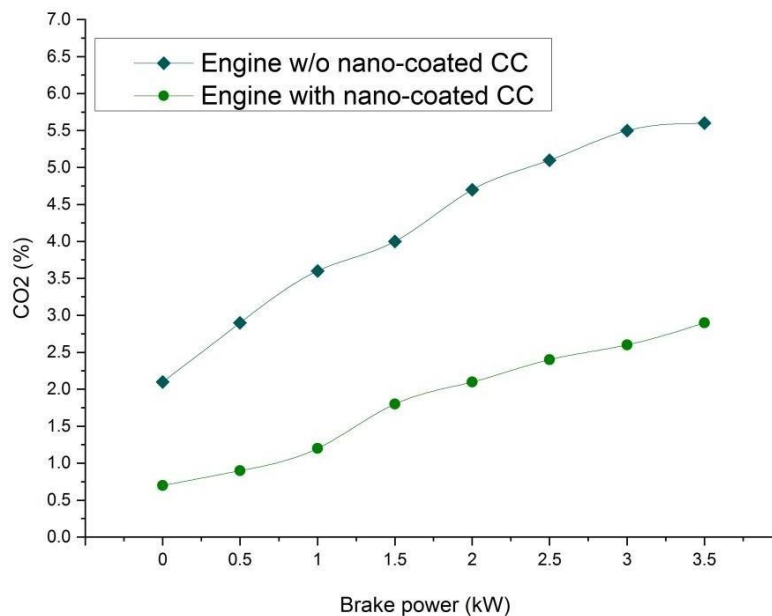


Figure 4. CO_2 emission with respect to brake power.

3.4. Emission level of Nitrogen oxides (NO_x)

Nitrogen oxides have an additional performance-enhancing impact. When nitrogen oxides vaporize, it has a strong chilling impact on the incoming air. When the air inlet temperature dropped, the volume of the air decreased, providing far more air within the chamber. By boiling potassium chloride, you may liberate the oxygen contained therein. It has been established that nitrogen oxides (NO_x) operates in the manner described. When nitrogen oxides are heated to around 290°C , it breaks into N_2 and O_2 . Thus, injecting nitrogen oxides into a cylinder resulted in increased oxygen availability throughout burning. NO_x emissions are seen in Figure 5 at various braking powers. At full load, engine with catalytic converter emits the fewest pollutants, which is significantly lower than the results derived from the emission of an engine without catalytic converter. During the full load, the nano-coated catalytic converter reduced HC emissions by 46.7%.

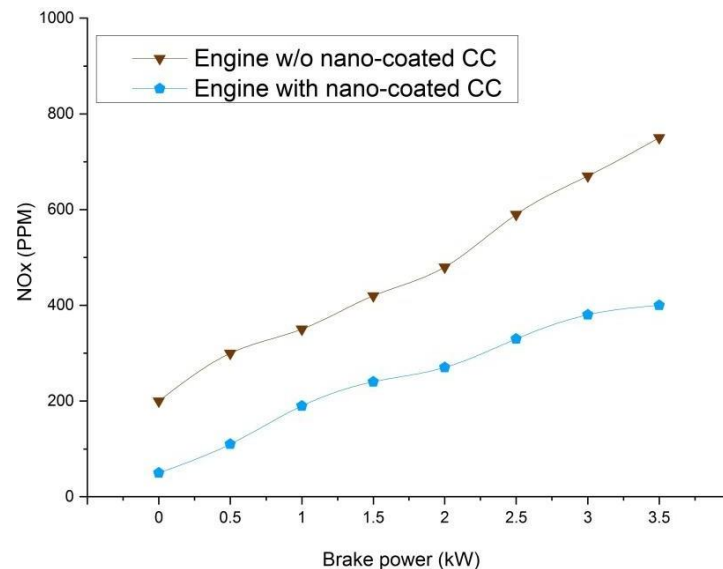


Figure 5. NO_x emission with respect to brake power.

4. Conclusion

The four stroke petrol engine was analyzed for its emission after integrating it with a new kind of nano-ZnO coated catalytic converter (CC). The results revealed that the incorporation of nano-ZnO coated CC significantly reduced the emission level of CO, CO₂, HC and NO_x from the engine exhaust. Quantitatively, the nano-ZnO coated CC reduced the CO, CO₂, HC and NO_x emissions by 41.3%, 71.4%, 48.2%, and 46.7%, respectively.

References

- [1] Ramalingam, S., Rajendran, S. and Ganesan, P. 2018. Performance improvement and exhaust emissions reduction in biodiesel operated diesel engine through the use of operating parameters and catalytic converter: a review. *Renewable and Sustainable Energy Reviews* 81:3215-3222.
- [2] Mohankumar, D., Pazhaniappan, Y., Kumar, R.N., Ragul, R., Kumar, P.M. and Babu, P.N. 2021. Computational study of heat-transfer in extended surfaces with various geometries. In *IOP Conference Series: Materials Science and Engineering* 1059 (1):012055. IOP Publishing. doi.org/10.1088/1757-899X/1059/1/012055
- [3] Zuo, Q., Xie, Y., Jiaqiang, E., Zhu, X., Zhang, B., Tang, Y., Zhu, G., Wang, Z. and Zhang, J. 2020. Effect of different exhaust parameters on NO conversion efficiency enhancement of a dual-carrier catalytic converter in the gasoline engine. *Energy* 191:116521.
- [4] Kumar, P.M., Chauhan, P., Sharma, A.K., Rinawa, M.L., Rahul, A.J., Srinivas, M. and Tamilarasan, A. 2022. Performance study on solar still using nano disbanded phase change material (NDPCM). *Materials Today: Proceedings*. doi.org/10.1016/j.matpr.2022.01.050
- [5] Kuppusamy, M., & Ramanathan Thirumalai, K Udayakumar, M Seenivasan. 2021. Experimental Analysis of the combustion chamber coated with Mo and Al₂O₃ – TiO₂ in a Diesel Engine. *Materials and Technology*, 55(4):509-515.
- [6] Balaji, M., Dinesh, S.N., Kumar, P.M. and Ram, K.H. 2021. Balanced Scorecard approach in deducing supply chain performance. *Materials Today: Proceedings*. doi: 10.1016/j.matpr.2021.05.541
- [7] Balaji, M., Dinesh, S.N., Raja, S., Subbiah, R. and Kumar, P.M. 2021. Lead time reduction and process enhancement for a low volume product. *Materials Today: Proceedings*. doi.org/10.1016/j.matpr.2021.12.240

- [8] Thirumalai, R., Senthilkumaar, J. S. 2013 Multi Criteria Decision Making in the selection of machining parameters for Inconel 718. *Journal of Mechanical Science and Technology* 27 (4):1109-1116.
- [9] Kumar, P.M. and Mylsamy, K. 2020. A comprehensive study on thermal storage characteristics of nano-CeO₂ embedded phase change material and its influence on the performance of evacuated tube solar water heater. *Renewable Energy* 162:662-676. doi.org/10.1016/j.renene.2020.08.122
- [10] Zuo, Q., Xie, Y., Guan, Q., Zhu, G., Jiaqiang, E., Zhu, X., Tang, Y., Wang, Z. and Chen, W. 2020. Effect of critical dual-carrier structure parameters on performance enhancement of a dual-carrier catalytic converter and the gasoline engine system. *Energy Conversion and Management* 204:112325.
- [11] King, M.F.L., Rao, P.N., Sivakumar, A., Mamidi, V.K., Richard, S., Vijayakumar, M., Arunprasath, K. and Kumar, P.M. 2021. Thermal performance of a double-glazed window integrated with a phase change material (PCM). *Materials Today: Proceedings*. doi.org/10.1016/j.matpr.2021.09.099
- [12] Yang, H., Shu, G., Tian, H., Ma, X., Chen, T. and Liu, P. 2018. Optimization of thermoelectric generator (TEG) integrated with three-way catalytic converter (TWC) for harvesting engine's exhaust waste heat. *Applied Thermal Engineering* 144:628-638.
- [13] Kaushik, N., Saravanakumar, P., Dhanasekhar, S., Saminathan, R., Rinawa, M.L., Subbiah, R., Sharma, R. and Kumar, P.M. 2021. Thermal analysis of a double-glazing window using a Nano-Disbanded Phase Changing Material (NDPCM). *Materials Today: Proceedings*. doi.org/10.1016/j.matpr.2021.11.537
- [14] Balaji, M., Dinesh, S.N., Vetrivel, S.V., Kumar, P.M. and Subbiah, R. 2021. Augmenting agility in production flow through ANP. *Materials Today: Proceedings*. doi.org/10.1016/j.matpr.2021.06.053
- [15] Nandhakumar, S., Thirumalai, R., Viswaaswaran, J., Senthil, T.A., Vishnuvardhan, V.T. 2021. Investigation of production costs in manufacturing environment using innovative tools. *Materials Today: Proceedings*, 37:1235-1238.
- [16] Mohan Kumar, A., Rajasekar, R., Manoj Kumar, P., Parameshwaran, R., Karthick, A. and Muhibbullah, M. 2021. Comparative analysis of drilling behaviour of synthetic and natural fiber-based composites. *Advances in Materials Science and Engineering* 2021. doi.org/10.1155/2021/9019334
- [17] Shaikh, S.K., Pathan, K.A., Chaudhary, Z.I., Marlpalle, B.G. and Khan, S.A. 2020. An Investigation of Three-Way Catalytic Converter for Various Inlet Cone Angles Using CFD. *CFD Letters* 12(9):76-90.
- [18] Ramya, D., Krishnakumari, A., Dineshkumar, P.T., Srivastava, M.P., Kannan, L.V., Puthilibai, G. and Kumar, P.M. 2021. Investigating the influence of nanoparticle disbanded phase changing material (NDPCM) on the working of solar PV. *Materials Today: Proceedings*. doi.org/10.1016/j.matpr.2021.11.419
- [19] Zhu, Z., Canova, M. and Midlam-Mohler, S. 2018. A physics-based three-way catalytic converter model for real-time prediction of temperature distribution. *IFAC-PapersOnLine* 51(31):166-171.
- [20] Dinesh, S.N., Ravi, S., Kumar, P.M., Subbiah, R., Karthick, A., Saravanakumar, P.T. and Pranav, R.A. 2021. Study on an ETC solar water heater using flat and wavy diffuse reflectors. *Materials Today: Proceedings*. doi.org/10.1016/j.matpr.2021.05.561
- [21] Dey, S. and Dhal, G.C. 2020. Controlling carbon monoxide emissions from automobile vehicle exhaust using copper oxide catalysts in a catalytic converter. *Materials Today Chemistry* 17:100282.
- [22] Rinawa, M.L., Pitchandi, P., Vigneshkumar, N., Sharma, R., Singh, M.K., Subbiah, R. and Kumar, P.M. 2021. Experimental analysis of the metal roofed industrial building using nano-silica disbanded crude wax (NDCW). *Materials Today: Proceedings*.

- doi.org/10.1016/j.matpr.2021.12.253
- [23] Puthilibai, G., Singaravelu, D.K., Dinesh, C., Chitradevi, S. and Sudhakar, M. 2021. Experimental investigation regarding emissivity of black nickel coated on aluminium surface. *Materials Today: Proceedings* 37:248-251.
- [24] Kumar, P.M., Mukesh, G., Naresh, S., Nitthilan, D.M. and Kumar, R.K. 2021. Study on performance enhancement of SPV panel incorporating a nanocomposite PCM as thermal regulator. In *Materials, Design, and Manufacturing for Sustainable Environment* 587-597. doi.org/10.1007/978-981-15-9809-8_44
- [25] Kuppusamy, M. and Ramanathan, T. 2021. Experimental analysis of the thermal-barrier coating for an Al₂O₃-TiO₂ ceramic coated CI engine operating on calophyllum inophyllum oil. *Materials and Technology* 55(1):121-126.
- [26] Saravanakumar, P.T., Arunkumar, S.P., Mansingh, B.B., Kumar, P.M., Subbiah, R. and Eswarlal, V.K. 2021. Investigating the effect of thermal cycling on thermal characteristics of the nano-silica based phase changing material (PCM). *Materials Today: Proceedings*. doi.org/10.1016/j.matpr.2021.09.095
- [27] Gunasekaran, N., Kumar, P.M., Raja, S., Sharavanan, S., Avinas, K., Kannan, P.A. and Gokul, S. 2021. Investigation on ETC solar water heater using twisted tape inserts. *Materials Today: Proceedings*. doi.org/10.1016/j.matpr.2021.04.586
- [28] Kumar, P.M., Arunthathi, S., Prasanth, S.J., Aswin, T., Antony, A.A., Daniel, D., Mohankumar, D. and Babu, P.N., 2021. Investigation on a desiccant based solar water recuperator for generating water from atmospheric air. *Materials Today: Proceedings* 45:7881-7884. doi.org/10.1016/j.matpr.2020.12.506
- [29] Jayaprakash, S., Siva Chandran, S., Sathish, T., Gugulothu, B., Ramesh, R., Sudhakar, M. and Subbiah, R. 2021. Effect of tool profile influence in dissimilar friction stir welding of aluminium alloys (AA5083 and AA7068). *Advances in Materials Science and Engineering*, 2021.
- [30] Prakash, K.B., Amarkarthik, A., Ravikumar, M., Kumar, P.M. and Jegadheeswaran, S. 2021. Optimizing performance characteristics of blower for combustion process using taguchi based grey relational analysis. In *Advances in Materials Research* 155-163. doi.org/10.1007/978-981-15-8319-3_17