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## Faculty Achievement

| | | | | | | |
|---|---|---|---|---|---|---|
| | | **Name of Department** | **Mechanical Engineering** | | **Year 2020-21** | |
| **Sr. No.** | **year** | **Name of the Faculty** | **Event Name** | **Title** | **Journal/college/university Name** | **Date** |
| 1 | 2020-21 | Mr. Vinayak Hindurao Deokar | Research article | Active cooling system for efficiency improvement of PV panel and utilization of waste-recovered heat for hygienic drying of onion flakes | Journal of Materials science- Materials in Electronics. Springer Nature. | January 2021 |
| 2 | | | Research article | Simulation modeling and experimental validation of solar photovoltaic PMBLDC motor water pumping system | Journal of Thermal Engineering | July 2021 |
| 3 | 2020-21 | Dr. Koli Gajanan Chandrashekhar | Ph.D. | Ph.D. completed | Visvesvaraya Technological University, Belagavi | 4/3/2021 |
| 4 | | | Faculty Develoment Program | Industrial Automation using CNC and Intelligent Systems | ATAL academy, Manipal Institute of Technology, Manipal | 16/8/2021 to 20/8/2021 |
| 5 | | | Faculty Develoment Program | Emerging Materials, Sensors and Devices for IoT and Industry 4.0 | ATAL academy, Raman Global University | 23/8/2021 to 27/8/2021 |
| 6 | 2020-21 | Mr Ajit Ashok Katkar | Paper setter | ENERGY AND POWER ENGINEERING.Sub. Code: 68509 | Shivaji University ,Kolhapur | Oct 2020 |
| 7 | | | Journal paper Publication | Microstructure, hardness and machinability analysis of gravity cast AA6061/SiC composites | Manufacturing Technology Today | Nov. 2020 |
| 8 | | | Paper setter | Heat Transfer(BTAMC601) | DBATU | 25/06/2021 |
| 9 | | | Journal paper Publication | Design and Study of a Three-Wheeled Transport Vehicle's Front Helical Coil Suspension Spring | International Research Journal of Engineering and Technology (IRJET) | June 2021 |
| 10 | | | Journal paper Publication | Design and Development exp. set up for Plasma coating for textile roller drum | International Journal of Science Technology & Engineering | Sept. 2021 |
| 11 | | | FDP/STTP | Mechatronics, Automation & Robotics | OP Jindal University, Raigarh, Rajasthan | 03/08/2020 to 07/08/2020 |

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| 12 | | | FDP/STTP | Advances In Manufacturing & Materials | D.Y. Patil College of Engineering , Kolhapur | 20/04/2021 to 24/04/2021 |
| 13 | | | Paper setter | Anlysis and Synthesis of Mechanisms (MDE12) MTECH | DBATU | 2/6/2021 |
| 14 | 2020-21 | Mr. Vinod Vasantrao Vanmore | CE&QIP Short term course | Inter-disciplinary Aspects in modeling of manufacturing processes | IIT Bombay and BATU Lonere | 21/11/2020to 25/11/2020 |
| 15 | | | TEQIP-III sponsored Two Week Faculty Development Programme | Digital Design and Emerging Trends in Signal Processing | Government Engineering College Bikaner Rajasthan | 10/08/2020 to 22/08/2020 |
| 16 | | | e-Conference organized | 3rd International e-Conference on Frontiers in Mechanical Engineering andnanotechnology [ICFMET] | Advances in Engineering and Nanotechnology ISSN (Online) 1741-8151, ISSN (Print) 1475-7435 | 27–28 November 2020 |
| 17 | | | Ph.D. | Ph.D. Thesis Submitted | Shivaji University Kolhapur (Research Center Walchand College of Engineering ) | 31/12/2020 |
| 18 | | | QIP Short term course | MultiscaleModeling and Simulation Techniques for 3D Printing | IIT Kanpur | 08/03/2021 to 13/03/2021 |
| 19 | | | QIP Short term course | MechanicalBehaviour of Materials | IIT Kanpur | 15/03/2021 to 20/03/2021 |
| 20 | | | ATAL Faculty Develoment Program | Micro-electromechanical Systems | Sardar Patel College of engineering Mumbai. | 23/11/2020 to 27/11/2020 |
| 21 | | | Faculty Development Programme | Nearly Zero Energy Building(nZEB) | SIT COE Yadrav MH | 10/08/2020 to 14/08/2020 |
| 22 | | | Faculty Development Programme | Industry 4.0 & condition monitoring | VJTI Mumbai and Eng. college Ajmer | 15/03/2021 to 19/03/2021 |
| 23 | | | Faculty Development Programme | Advances in Manufacturing and Materials | DYP COE&T Kolhapur | 20/04/2021 to 24/04/2021 |
| 24 | | | ATAL Faculty Develoment Program | Emerging Technologies in Product Design & Development | Government College Of Engineering Chandrapur, MH | 14/06/2021 to 18/06/2021 |
| 25 | | | ATAL Faculty Develoment Program | 3D Printing & Design for Innovative Medical Devices | Malaviya National Institute of Technology Jaipur. | 28/06/2021 to 02/07/2021 |
| 26 | | | National Level Workshop | Digital Transformation & Pedagogies | Government College of Engineering, Karad & Walchand College of Engineering, Sangli | 10/08/2020 to 14/08/2020 |
| 27 | | | Journal paper Publication | Enhancement of heat and mass transfer characteristics of metal hydride reactor for hydrogen storage using various nanofluids | International Journal of Hydrogen Energy | April 2021 |

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| 28 | 2020-21 | Mr. Rahul Uday Urunkar | Workshop | Disruptive Entrepreneurship-2021 | Karmaveer Adv. Baburao Ganpatrao Thakare College of Engineering, Nashik | 27/05/2021 30/05/2021 |
| 29 | | | Reviwer for SCOPUS Journal | Tech Science Press | Energy Engineering | June 2021 |
| 30 | | | Faculty Develoment Program | Augmented Reality & Virtual Reality | All India Shri Shivaji Memorial Society, College of Engineering, Pune | 21/06/2021 to 25/06/2021 |
| 31 | | | Short Term Training Program | Innovative & Inventive Problem Solving | All India Shri Shivaji Memorial Society, College of Engineering, Pune | 29/06/2021 to 04/07/2021 |
| 32 | 2020-21 | Mr. Deshmukh Sardar Balaso | Faculty Develoment Program | Research in Energy Technologies | Bharati Vidyapith College of Engineering, Pune | 06/07/2020 to 11/07/2020 |
| 33 | | | Faculty Develoment Program | Recent trends in heat exchangers (RTHX 2020) | Walchand College of Engineering, Sangli | 13/07/2020 to 18/07/2020 |
| 34 | | | Faculty Develoment Program | Electro-Mechanical Systems | Walchand College of Engineering, Sangli | 20/07/2020 to 25/07/2020 |
| 35 | | | Workshop | Digital Transformation & Pedagogies | Government College of Engineering, Karad & Walchand College of Engineering, Sangli. | 10/08/2020 to 14/08/2020 |
| 36 | | | Faculty Develoment Program | Blended Learning and Flipped Classroom | National Institute of Technical Teachers Training & Research, Chandigarh | 31/08/2020 to 04/09/2020 |
| 37 | | | Short Term Training Program | Teaching Learning Pedagogies | A. G. Patil Polytechnic, Solapur | 07/09/2020 to 12/09/2020 |
| 38 | | | Faculty Develoment Program | Alternate Fuels | Don Bosco Institute of Technology | 21/09/2020 to 25/09/2020 |
| 39 | | | Faculty Develoment Program | Emotional Intelligence | Motilal Nehru Institute of Technology Allahabad | 18/01/2021 to 22/01/2021 |
| 40 | | | Faculty Develoment Program | Research at A Glance | Sinhgad Institutes, Pune | 18/01/2021 to 23/01/2021 |
| 41 | | | Faculty Develoment Program | Outcome Based Education (OBE) and Accreditation Process | Government Residence Women Polytechnic Tasgaon | 14/06/2021 to 18/06/2021 |
| 42 | | | Faculty Develoment Program | Applications of Artificial Intelligence in Mechanical Engineering | K. Ramakrishnan College of Engineering | 02/08/2021 to 06/08/2021 |
| 43 | | | Webinar | Numerical Investigation of flow and heat transfer using nanofluids | Francis Xavier Engineering College | 7/4/2020 |

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| 44 | 2020-21 | Mr. Dhananjay Vasantrao Patil | Faculty Develoment Program | Role of national education policy for national development | Karmayogi Engineering College, Shelve Pandharpur | 30/03/2021 |
| 45 | | | Faculty Develoment Program | Advances in manufacturing & materials | D.Y.Patil college of engineering and technology, kolhapur. | 20/04/2021 to 24/04/2021 |
| 46 | 2020-21 | Mr. Praveen Shivaji Atigre | Faculty Development Program | Research at A Glance: Current Protocols | SIT, Lonavala | 18/01/2021 to 23/01/2021 |

*J Mater Sci: Mater Electron*

# Active cooling system for efficiency improvement of PV panel and utilization of waste-recovered heat for hygienic drying of onion flakes

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## ABSTRACT

In the modern age, photovoltaic panel (PV) is a popular option for solar energy conversion. The PV panel's efficiency considerably depends on the parameters like dust or dirt on the surface and the cell operating temperature. As the cells operating temperature exceeds more than 25 °C, the PV panel's efficiency decreases by 0.4% for every degree centigrade rise in temperature. The higher cell operating temperature causes hot spots on the PV panel, drastically reducing the PV panel's life. There are different methods used for cooling of PV panel, but the utilization of waste heat recovered for further application is not reported. In this context, this research work proposes an active cooling system using thermal grease and M.S chips for effective cooling of the PV panel, and simultaneously heat rejected during cooling of the panel is being used for solar thermal drying. The proposed active cooling system using thermal grease and M.S chips showed promising results at 5.2 m/s air velocity. The average voltage and average electrical efficiency of the cooled PV panel was improved by ~ 4.0% and 12.3%, respectively, than the non-cooled PV panel. The cooled PV panel's cell operating temperature was reduced by 16.1 °C compared to non-cooled PV panel, and 1400 g onion flakes were dried hygienically in time 10 h 30 min.

## Nomenclature

| | |
|---|---|
| PV | Photovoltaic |
| STC | Standard testing condition |
| TWh | Terawatt-hour |
| $m_a$ | Mass flow rate of air (kg/s) |
| $v$ | Velocity of air (m/s) |
| $\sigma$ | Density of air (kg/m$^3$) |
| $w$ | Width of duct (m) |
| $h$ | Height of duct (m) |
| $m$ | Parametric constant (m$^{-1}$) |

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| | |
|---|---|
| $A_c$ | Area of panel ($m^2$) |
| $A_{chip}$ | Areas of chips ($m^2$) |
| $P$ | Fin perimeter (m) |
| $T_{amb}$ | Ambient air temperature (°C) |
| $T_{in}$ | Cabinet inlet air temperature (°C) |
| $T_{ex}$ | Exit air temperature (°C) |
| $T_{pb}$ | PV panel backside temperature (°C) |
| $T_{rpb}$ | Reference PV panel temperature (°C) |
| $C_p$ | Specific heat capacity of air (kJ/kg) |
| $D_h$ | Hydraulic mean diameter (m) |
| $h_c$ | Heat transfer coefficient (W/$m^2$ °C) |
| $k$ | Thermal conductivity (W/m K) |
| $\mu$ | Dynamic viscosity $1.895 \times 10^{-5}$ kg/m s |
| $A_{cs}$ | Cross section area of duct (m) |

## 1 Introduction

Solar power is abundantly available on the earth's surface free of cost, which naturally replenishes on a human timescale. Most people worldwide live in areas with irradiation levels of 500 W/$m^2$ to 750 W/$m^2$ per day. It is essential to conserve solar energy and to convert it into useful forms. The world's primary energy need is 157,063.7 TW h. The solar energy striking on the earth's surface is 173,000 TW, 10,000 times greater than the world's total primary energy need. The PV panel is the only promising option available for converting sunshine directly into electricity. It is also preferred to operate the PV panel at Standard Testing Condition (STC) for getting the maximum efficiency, where cell operating temperature and irradiation are 25 °C and 1000 W/$m^2$, respectively. In countries like India, it is challenging to maintain the cell operating temperature around 25 °C [1].

Onion is 3rd ranked vegetable most commonly used worldwide. It is used in fresh and dried forms for foods and medicine use. Due to high moisture content, it is a semi-perishable commodity. That is why the storage of fresh onion on the shelf for a more extended period is not possible as it gets deteriorated. India is the second largest onion producing country, followed by China in the world. India's total onion production is 23.28 million tons, and Indian onions are famous for their flavour [2]. Seasonally, there are considerable fluctuations in onion rates; whenever the onion production is high, onion rates fall. Whenever there is a shortage in its supply, maybe due to weather conditions or lower yield, its price touches the sky. Sometimes onion prices, indeed, bring a tear to human eyes. Rather than storing fresh onions, the better option is to use dried onion flakes or powder. Dried onion in any form can be directly used as flavour additives in foods or herb mixes. It is possible to reduce the moisture content from fresh onion and dry it without losing its nutrients, colour, aroma, and taste.

Many researchers worked rigorously in the active or passive cooling of the PV panel. Ahmad et al. investigated experimentally natural cooling of the PV panel attached with the aluminium finned plate. The 30 W PV panel was used for experimentation. It was found that the efficiency and output power of the PV panel was increased by 1.75% and 1.86 W, respectively [3]. Fillip Grubisic Cabo et al. evaluated the cooled PV panel's performance by passive air cooling with aluminium fins on the 50 W polycrystalline PV panel's backside. They tested different aluminium fins geometry and found that perforated and randomly positioned fins showed better temperature decrement results [4]. Aly M A. Soliman et al. experimentally investigated the impact of heat sink cooling system on solar cell performance. To simulate the solar irradiation, halogen lamp was used. They studied both active and passive cooling. They reported a 5.4% and 11% temperature reduction in passive and active cooling, whereas efficiency and power output were increased by 16% [5]. Catalin George Popovici et al. studied numerical analysis of PV panel air cooling using a heat sink. The angle between the ribs and the base plate was modified. The numerical model was done in ANSYS- fluent, and results were presented for turbulent flow. They reported that temperature was reduced by 10 °C, and the power output was increased from 6.9 to 7.5% in 45° angled ribs over 90° ribs [6]. Actively air-cooled PV panel gave better results than the non-cooled and passively cooled PV panel [7–10].

Drying of products using solar energy can be achieved by natural sun drying or indirect solar drying. Natural sun drying has inherent limitations such as unhygienic, dust and dirt contaminated products, loss of nutrients, aroma and natural colour. These limitations can be overcome using an indirect solar dryer that produces dried products rich in taste, aroma and nutrition than open sun drying. Many researchers conducted research on onion drying for reducing the drying time, improvement in product quality and efficiency of the system. Different onion drying methods were used, like indirectly forced convection drying, oven drying, microwave drying, infrared drying, vacuum drying, and freeze-drying [11]. Ciftciogly developed a cost-effective and efficient prototype of the solar dryer with selective coating. The authors reported the comparison of the cost of heat for solar energy over natural gas, electricity and LPG. The system with renewable energy technology showed 2, 4 and 5 times cost reduction over the system with natural gas, electricity and LPG [12]. Musembi et al. designed and fabricated an indirect natural convection solar dryer. Experimentation was carried out on 886 g sliced Apples of 2.5 mm thickness. Initial and final moisture content was 86% and 8.12%, respectively. The total time taken for drying was 9 h 20 min, with average irradiation of 534 $W/m^2$ [13]. Slimani et al. worked on a numerical model of an indirect solar dryer system. The result of the proposed model was found close to the experimental model. Indirect solar dryers can provide the required air temperature for the drying of various agricultural products. They achieved 10.5%, 70% and 90% electrical, thermal and overall energy efficiency at 0.015 kg/s mass flow rate [14]. S. Nabnean et al. worked on a universal indirect solar dryer performance with a heat exchanger and storage unit. The cabinet size used was 1 × 3 × 1.4 m, where 100 kg cherry tomatoes was dried in 4 days. The efficiency of the solar dryer observed was 21–69%, with 1.37 years of the payback period. The drying temperature was varied from 30 to 65 °C. The dried products were good in quality [15]. Anil Kumar et al. studied the effect of the convective mass transfer coefficient on onion flakes drying. For experimentation, 300 g, 600 g, and 900 g onion sets were used. The authors carried out open sun & roof type onion drying methods for 33 h and compared their performances. The results showed that the rate of moisture evaporation was more in greenhouse drying because of the energy stored in it than that of open sun drying [16]. So Choi investigated sensory characteristics and volatile composition in onion powder. The powder was prepared by convection heat transfer at temperatures 50 °C, 70 °C and 90 °C. At low-temperature drying aroma of fresh onion was retrained [17].

It was noted from the literature that active and passive cooling are two methods used for cooling of PV panel. In passive cooling, air flows over the back surface naturally, while in active cooling, forced air passes over the backside surface of the PV panel using an external source like a fan or blower. Though active water cooling gives better results, its significant limitations are the amount of water required for cooling, which gets evaporated, and the cost associated with water pumping [18–21]. Almost all active air cooling methods used an Aluminium heat sink for better heat dissipation; this adds 4 $Kg/m^2$ weight in the system, thus causing bending of the large size photovoltaic panel [22–25].

The increased cell operating temperature than STC hampers on PV panel efficiency resulting in lower power output. The monocrystalline cell's efficiency is about 16–20%, which means about 80% of falling solar energy is not converted into electricity. Most of the falling solar energy gets converted into the thermal form, which goes into the waste. This energy can be utilized for drying onion flakes, which will increase its shelf life [26–32]; this is the motivation behind this research.

In this context, it aimed to cool the PV panel with an efficient cooling system, which will improve the power output of the PV panel and use the waste heat recovered while cooling in hygienically drying onion flakes. It was also aimed that the active cooling will not add much more weight to fulfilling the research objectives. The experimental testing setup was developed to cool the PV panel with the active cooling system using thermal grease and M.S chips. The waste heat extracted during active cooling was directly used to dry the onion flakes hygienically. The PV panel cooling was carried out at different airflow rates, for analysing the airflow rates effect on the PV panel efficiency and onion flakes drying time. The condition for the higher overall electrical and drying system efficiency was searched out critically and reported with detailed analysis.

## 2 Effect of Cell operating temperature on PV panel efficiency

A solar panel is an assembly of various components, as shown in Fig. 1. Initially, an anti-reflective coating is applied to the solar cells, which reduces solar light reflection and helps in the cell efficiency increment. The cells are then sandwiched in the layers of the encapsulant, made up of Ethylene Vinyl Acetate

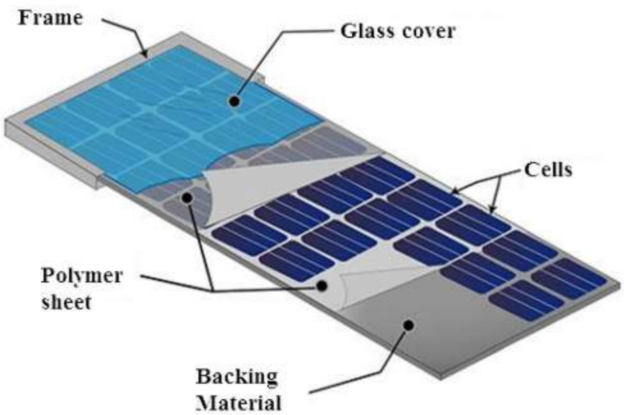


**Fig. 1** Construction of solar PV panel

(EVA), which prevents solar cells from water and dirt and provides adhesion between solar cells. At the top, toughened glass four times stronger than regular glass was fitted, and this protects solar cells against harmful external factors like water, vapour and dirt. At the backside, poly vinyl chloride (PVC) is used, which protects the panel against environmental damage, provides electrical insulation and offers durability to a PV panel.

As sun rays strike the solar cell, the photons excite the electron in cells. The electron utilizes part of the energy, and the rest of the energy is mostly converted into thermal energy. The thermal energy causes increased solar cell temperature, due to which output voltage drops drastically, resulting in reduced power output. Figure 2 shows the effect of cell operating temperature on PV panel output voltage. At 25 °C cell operating temperature, the output voltage is 46 V,

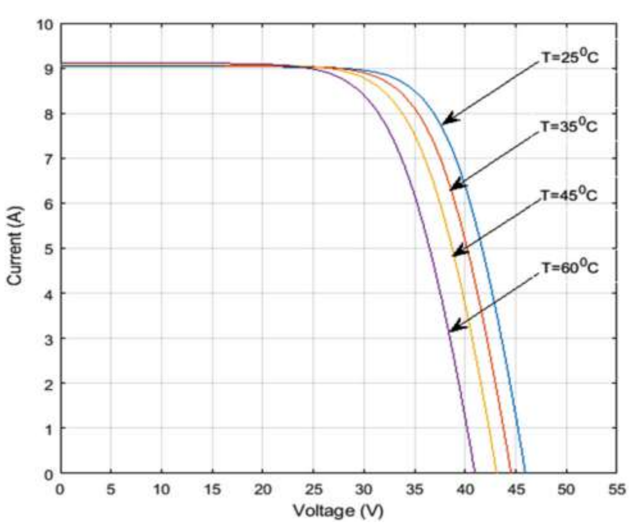


**Fig. 2** Effect of temperature on PV panel's output voltage

which reduces to 41 V at 60 °C. It is noted from the latest literature survey that cell operating temperature is the critical factor in the efficiency reduction of the PV panel. The effect of dust, dirt and accumulation can be minimized by cleaning the PV panel periodically, and the cell operating temperature can be reduced by continuous cooling of the PV panel.

It is necessary to keep the cell operating temperature as minimum as possible to achieve more excellent PV panel efficiency. Table 1 shows the thermal conductivity of various components of the PV panel. The thermal conductivity of the encapsulant and polymer sheet used at the PV panel backside is very low; this is why temperature around the cell increases. Therefore, it is essential to increase heat dissipation from the PV panel's back surface. It is possible only with the help of some unique system that will accelerate the heat transfer.

## 2.1 Active air cooling system using thermal grease and M.S Chips

For accelerating heat transfer from the back panel surface, thermal grease and M.S chips were used. Thermal grease is a thermally conductive but electrically insulating material; it reduces the air pockets between two surfaces and acts as the glue. It is a composition of matrix material like epoxies, silicon or acrylates and filler materials like boron nitride or zinc oxide. The filler material is 70–80% by mass and raises the base material thermal conductivity from 0.2 to 6.0 W/m K. In this research work, silicon and carbon-based thermal grease with thermal conductivity of 5.0 W/m K were used. The backside area of PV panel used for experimentation was 2 $m^2$. As the heat transfer depends on the surface area, the backside area of PV panel was increased with the help of micro M.S steel chips of IS 2830. The thermal

**Table 1** Thermal Conductivity of various components of PV panel

| Component | Thermal conductivity (W/m K) |
|---|---|
| Glass | 1.8 |
| Anti-reflective coating | 32 |
| Photovoltaic cell | 148 |
| Encapsulant | 0.35 |
| Back sheet | 0.2 |

conductivity of M.S chips materials used was 60.0 W/m K, and the average chip size was 3 × 0.2 × 2 mm. A thin layer of 1 mm thermal grease was applied at the backside of the PV panel, and then M.S chips were uniformly smeared on it, as shown in Fig. 3. Then the chips were gently pressed so that they get in contact with the back surface of the PV panel. Thermal grease serves in the firm adhesion of chips with the PV panels back surface and helps in accelerating the heat transfer. The high-velocity air from the blower flows over the thermal grease and M.S chips, which took away the heat with it, and the cell operating temperature of the PV panel gets lowered.

## 2.2 Complete experimental Setup

Figure 4 shows the complete experimental setup. A 320 W solar PV panel is fitted on the duct and steel structure at a latitude angle of 16.7° due south. As the sunshine strikes on the PV panel, it starts converting it into electrical energy. A significant portion of solar rays gets converted into heat, partially reflected in the atmosphere, and partly absorbed by the PV panel. A 30 W blower passes continuously ambient cold air in the duct, which flows over the PV panel's back surface, on which thermal grease and M.S chips are applied. Two exhaust fans of 4W capacities fitted at the outlet of the duct help to accelerate airflow from the duct to the drying cabinet. 80 mm diameter pipes are used to carry the hot air from the duct to the drying cabinet. Hot Air enters into the drying cabinet from the inlet provided at the bottom and flows over the onion flakes, kept in the trays for drying. Hot air takes away the moisture from the product with it, and it is released in the ambiance through the outlet provided to the drying cabinet. A cage is hanged to a load cell in which drying trays are kept with spread onion flakes. The load cell helps in continuous monitoring of the onion flake's weight reduction.

**Fig. 3** Thermal grease and M.S chips applied on the backside of the PV panel

## 2.3 Instrumentation and sensors

For continuous measurement of the observations, a customized data logger system was used. It consisted of the three significant components such as transmitter, receiver and sensors, as shown in Fig. 5. Anemometer was used for airflow measurement, and LM 35 analog sensors were used for the various temperatures measurement. Irradiation was measured with the help of a pyranometer sensor. All the sensors were connected to the data logger system, which continuously monitored and recorded the sensor's data.

# 3 Experimental testing, results and discussion

The experimental setup shown in Fig. 4 was tested continuously on clear sky days from 15th February to 25th May 2020. The observation of irradiation, various temperatures, air velocity, voltage and the current was observed and recorded on trial days by varying the system working conditions.

## 3.1 Performance analysis of PV panel

For analysing the effect of active cooling using thermal grease and M.S chips on the PV panel efficiency, observations of 8th April 2020 and 9th April 2020 are discussed in detail. The testing on 8th April was carried out in the absence of an active cooling system, while on 9th April, testing was done with the active cooling system at air velocity 5.2 m/s.

Figure 6 shows the irradiation-solar time characteristic of 8th April and 9th April. The curve of both days follows a perfect bell shape. The observation was taken from 7.25 am to 17.00 pm. The irradiation


**Fig. 4** Complete experimental setup: (1) 320W solar panel, (2) MPPT controller, (3) DC blower, (4) duct, (5) drying cabinet, (6) data logger and (7) 20 W reference panel

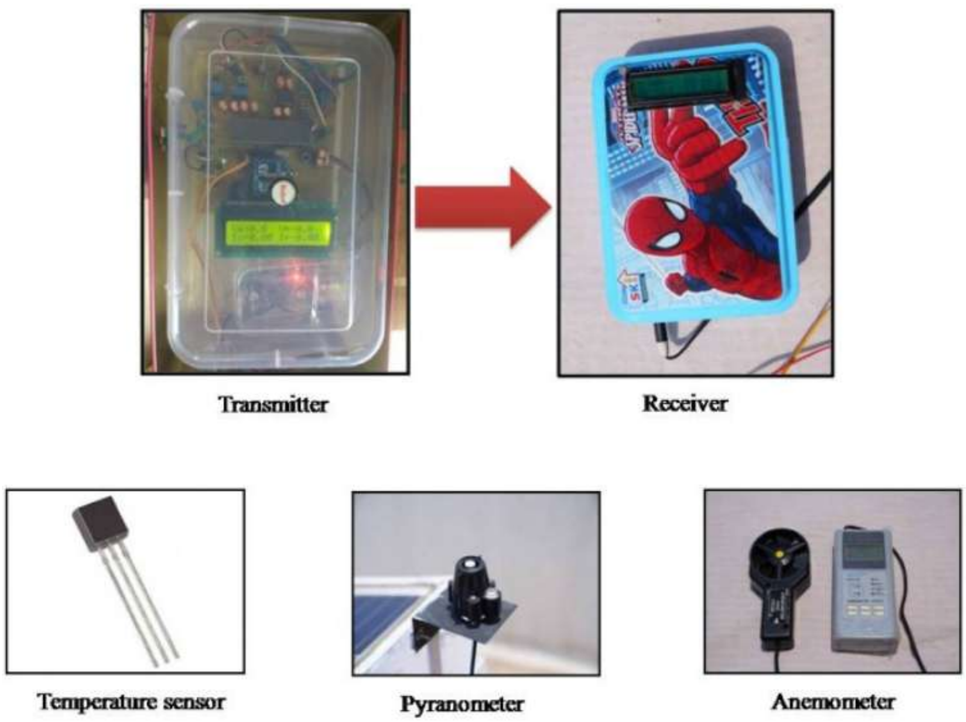


**Fig. 5** Data logger and sensors used for measurement

increased from the morning and continued till the local solar noon at 12.26 pm. The average and maximum irradiation observed on 8th April was 692 W/m$^2$ and 977 W/m$^2$, respectively, while on 9th April, it was 668 W/m$^2$ and 932 W/m$^2$ , respectively. The Maximum irradiation observed was 977 W/m$^2$ and 932 W/m$^2$ on 8th and 9th April, respectively. The total Sun energy fell on the PV panel's 2 m$^2$ surface areas was 13,156 W and 12,330 W on 8th and 9th April.

Figure 7 shows the ambient air-solar time characteristic of the testing days. As irradiation increased, ambient air temperature also increased linearly. The difference between the two curves was observed as the fallen irradiation level on both days was different. On 8th April in the morning, the temperature

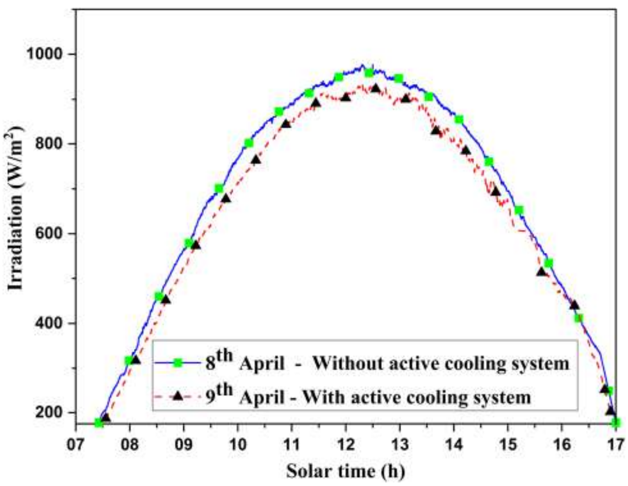


**Fig. 6** Irradiation-solar time characteristics

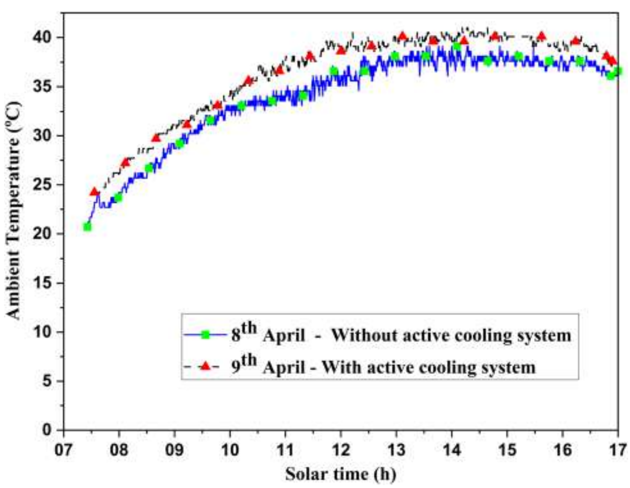


**Fig. 7** $T_{amb}$-solar time characteristics

observed was 20.7 °C, which reached a maximum of 39.1 °C, while the average ambient temperature observed was 34.3 °C. On the 9th April, the maximum and average ambient temperature observed was 41.0 °C and 36.3 °C, respectively.

Figure 8 shows the PV panel back surface temperature-solar time characteristic of 8th and 9th April. On 8th April, the observation was taken without an active cooling system by keeping a PV panel in the natural environment. While on 9th April, the PV panel was tested with an active cooling system using thermal grease and steel chips. Initially, the ambient air and PV panel back surface temperature were the same, but as irradiation increased, it also increased rapidly. The maximum PV panel back surface temperature reached 70.9 °C on 8th April. On 9th April, due to active cooling, the maximum PV

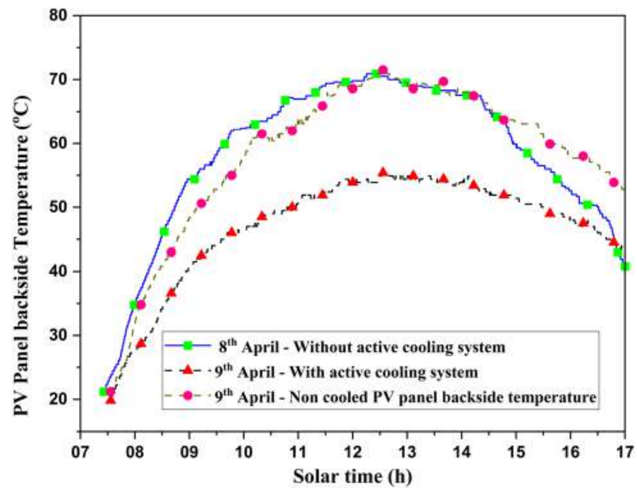


**Fig. 8** $T_{pb}$-solar time characteristics

panel back surface temperature was limited to 55.4 °C at the same time, the non-cooled PV panel temperature observed was 71.5 °C. In the 9th April's testing, the actively cooled PV panel's cell operating temperature was successfully reduced by 16.1 °C than non-cooled PV panel temperature. The average temperature difference observed between cooled and non-cooled PV panels was 12.8 °C. The active cooling system using thermal grease and steel chips showed good temperature decrement in PV panel back surface (Cell operating) temperature.

Figure 9 shows the voltage-solar time characteristic of the actively cooled and non-cooled PV panel. The temperature adversely affects the voltage output resulting in decreased power output of the PV panel. On 8th and 9th April, the maximum voltage

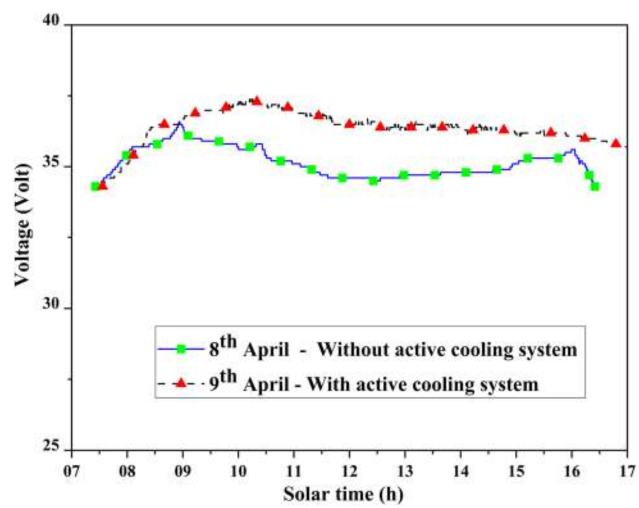


**Fig. 9** Voltage-solar time characteristics

produced by the non-cooled and cooled PV panels observed was 36.1 V and 37.6 V, respectively, while the average voltage observed was 35.1 V and 36.5 V on the 8th and 9th April, respectively. Due to the active cooling system, the average voltage output of the cooled PV panel was increased by 1.4 V over the non-cooled PV panel.

Figure 10 shows the current-solar time characteristic of the cooled and non-cooled PV panel. As current is directly proportional to fallen irradiation value, cell operating temperature does not severely affect it. Therefore, both the curves are nearly matching with each other. The non-cooled and cooled PV panel's maximum current observed was 6.9 A and 6.7 A, whereas the average current observed was 4.9 A and 4.8 A. The small difference in the average current of non-cooled and cooled PV panels clearly shows that the temperature increment higher than 25 °C does not reduce the current; instead, it is increased marginally.

Figure 11 shows the power generated by the PV panel. The power generated by the panel showed a linear relation with irradiation. The maximum power developed by non-cooled and cooled PV panels was observed at 226.7 W and 268.2 W, respectively, on 8th April and 9th April. The non-cooled and cooled PV panel's average power was found to be 166.3 W and 189.5 W, respectively. At the same irradiation level, 932 W/m$^2$, the power generated by non-cooled and cooled PV panels was 222 W and 265 W, respectively. The difference in power generated was observed because the cell operating temperature at the same irradiation level was 69.5 °C and 53.9 °C, respectively.

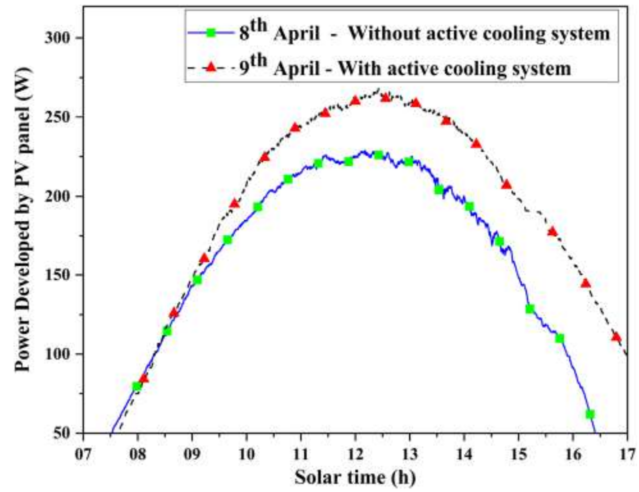


**Fig. 11** Power generated-solar time characteristics

The cooled PV panel's power output was improved by 43 W at the same irradiation level due to an active cooling system. The total power generated by the non-cooled PV panel and cooled PV panel was 1.6 kWh and 1.9 kWh on 8th and 9th April, respectively.

Figure 12 shows efficiency-solar time characteristics of the cooled and non-cooled PV panel. There was a considerable difference in both the cooled and non-cooled PV panel efficiencies. The average electrical efficiency observed experimentally for the actively cooled PV panel at 5.2 m/s air velocity and non-cooled PV panel was 14.6% and 13.0%, respectively. Therefore, in the actively cooled PV panel at 5.2 m/s air velocity, average electrical efficiency was increased by 12.3% compared to the non-cooled PV panel. The non-cooled PV panel's efficiency was observed minimum when the panel's cell operating

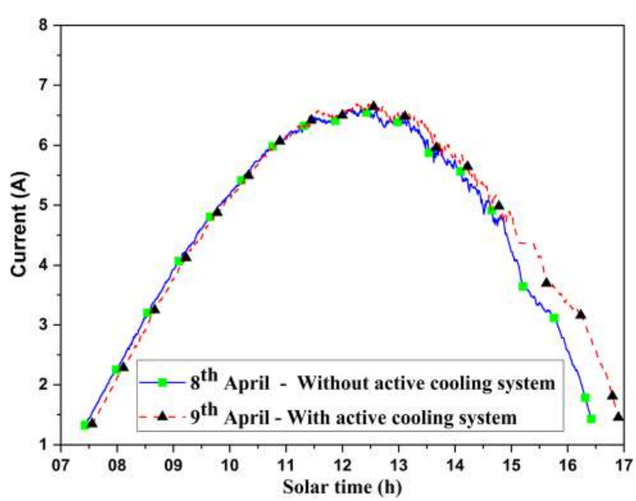


**Fig. 10** Current-solar time characteristics

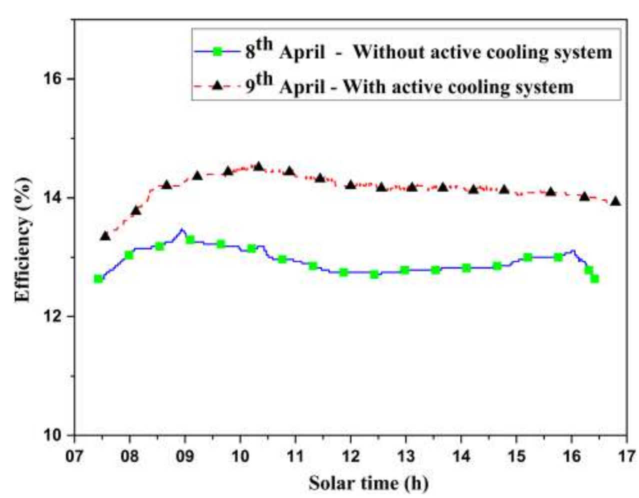


**Fig. 12** Efficiency-solar time characteristics

temperature was higher at 12.30 pm. A clear drop was seen from 9.0 am to 16.0 pm, where the non-cooled PV panel temperature increased at maximum. Hence the active cooling system showed extra added benefits in efficiency improvement of the cooled PV panel over the non-cooled PV panel.

## 3.2 The drying system using waste heat recovered

For hygienically drying of the onion flakes, waste heat recovered while cooling was directly utilized. At the time of active cooling of the PV panel test, drying tests were simultaneously carried out by varying the mass flow rate of the hot air. For one drying test, the air velocity was kept constant; the drying tests were carried at different air velocities from 3.2 to 5.4 m/s for analysing its effect on system performance. The fresh onion bulbs were peeled and then finely chopped in the form of flakes, and they were uniformly spread in the trays as shown in Fig. 13. The drying observations at 5.2 m/s air velocity on 15th and 16th May 2020 are discussed in detail here.

The onion flakes drying at 5.2 m/s air velocity was carried on two successive days, 15th and 16th May 2020, in sufficient sunlight. The onion flakes were kept for drying in the dryer cabinet for 7 h 10 min (10.17 am to 17.27 pm) on 15th May, which gets incompletely dried. The incompletely dried onion flakes were again kept for drying on 16th May, which took 3 h 20 min (9.10 am to 12.30 pm) for complete drying. Figure 14 shows the irradiation-solar time characteristic of 15th and 16th May. The maximum irradiation observed was 962 W/m$^2$ and 956 W/m$^2$ on 15th and 16th May, respectively. The sufficient sunlight for drying was observed from 10.17 am to 17.27 pm on 15th May.

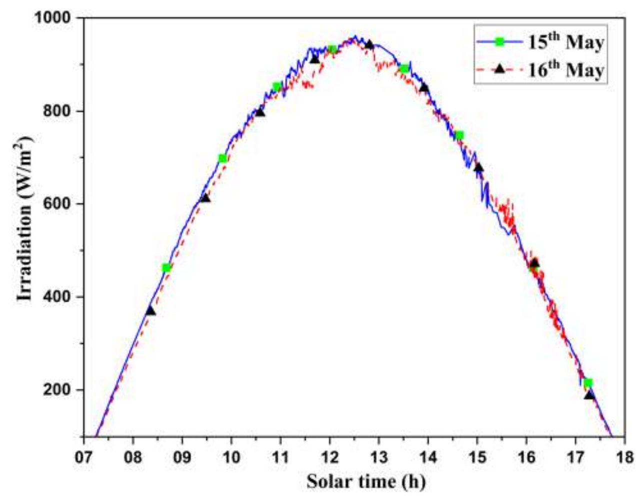


**Fig. 14** Irradiation-solar time characteristic

Figure 15 shows the various temperatures-solar time characteristic of 15th May. The ambient air temperature, cabinet inlet air temperature, exit air temperature, and PV panel back surface temperatures during the test period were observed in the range 31.6–37.6 °C, 41.0–52.4 °C, 39.6–47.0 °C and 41.0–56.4 °C, respectively. During the test, the air velocity was kept constant at 5.2 m/s. The cabinet inlet air temperature was increased linearly in proportion to the PV panel back surface temperature. Initially, there was a massive difference in cabinet inlet air temperature and exit air temperature observation, which gradually decreased further.


**Fig. 13** Onion used as raw material for drying

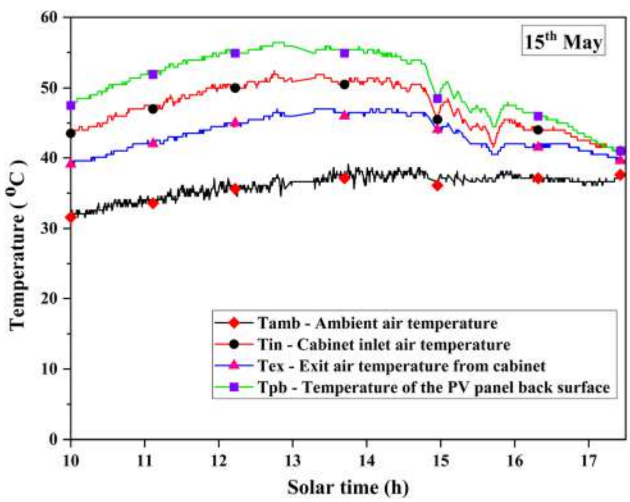


**Fig. 15** Temperatures-solar time characteristic

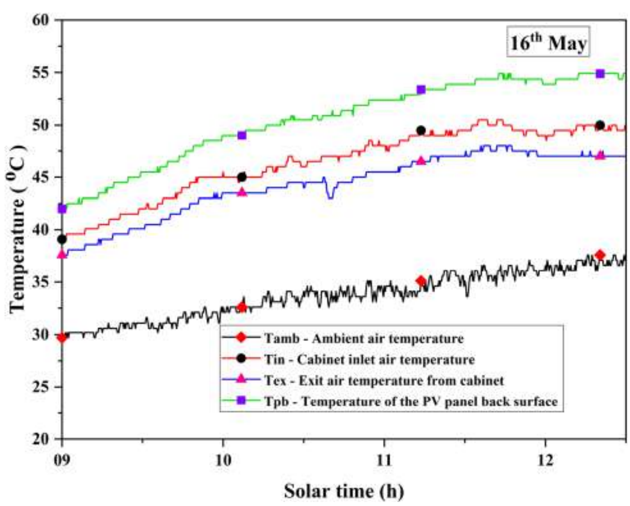


**Fig. 16** Temperatures-solar time characteristic

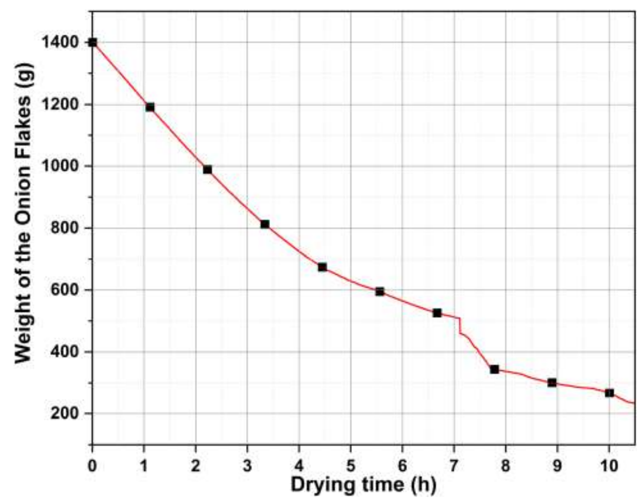


**Fig. 17** Weight reduction-drying time characteristic

Figure 16 shows the temperature-solar time characteristics of 16th May. The ambient temperature, cabinet inlet air temperature, exit air temperature, and PV panel back surface temperatures during the test period were observed in the range 29.7–37.6 °C, 39.1–50.5 °C, 37.6–48.0 °C and 42.0–54.9 °C, respectively. In the last 3 h 20 min, the lower difference in inlet air temperature and the exit air temperature was observed, as most of the moisture was removed in the first 7 h 10 min.

Figure 17 shows the weight reduction of the onion flakes concerning time. The continuous weight measurement was done with a load cell. The cage was attached to the load cell where onion flakes loaded drying trays were kept; this completely reduced product handling for weight measurement resulting in the hygienic drying. Due to the load cell, it was possible to open the cabinet two times initially for loading and at the end for unloading after drying. 1400 g onion flakes were kept initially in the tray for moisture removal on 15th May. During the initial 3 hours, the moisture removal rate was higher as the moisture contained in onion flakes was also higher; further, the moisture removal rate gradually reduced. In the first hour of drying, total of 189 g of moisture was removed from the onion flakes. On 15th May, after 7 h 10 min, the onion flakes weight was 509 g that means a total of 891 g of moisture was removed after 7 h 10 min. On 16th May, the incompletely dried onion flakes weight was 460 grams, which were reduced to 232 g after 3 h 20 min of drying. The total time taken by the onion flakes for complete drying from 1400 to 232 g was 10 h 30 min. The dried onion flakes were found rich in colour, taste and aroma.

Table 2 shows the summarized results of the drying system tested at 5.2 m/s. Initially, more amount of heat energy was utilized for moisture removal due to higher moisture content in the onion flakes. However, the heat needed for moisture removal got reduced when the moisture contained in the onion flakes decreased. At a higher irradiation level, it was observed that more latent heat was available for drying. On 15th May in 7 h 10 min, almost 77% of the moisture was removed. The rest moisture is released in 3 h 20 min on 16th May. As the onion flakes contain 84% of moisture, theoretically, total latent heat

**Table 2** Result summary of dryer system testing at 5.2 m/s

| Date | Time period | Time in minutes | Average irradiation G (W/m$^2$) | Average teperatures (°C) | | | | Heat energy utilized for moisture removal (kJ) |
|---|---|---|---|---|---|---|---|---|
| | | | | $T_{amb}$ | $T_{in}$ | $T_{ex}$ | $T_{Pb}$ | |
| 15th May 2020 | 10.17 -11 am | 43 | 797 | 33.0 | 45.4 | 40.5 | 49.8 | 246 |
| | 11–12 am | 60 | 904 | 34.8 | 48.5 | 43.1 | 53.3 | 396 |
| | 12 − 1 pm | 60 | 943 | 36.0 | 50.7 | 45.5 | 55.5 | 333 |
| | 1–2 pm | 60 | 882 | 37.4 | 51.1 | 46.6 | 55.3 | 406 |
| | 2–3 pm | 60 | 764 | 37.7 | 50.3 | 46.4 | 54.0 | 349 |
| | 3–4 pm | 60 | 561 | 37.2 | 44.9 | 42.2 | 47.4 | 275 |
| | 4–5 pm | 60 | 381 | 36.9 | 43.8 | 41.7 | 45.3 | 216 |
| | 5–5.27 pm | 27 | 217 | 36.8 | 41.5 | 40.3 | 41.7 | 59 |
| 16th May 2020 | 9.10–10 am | 50 | 632 | 31.1 | 42.7 | 40.9 | 46.0 | 152 |
| | 10–11 am | 60 | 788 | 33.4 | 46.4 | 44.3 | 50.6 | 135 |
| | 11–12 am | 60 | 875 | 35.3 | 49.3 | 47.0 | 53.8 | 104 |
| | 12–12.30 pm | 30 | 938 | 36.7 | 49.6 | 47.0 | 54.6 | 83 |
| Total time | | 10 h 30 min | Total latent heat (kJ) | | | | | 2757 |

required for removal of 1168 grams of moisture is 2558 kJ, while experimentally, it took 2757 kJ.

The effect of air velocity on PV panel efficiency was also analysed thoroughly by testing the system at different airflow; for each trial, constant air velocity was maintained till the product gets completely dried. Table 3 shows the summarized results of the testing by varying the air velocity from 3.0 m/s to 5.4 m/s. During every trial, the PV panel's average electrical efficiency, the time required for drying, average drying system efficiency, and average total system efficiency were observed. At air velocity, 3.0 m/s the average voltage of the panel observed was 35.5 V, and the average power produced by the PV panel was 179.4 W. Time taken for complete drying was 13 h 57 min. The average PV panel electrical efficiency and average total system efficiency were observed to be 13.5% and 9.9%, respectively. As the air velocity increased, the electrical and drying parameters were also improved. The higher velocity of the air helped in taking away the maximum heat from the backside of the PV panel, resulting in better cooling of the PV panel. More excellent results were observed at 5.2 m/s air velocity, where the average voltage observed was 36.5 V. The average PV panel electrical efficiency and average total system efficiency were observed to be 14.6% and 13.2%, respectively. Time taken by the onion flakes for drying was reduced to 10.30 min.

## 3.3 Formulas used for calculations

$$\text{Heat energy utilized for moisture removal (kJ)} = m_a \times c_p \times (T_{in} - T_{ex}) \quad (1)$$

$$\text{Dry cabinet efficiency} = \frac{\text{Heat energy utilized for moisture removal}}{\text{Heat energy available for drying in the dryer cabinet}} \quad (2)$$

$$\text{Coolingsystemefficiency} = \frac{\text{HeatenergytakenawaybytheairfromPVpanelbackside}}{\text{TotalheatenergyavailableatthePVpanelbackside}} \quad (3)$$

$$D_h = 4 \times ((w \times h)/2w) \quad (4)$$

$$\text{Re} = \frac{(\rho \times v \times D_h)}{\mu} \quad (5)$$

$$\text{Dittus Boelter Equation } N_u D_h = 0.23 \times \text{Re}^{0.8} \times \text{Pr}^{0.4} \quad (6)$$

$$N_u = \frac{h_c D_h}{k} \quad (7)$$

Table 3 Performance of the system at different air velocity

| Air velocity (m/s) | Date | PV panel | | | Solar dryer system | | | |
|---|---|---|---|---|---|---|---|---|
| | | Average voltage (V) | Average power produced (W) | Average electrical efficiency of PV panel (%) | Time taken for complete drying | Average cabinet efficiency (%) | Average cooling system efficiency (%) | Average total system efficiency (%) |
| 3.0 | 27–28 April 2020 | 35.5 | 179.4 | 13.5 | 13 h 57 min | 23.2 | 47.4 | 9.9 |
| 3.6 | 21–22 April 2020 | 35.9 | 180.7 | 13.7 | 12 h 45 min | 22.7 | 50.2 | 10.3 |
| 4.2 | 25–26 April 2020 | 36.0 | 181.9 | 13.8 | 12 h 05 min | 22.7 | 53.9 | 11.0 |
| 4.6 | 1–2 April 2020 | 36.1 | 183.6 | 14.0 | 11 h 20 min | 22.4 | 56.7 | 11.4 |
| 5.0 | 3–4 May 2020 | 36.3 | 186.2 | 14.3 | 10 h 45 min | 22.5 | 62.8 | 12.7 |
| 5.2 | 15–16 May 2020 | 36.5 | 189.5 | 14.6 | 10 h 30 min | 22.6 | 64.8 | 13.2 |
| 5.4 | 22–23 April 2020 | 36.5 | 189.6 | 14.6 | 10 h 27 min | 22.6 | 64.5 | 13.1 |

$$Q_{\text{fin}} = \sqrt{P \times h \times k \times A_{\text{cs}}} \times (T_{\text{in}} - T_{\text{amb}}) \times \frac{\tanh(ml) + (h/km)}{1 + (h/km) \times \tanh(ml)} \quad (8)$$

$$m = \sqrt{\frac{h \times P}{k \times A_{\text{cs}}}} \quad (9)$$

$$Q_{\text{without fins}} = h_c \times A \times (T_{\text{in}} - T_{\text{amb}}) \quad (10)$$

$$\text{Heat transfer through thermal grease area } H_{\text{Tg}} = h_c \times (A_c = A_{\text{chips}}) \times (T_{\text{in}} - T_{\text{amb}}) \quad (11)$$

$$Q_{\text{Total}} = Q_{\text{With fins}} + Q_{\text{With thermal grease}} \quad (12)$$

$$\text{Fin effectiveness} = Q_{\text{Total}}/Q_{\text{Without fins}} \quad (13)$$

By using above mathematical relation 1–13 [33], values of different parameters were calculated. For 2*0.1 m cross section of duct, the hydraulic diameter of duct ($D_h$) was 0.2 m, Reynolds number (Re) and Nusselt number (Nu) were 60734.1 and 133.8 respectively, and convective heat transfer coefficient (hc) was 18.3 W/m$^2$ °C.

For M.S chips of size 3 × 0.2 × 2 mm, the value of constant parameter 'm' found was to be 57.0 m$^{-1}$, while the heat transfer through a single fin ($Q_{\text{fin}}$) was 0.032 W. Total area '$A_{\text{chips}}$' of the 17,000 fins, which were uniformly spread over the 2 m$^2$ surface, was 0.01 m$^2$ where heat transfer through fins was 552 W, while total heat transfer through thermal grease and fins was found to be 1105 W. Heat transfer through the panel to air without fins and thermal grease was 555 W. The fin effectiveness was ~ 2.0, which shows that fins helped in accelerating the heat transfer from the PV panel backside thus yielding more heat energy available for drying of onion flakes. Due to this, overall system efficiency was also improved.

## 4 Conclusion

In this experimental research, the effect of the active cooling systems on the PV panel's performance improvement and utilization of residual heat recovered for the hygienic drying of the onion flakes was investigated. For active cooling of PV panel, thermal grease and M.S chips were added only with 0.75 kg/m$^2$ weight, significantly less than aluminium fins. The results for the actively cooled PV panel showed a significant improvement over the non-cooled PV panel. The effect of air flow rate on the PV panel's electrical efficiency, drying time and total system efficiency is experimentally investigated, and more promising results were obtained at 5.2 m/s air velocity. The maximum temperature at the PV panel's rear surface in the cooled and non-cooled PV panels observed was 55.4 °C and 71.5 °C, respectively. In an actively cooled PV panel, the maximum cell operating temperature was reduced by 16.1 °C than the non-cooled PV panel. The average voltage produced by the cooled PV panel at 5.2 m/s and non-cooled PV panel observed were to be 36.5 V and 35.1 V, respectively, resulting in ~ 4.0% average voltage improvement in cooled PV panel than non-cooled PV panel.

At the same irradiation level, 923 W/m$^2$, the cooled PV panel's power output was improved by 43 W. The total power generated by the cooled PV panel and the non-cooled PV panel was 1.9 kWh and 1.6 kWh, respectively. The electrical efficiency of the actively cooled PV panel observed was 14.6% compared to the 13% observed in the non-cooled PV panel. Therefore, in the cooled PV panel at 5.2 m/s air velocity, average electrical efficiency increased by 12.3% compared to a non-cooled PV panel. At 5.2 m/s air velocity, the average total system efficiency observed was 13.2%, and the time taken for completely drying of 1400 g onion flakes was 10 h 30 min. The dried onion flakes were found to be rich in colour, taste, and aroma as hygiene is maintained. An active cooling system showed improved results by reducing the cells operating temperature of the PV panel. At the same time, it has improved the electrical efficiency of PV panel and total systems efficiency.

This system is useful in the drying of agricultural products at the production site. Onsite drying will help in transporting the dried products directly by eliminating raw material transport. An active cooling system will help in improving the output and life of the PV panel.

## Compliance with ethical standards

**Conflict of interest** The authors declare that they have no conflict of interest.

## References


1. U. Sajjad, M. Amer, H.M. Ali, A. Dahiya, N. Abbas, Cost-effective cooling of photovoltaic modules to improve efficiency. Case Stud. Therm. Eng. **14**, 100420 (2019). https://doi.org/10.1016/j.csite.2019.100420
2. M.K.I. Khan, M. Ansar, A. Nazir, A.A. Maan, Sustainable dehydration of onion slices through novel microwave hydro-diffusion gravity technique. Innov. Food Sci. Emerg. Technol. **33**, 327–332 (2016). https://doi.org/10.1016/j.ifset.2015.12.010
3. AEl. Mays et al., Improving Photovoltaic Panel Using Finned Plate of Aluminum. Energy Procedia **119**, 812–817 (2017). https://doi.org/10.1016/j.egypro.2017.07.103
4. F. Grubisic-Cabo, S. Nizetic, D. Coko, I. Marinic Kragic, A. Papadopoulos, Experimental investigation of the passive cooled free-standing photovoltaic panel with fixed aluminum fins on the backside surface. J. Clean. Prod. **176**, 119–129 (2018). doi:https://doi.org/10.1016/j.jclepro.2017.12.149
5. A.M.A. Soliman, H. Hassan, S. Ookawara, An experimental study of the performance of the solar cell with heat An experimental study of the performance of the solar cell with heat sink cooling system District Heating and Cooling cooling on Assessing feasibility. Sci. Energy Procedia **162**, 127–135 (2019). doi:https://doi.org/10.1016/j.egypro.2019.04.014
6. G. Popovici, S. Valeriu, T. Dorin, N.-C. Cherche, Efficiency improvement of photovoltaic panels by using air-cooled heat sinks. Energy Procedia **85**, 425–432 (2016). https://doi.org/10.1016/j.egypro.2015.12.223
7. U. Banik et al., Solar energy materials and solar cells enhancing passive radiative cooling properties of flexible CIGS solar cells for space applications using single-layer silicon oxycarbonitride films. Sol. Energy Mater. Sol. Cells **209**, 110456 (2020). https://doi.org/10.1016/j.solmat.2020.110456
8. A.E. Kabeel, M. Abdelgaied, Performance enhancement of a photovoltaic panel with reflectors and cooling coupled to a solar still with air injection. J. Clean. Prod. **224**, 40–49 (2019). doi:https://doi.org/10.1016/j.jclepro.2019.03.199
9. L. Micheli, K.S. Reddy, T.K. Mallick, Plate micro-fins in natural convection: an opportunity for passive concentrating photovoltaic cooling. Sci. Energy Procedia **82**, 301–308 (2015). doi:https://doi.org/10.1016/j.egypro.2015.12.037
10. Z. Serag, H.A. Kandil, An innovative solution to the over-heating problem of P.V. panels. Energy Convers. Manage. **157**, 452–459 (2018). https://doi.org/10.1016/j.enconman.2017.12.017
11. M. Castillo-Tellez, I. Pilatowsky-Figueroa, E.C. Lopez-Vidana, O. Sarracino-Martinez, G. Hernandez-Galvez, Dehydration of the red chili using an indirect-type forced convection solar dryer. Appl. Therm. Eng. **114**, 1137–1144 (2017). doi:https://doi.org/10.1016/j.applthermaleng.2016.08.114
12. G.A. Ciftcioglu, F. Kadırgan, M.A.N. Kadırgan, G. Kaynak, Smart agriculture through using cost-effective and high-efficiency solar drying. Heliyon **6**(2), 1–7 (2020). https://doi.org/10.1016/j.heliyon.2020.e03357
13. M.N. Musembi, K.S. Kiptoo, N. Yuichi, Design and analysis of solar dryer for mid-latitude region. Energy Procedia **100**, 98–110 (2016). https://doi.org/10.1016/j.egypro.2016.10.145
14. M.E.A. Slimani, M. Amirat, S. Bahria, I. Kurucz, M. Aouli, R. Sellami, Study and modeling of the energy performance of a hybrid photovoltaic/thermal solar collector: configuration suitable for an indirect solar dryer. Energy Convers. Manage. **125**, 209–221 (2016). https://doi.org/10.1016/j.enconman.2016.03.059
15. S. Nabnean, S. Janjai, S. Thepa, K. Sudaprasert, R. Songprakorp, B.K. Bala, Experimental performance of a new design of solar dryer for drying osmotically dehydrated cherry tomatoes. Renew. Energy **94**, 147–156 (2016). doi:https://doi.org/10.1016/j.renene.2016.03.013
16. A. Kumar, G.N. Tiwari, Effect of mass on convective mass transfer coefficient during open sun and greenhouse drying of onion flakes. J. Food Eng. **79**(4), 1337–1350 (2007). doi:https://doi.org/10.1016/j.jfoodeng.2006.04.026
17. S.M. Choi, D.J. Lee, J.Y. Kim, S.T. Lim, Volatile composition and sensory characteristics of onion powders prepared by convective drying. Food Chem. **231**, 386–392 (2017). https://doi.org/10.1016/j.foodchem.2017.03.129
18. Y.M. Irwan, W.Z. Leow, M. Irwanto, M. Fareq, A.R. Amelia, N. Gomesh, *Indoor Test Performance of P.V. Panel through Water Cooling Method* (Elsevier B.V., New York, 2015).
19. P. Universiti, J. Abdul, M. Tan, Investigating the performance improvement of and a photovoltaic system in a tropical climate using water cooling method assessing the feasibility of using the heat demand-outdoor district heat demand forecast. Sci. Energy Procedia **159**, 78–83 (2019). https://doi.org/10.1016/j.egypro.2018.12.022
20. H. Bahaidarah, A. Subhan, P. Gandhidasan, S. Rehman, Performance evaluation of a P.V. (photovoltaic) module by back surface water cooling for hot climatic conditions. Sci. Energy **59**, 445–453 (2013). doi:https://doi.org/10.1016/j.energy.2013.07.050
21. A. Yadav, F. Grubisic, Water spray cooling technique applied on a photovoltaic panel: the performance response. Energy Convers. Manage. **108**, 287–296 (2016). https://doi.org/10.1016/j.enconman.2015.10.079
22. S. Dubey, J.N. Sarvaiya, B. Seshadri, Temperature-dependent photovoltaic (P.V.) efficiency and its effect on P.V. production in the world: a review. Sci. Energy Procedia **33**, 311–321 (2013). https://doi.org/10.1016/j.egypro.2013.05.072

23. S. Abdo, H. Saidani-Scott, J. Benedi, M.A. Abdelrahman, Hydrogels beads for cooling solar panels: experimental study. Renew. Energy **153**, 777–786 (2020). https://doi.org/10.1016/j.renene.2020.02.057
24. L. Idoko, O. Anaya-Lara, A. Mcdonald, PV enhancing modules efficiency and power output using the multi-concept cooling technique. Energy Rep. **4**, 357–369 (2018). https://doi.org/10.1016/j.egyr.2018.05.004
25. A. Craciunescu, A.M. Croitoru, G. Colţ, C.L. Popescu, M.O. Popescu, Thermal experimental investigation on air cooled PV panel. Renew. Energy Power Qual. J. **14**, 6–9 (2016)
26. A. Syafiq, A.K. Pandey, N.A. Rahim, B. Vengadaesvaran, S. Shahabuddin, Self-cleaning and weather resistance of nano-$SnO_2$/modified silicone oil coating for photovoltaic (P.V.) glass applications. J. Mater. Sci. Mater. Electron. **30**(13), 12584–12596 (2019). https://doi.org/10.1007/s10854-019-01619-z
27. I.M. Dharmadasa, Y. Rahaq, A.E. Alam, Perovskite solar cells: short lifetime and hysteresis behavior of current-voltage characteristics. J. Mater. Sci. Mater. Electron. **30**, 14, pp. 12851–12859 (2019). doi:https://doi.org/10.1007/s10854-019-01759-2. no.
28. J. Mitra, S.L. Shrivastava, P.S. Rao, Onion dehydration: a review. J. Food Sci. Technol. **49**(3), 267–277 (2012). https://doi.org/10.1007/s13197-011-0369-1
29. M.C. Roman, M.P. Fabani, L.C. Luna, G.E. Feresin, G. Mazza, R. Rodriguez, Convective drying of yellow discarded onion (Angaco INTA): modelling of moisture loss kinetics and effect on phenolic compounds. Inf. Process. Agric. **7**(2), 333–341 (2020). https://doi.org/10.1016/j.inpa.2019.07.002
30. D. Eshel, P. Teper-Bamnolker, Y. Vinokur, I. Saad, Y. Zutahy, V. Rodov, Fast curing: a method to improve postharvest quality of onions in hot climate harvest. Postharvest Biol. Technol. **88**, 34–39 (2014). https://doi.org/10.1016/j.postharvbio.2013.09.002
31. J.A. Folayan, F.N. Osuolale, P.A.L. Anawe, Data on exergy and exergy analyses of drying process of onion in a batch dryer. Data Br. **21**, 1784–1793 (2018). https://doi.org/10.1016/j.dib.2018.10.132
32. J. Mitra, S.L. Shrivastava, P. Srinivasa Rao, Vacuum dehydration kinetics of onion slice. Food Bioprod. Process. **89**(1), 1–9 (2011). https://doi.org/10.1016/j.fbp.2010.03.009
33. R.K. Rajput, *Heat and Mass Transfer, Chap. 2-Conduction Steady-State One Dimensional*, 3rd edn. (S. Chand publication, New Delhi, 2009), pp. 207–245

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Research Article

# Simulation modeling and experimental validation of solar photovoltaic PMBLDC motor water pumping system

**Vinayak DEOKAR[1,2,*], Rupa S. BINDU[1], Tejashri DEOKAR[2]**

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## ARTICLE INFO

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**Key words:**
Renewable energy; Photovoltaic panel; Simulation; Solar PMBLDC motor water pumping system; Error analysis

## ABSTRACT

Solar energy is abundantly available on the earth and can be utilized in various applications by converting it in a suitable form. Water supply in remote places and rural areas is still critical due to the unavailability of the grid power. In a developing country like India, the grid construction cost is 6670 $/km because of which some remote areas are still waiting for electricity. There is a large scope to meet this need with the help of a standalone solar water pumping system. In this context, this work presents detailed simulation in MATLAB/Simulink and experimental validation of photovoltaic (PV) permanent magnet brushless DC (PMBLDC) motor water pumping system without energy storing. Simulation is a tool to get system behavior at the various input parameters immedi ately reflects a change in the output parameter. The simulation results are validated with the help of field trials on the experimental setup. A 0.5 hp photovoltaic permanent magnet brushless DC (PMBLDC) motor water pumping system was used for extensive field trials experimentation. After extensive field trials, the optimum irradiation observed for full water discharge 19.9 L/min was 330 W/m$^2$ where voltage and current were 35.1 V and 3.1 A respectively. The Water flow – Irradiation characteristic curve and percentage variation in simulation and experimental results showed a good agreement with each other. The efficiency of the photovoltaic panel and the entire solar water pumping system observed was 12.76 ± 0.64 % and 9.07± 0.45 % respectively. The 0.5 hp PMBLDC motor water pumping system is sufficient to lift 10000 L water every day. PMBLDC motor, shown added advantage of lesser running maintenance due to the absence of carbon brushes which need frequent replacement in case of brushed DC motor.

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## INTRODUCTION

A rapid increase in industrialization and population has almost doubled the energy demand of India. India's total installed capacity is 349.3 GW as on 31 January 2019, in which thermal energy contribution is 63.7 %, Nuclear is 1.93 %, hydro energy 12.85 %, and contribution of renewable energy is 21.14 % [1]. To meet India's huge power requirement, the sustainable solution is maximizing

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| Faculty Achievement | | | | | | |
|---|---|---|---|---|---|---|
| | | **Name of Department** | **Mechanical Engineering** | | **Year 2020-21** | |
| **Sr. No.** | **year** | **Name of the Faculty** | **Event Name** | **Title** | **Journal/college/university Name** | **Date** |
| 1 | 2020-21 | Mr. Vinayak Hindurao Deokar | Research article | Active cooling system for efficiency improvement of PV panel and utilization of waste-recovered heat for hygienic drying of onion flakes | Journal of Materials science- Materials in Electronics. Springer Nature. | January 2021 |
| 2 | | | Research article | Simulation modeling and experimental validation of solar photovoltaic PMBLDC motor water pumping system | Journal of Thermal Engineering | July 2021 |

## Faculty Achievement

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|---|---|---|---|---|---|---|
| | | Name of Department | | | Year 2020-21 | |
| Sr. No. | year | Name of the Faculty | Event Name | Title | Journal/college/university Name | Date |
| 1 | 2020-21 | Dr. Koli Gajanan Chandrashekhar | Ph.D. | Ph.D. completed | Visvesvaraya Technological University, Belagavi | 03/04/2021 |
| 2 | 2020-21 | Dr. Koli Gajanan Chandrashekhar | Faculty Develoment Program | Industrial Automation using CNC and Intelligent Systems | ATAL academy, Manipal Institute of Technology, Manipal | 16/8/2021 to 20/8/2021 |
| 3 | 2020-21 | Dr. Koli Gajanan Chandrashekhar | Faculty Develoment Program | Emerging Materials, Sensors and Devices for IoT and Industry 4.0 | ATAL academy, Raman Global University | 23/8/2021 to 27/8/2021 |

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*in*

FACULTY OF MECHANICAL ENGINEERING SCIENCES

*for the thesis entitled*

STUDY OF MECHANICAL, WEAR AND CORROSION CHARACTERISTICS OF AL6061 REINFORCED WITH GRANITE PARTICULATES

*in recognition of the fulfillment of requirements for the said degree*

PH 19 001108 Given under the seal of the University

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| | | **Name of Department** | **Mechanical Engineering** | | **Year 2020-21** | |
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| 1 | 2020-21 | Mr Ajit Ashok Katkar | Paper setter | ENERGY AND POWER ENGINEERING.Sub. Code: 68509 | Shivaji University ,Kolhapur | Oct 2020 |
| 2 | | | Journal paper Publication | Microstructure, hardness and machinability analysis of gravity cast AA6061/SiC composites | Manufacturing Technology Today | Nov. 2020 |
| 3 | | | Paper setter | Heat Transfer(BTAMC601) | DBATU | 25/06/2021 |
| 4 | | | Journal paper Publication | Design and Study of a Three-Wheeled Transport Vehicle's Front Helical Coil Suspension Spring | International Research Journal of Engineering and Technology (IRJET) | June 2021 |
| 5 | | | Journal paper Publication | Design and Development exp. set up for Plasma coating for textile roller drum | International Journal of Science Technology & Engineering | Sept. 2021 |
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| 8 | | | Paper setter | Anlysis and Synthesis of Mechanisms (MDE12) MTECH | DBATU | 2/6/2021 |

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1 message

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**Sanjay Sawant** <sanjaysawant2010@gmail.com> 15 October 2020 at 13:33
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महोदय / महोदया,

सत्र ८ च्या परीक्षा ह्या online होणार असल्याने विध्यार्थ्यांना प्रश्न पत्रिकेची ओळख होणे करिता आपल्या विद्याशाखे अंतर्गत येणाऱ्या विषयांचे काही ठराविक (५ ) प्रश्न व पर्यायासह या विभागाच्या appointment.b@unishivaji.ac.in या ई -मेल वर दि. १५-१०-२०२० पर्यंत देणेत यावेत व विद्यापीठास परीक्षा कामास सहकार्य करावे हि विनंती. सदर चे प्रश्न हे विद्यार्थ्यांना सरावासाठी विद्यापीठाच्या संकेतस्थळावर उपलब्ध करून देणेत येणार आहेत.

कळावे.

आपला उपकुलसचिव



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**Prof. (Dr.) Sanjay H. Sawant**
**Principal - Sant Gajanan Maharaj College of Engineering,Mahagaon**
**Associate Dean -Faculty of Science and Technology, S.U. Kolhapur.**

# Microstructure, hardness and machinability analysis of gravity cast AA6061/SiC composites

**Katkar Ajit Ashok[1*], D.P. Girish[2], G.C. Koli[3]**

[1,3]Sanjeevan Engineering & Technology Institute, Panhala Kolhapur, Maharashtra, India
[2]Government Engineering College, Ramanagar, Karnataka, India

KEYWORDS

Metal Matrix Composites,
Hardness,
Machining,
Chip Formation.

ABSTRACT

*In the present work, machinability analysis of AA6061/SiC composites developed using gravity die casting technique. The microstructure of composites and the chip formed are studied using optical and electron microscopes. Brinell hardness measurements were carried out to check the effect of varying SiC particle content for both the composites. The machinability analysis was carried out by varying feed rate, depth of cut and speed for all composites. From optical studies it was confirmed that addition and increase in SiC content led to grain refinement of AA6061 matrix. The hardness of composites was found to higher than that of unreinforced owing to addition of SiC particles. Machinability studies revealed that increase in feed rate, depth of cut and cutting speed led to increase in the tangential force. The increase in tangential force was attributed to increase in chip thickness and width during the machining operation.*

## 1. Introduction

More than dozens of aluminium alloys are being used for variety applications in different areas of manufacturing and technology. These alloys are available in the form of wrought products like plate, sheet, bar and angle in the market in and later cut or welded or machined according to the requirements of components. In particular, AA6XXX and AA7XXX alloy series in which Mg, Zn, Cu and Si are principal alloying elements are known for low density, high strength and better corrosion resistance. Take for example the complex architectural parts and structural members are made up of AA6XXX series as they are known for high compressive and tensile strength. Similarly AA7XXX series which possess high strength and high toughness is used in making aircraft wing structures. Further AA6XXX and AA7XXX alloy series are heat treatable and their strength can be enhanced by precipitation hardening by opting different temper conditions [1, 2]. But due to increase in the popularity of light metal matrix based composites and their possible applications in the almost all fields of engineering has led to lot of advancements. Compared to pure and unreinforced metals, metal matrix composites are known to have low density, high strength and high stiffness to weight ratio. In this regard AA6XXX and AA7XXX alloys are widely being tried as matrix material in the manufacturing of composites as they are easy to process and possess good mechanical properties. Variety of reinforcements like graphite, TiC, SiC, $Al_2O_3$, $TiB_2$, $Si_3N_4$, $TiO_2$ and flyash are used to reinforce these aluminium alloys [3-10]. After addition of reinforcements the aluminium composites showed improvement in mechanical and tribological properties. However, selection of appropriate reinforcement and processing technique is very crucial and highly dependent on the type of application.

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Machining is the most important and major manufacturing process in which final shape to a component is given by turning, milling, drilling or other miscellaneous operations. As aluminium alloys and its composites have huge role in the manufacturing of various automotive and aircraft parts it is necessary to understand their machining performance especially when a new type of reinforcement or thermal treatment is given. The effect of processing conditions like secondary deformation processing, heat treatment, addition of alloying elements and filler materials like SiC into aluminium alloys has created considerable apprehension due to lack of information on machining attributes. In their work Bansal and

From : The Controller of Examinations, Dr. Babasaheb Ambedkar Technological University, Lonere

No: DBATU/EXAM/BTECH/REG/2021/13
Date: 25 June, 2021

**To,**

**Mr. Ajit Ashok Katkar,**

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**SETI, Panhala**

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# Design and Study of a Three-Wheeled Transport Vehicle's Front Helical Coil Suspension Spring

**Rajat Kumthekar[1], Dr. Gajanan Koli[2], Prof. A. A. Katkar[3]**

*[1]Student, Department of Mechanical Engineering, Sanjeevan Engineering and Technology Institute, Kolhapur, Maharashtra, India.*
*[2]Professor, Department of Mechanical Engineering Sanjeevan Engineering and Technology Institute, Kolhapur, Maharashtra, India.*
*[3]Professor, Department of Mechanical Engineering Sanjeevan Engineering and Technology Institute, Kolhapur, Maharashtra, India.*

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**Abstract -** *The functionality of the suspension and steering system must maintain an appropriate balance along with a strong supporting structure that strengthens the design and adds to comfortable driving. The design should be low-cost and light-weight as possible without compromising the required strength. This project result gives an optimized front suspension spring of three-wheeled passenger vehicles and offers modifications to improve the vehicle's directional stability. This improved suspension spring is also suitable for smaller versions of the three-wheeler passenger vehicle. The material IS 4454 is used in this study.*

***Key Words*: Finite Element Analysis, Three Wheeler Suspension Spring, Weight Optimization, IS 4454**

## 1.INTRODUCTION

The suspension system of a three-wheeled vehicle must be adequately constructed in order to drive it comfortably and with firm control. The driver will be unable to direct the engine's power unless he or she gains strong control of the vehicle. As a result, without a suspension system, all other parameters for automotive performance, such as horsepower, torque, and 0-100kmph acceleration, are useless. As a result, the suspension system is one of the most crucial elements of a vehicle.

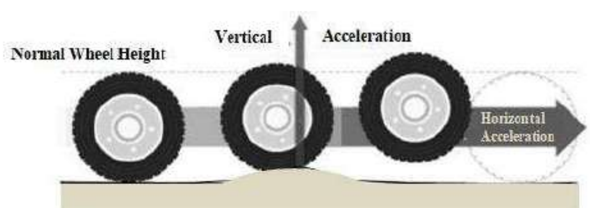


**Fig -2**: Concept of suspension working

The suspension system's aim is to give road grip through maximum friction between the tyre treads and the road surface, to guarantee adequate steering stability and handling, and to keep the occupants comfortable.

Whenever there is a surface irregularity, the wheel will experience a vertical acceleration. All of the wheels send vertical energy to the frame, which moves in the same direction, in the absence of intervening structure such as suspension spring. The wheels barely make touch with the road in this situation. When a wheel goes over a bump, the wheels slam back into the road due to gravity's downward force.

Therefore, it is necessary to have a mechanism that absorbs the vertically-accelerated wheels' energy allows the frame and body to ride pleasantly and without disruption while the wheel follows bumps in the road can make controlling the vehicle and driving more comfortable.

## 2. PROBLEM DEFINITION

After a thorough examination of the vehicle's issue, it was discovered that when the driver releases the steering wheel, the vehicle quickly drifts to the right side. Because of the weight of the suspension components, the vehicle drags to one side. The front suspension spring was modified and optimized to deal with this issue.

# Design and Development of Expt. Setup for Plasma Coating for Textile Roller Drum

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*PG Student*
*Department of Mechanical Design Engineering*
*Sanjeevan Engineering Technology University, Panhala, Kolhapur, India*

**Ajit Ashok Katkar**
*PG Student*
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**Koli G. C.**
*Assistant Professor*
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*Sanjeevan Engineering Technology University, Panhala, Kolhapur, India*

**Abhijit Babaso Chopade**
*PG Student*
*Department of Mechanical Design Engineering*
*Sanjeevan Engineering Technology University, Panhala, Kolhapur, India*

## Abstract

In most of the textile industries as well as paper making machine, rollers are major component is used for rolling mechanism which is always in contact with product like textile cloths, papers. Continuous rolling action causes wear and tear of the roller's surface, which leads to uneven distribution of the cloths and papers as these products are having thickness in microns. So after such wear of roller, it is coated with the same material as roller using plasma coating technique. Now a day's manual techniques are used for plasma coating which consumes more time and requires extra labors resulting in high cost for coating. In this project we designed and developed a new mechanism using lead screw, tail stocks, motors, belt drives etc. for semi-automated plasma coating mechanism for roller coating. This mechanism uses lead screw for movement of the plasma coating gun, hence requires less labors and it has arrangement for coating two rollers simultaneously. Tailstock and chuck mechanism is used for holding of roller while AC motors are used for rotation of chuck with the help of the belt and drive arrangement.

**Keywords: Textile, Roller, Plasm-Coating, Tailstock**

## I. INTRODUCTION

Coating techniques are becoming more and more important for the added value to the technical textiles. It improves and widens the spectrum of functional performance criteria of textiles and thus their use grows significantly, given the diversification of uses for technical textiles. The traditional process for coating required more time and higher value to the manufacturer. The use of appropriate technology with modern machines is the key to textile coating success. Productivity of the machine is essential but flexibility in the range of production speeds, high level of process monitoring, and automation are also essential factors to fulfill technical criteria. But this high automation required higher initial cost, so we design the semiautomatic plasma coating setup which minimizes the initial investment and also the production cost.

## II. LITERATURE REVIEW

The literature review for the dissertation project outlined in the previous chapter falls under this heading.

Jovana Ruzicl, Miroljub, Dusan [1] discussed different thermal spray coating methods for applying metallic and non-metallic coatings. The coating material is heated to either a molten or semi-molten state and then directed toward a surface which is to be coated using carrier gases or injection jets. Plasma spraying materials are typically powder, and they require a carrier gas to be fed into the plasma jet that flows between the heated cathode and the cylindrical nozzle-shaped anode.

Sagar Amin, Hemant Panchal [2] have discussed about surface coating which is cost-effective way to produce materials, equipment, and machine components with desirable surface qualities like corrosion, erosion, and wear resistance. To attain the desired qualities, various coatings are utilized. Thermal spray coating is the most successful methods for protecting new parts against wear, high-temperature corrosion, and erosion, as well as for forming strong and heavy coatings that extend the material's life. This article discusses the fundamental principles, benefits, applications, and comparisons of different spraying methods like Plasma Spray, Flame Spray, and High Velocity Oxy-Fuel Spray (HVOF).

Armelle Vardelle, Christian Moreau, Nickolas J. Themelis, Christophe Chazelas[3] have given information about plasma spraying which merely thought to be a significant technology wherein all the key parameters have been observed and addressed. Morever, some complex interactions between the conducting fluid and plasma torch operation are still unknown. Variations of the plasma spray method are now surfacing, posing new scientific questions. These relatively new approaches enable the fabrication

 

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participated in the Five Day Online Faculty Development Programme on "Mechatronics, Automation and Robotics" organized by Department of Mechanical Engineering, SoE in association with IEEE Bombay Section and AICRA during August 3-7, 2020.

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No: DBATU/EXAM/MTECH/REG/2020/ MECH/71
Date: 02 June, 2021

**To,**

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**Dept. of Mechanical Engg,**

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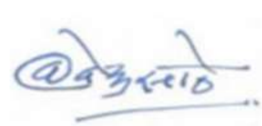

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| | | Name of Department | Mechanical Engineering | | Year 2020-21 | |
|---|---|---|---|---|---|---|
| **Sr. No.** | **year** | **Name of the Faculty** | **Event Name** | **Title** | **Journal/college/university Name** | **Date** |
| 1 | 2020-21 | Mr. Vinod Vasantrao Vanmore | CE&QIP Short term course | Inter-disciplinary Aspects in modeling of manufacturing processes | IIT Bombay and BATU Lonere | 21/11/2020to 25/11/2020 |
| 2 | | | TEQIP-III sponsored Two Week Faculty Development Programme | Digital Design and Emerging Trends in Signal Processing | Government Engineering College Bikaner Rajasthan | 10/08/2020 to 22/08/2020 |
| 3 | | | e-Conference organized | 3rd International e-Conference on Frontiers in Mechanical Engineering andnanotechnology [ICFMET] | Advances in Engineering and Nanotechnology ISSN (Online) 1741-8151, ISSN (Print) 1475-7435 | 27–28 November 2020 |
| 4 | | | Ph.D. | Ph.D. Thesis Submitted | Shivaji University Kolhapur (Research Center Walchand College of Engineering ) | 31/12/2020 |
| 5 | | | QIP Short term course | MultiscaleModeling and Simulation Techniques for 3D Printing | IIT Kanpur | 08/03/2021 to 13/03/2021 |
| 6 | | | QIP Short term course | MechanicalBehaviour of Materials | IIT Kanpur | 15/03/2021 to 20/03/2021 |
| 7 | | | ATAL Faculty Develoment Program | Micro-electromechanical Systems | Sardar Patel College of engineering Mumbai. | 23/11/2020 to 27/11/2020 |
| 8 | | | Faculty Development Programme | Nearly Zero Energy Building(nZEB) | SIT COE Yadrav MH | 10/08/2020 to 14/08/2020 |
| 9 | | | Faculty Development Programme | Industry 4.0 & condition monitoring | VJTI Mumbai and Eng. college Ajmer | 15/03/2021 to 19/03/2021 |
| 10 | | | Faculty Development Programme | Advances in Manufacturing and Materials | DYP COE&T Kolhapur | 20/04/2021 to 24/04/2021 |
| 11 | | | ATAL Faculty Develoment Program | Emerging Technologies in Product Design & Development | Government College Of Engineering Chandrapur, MH | 14/06/2021 to 18/06/2021 |
| 12 | | | ATAL Faculty Develoment Program | 3D Printing & Design for Innovative Medical Devices | Malaviya National Institute of Technology Jaipur. | 28/06/2021 to 02/07/2021 |

**Indian Institute of Technology Bombay**

Continuing Education &

Quality Improvement Programmes (CE & QIP)

# CERTIFICATE

This is to certify that

*Vinod Vasantrao Vanmore*

has participated in the CEP course on

**Inter-disciplinary Aspects in Modeling of Manufacturing Processes**

Conducted for Dr. Babasaheb Ambedkar Technological University, Lonere, by IIT Bombay during November 21 - 29, 2020

Preeti Rao

**Prof. Preeti Rao**

Professor-In-Charge (CE & QIP)

Please Scan QR Code OR type code in [illegible]

T18-2021-75

**Prof. Suhas Joshi**

Course Coordinator

# Department of Electronics & Communication Engineering
# (Government Engineering College Bikaner)

## TWO WEEK FACULTY DEVELOPMENT PROGRAMME

## Certificate of participation

*This is to certify the Vinod Vasantrao Vanmore of SETI PANHALA KOLHAPUR has successfully completed a TEQIP-III sponsored Two Week Faculty Development Programme on "Digital Design and Emerging Trends in Signal Processing" from August 10th to August 22nd, 2020 conducted online by department of Electronics & Communication Engineering, Government Engineering College Bikaner.*

Certificate ID: 98ER30-CE000124

| | | |
|---|---|---|
| Mr. Rajendra Singh Shekhawat<br>Organizing Secretary | Dr. Manoj Kuri<br>Convener | Dr. J. P. Bhamu<br>Principal |

# Editorial

## Vinod V. Vanmore

Department of Mechanical Engineering,
Sanjeevan Engineering and Technology Institute,
Panhala, Kolhapur, Maharashtra – 416201, India
Email: vinodvanmore@gmail.com

## Rahul B. Patil

Department of Physics,
Yashwantrao Patil Science College,
Solankur, Kolhapur, Maharashtra – 416211, India
Email: rrahulpatil@gmail.com

**Biographical notes:** Vinod V. Vanmore has 12 years of professional experience (industry, research and academics). He has completed his Masters in Production Engineering from the premier institute – Walchand College of Engineering, Sangli. He has submitted his PhD in Mechanical Engineering to Shivaji University, Kolhapur – a leading university in research outputs. He has published six research articles in refereed journals. His research interests include non-conventional machining and micro-machining for difficult to cut materials, fluidics, and optimisation techniques.

Rahul B. Patil has 17 years of professional experience (research and academics). He has been awarded the Departmental Research Fellowship by Shivaji University, Kolhapur and completed PhD in Physics in 2008. Further, he has been PostDoctoral Fellow at National Central University Taiwan during 2009–2010. He has authored five textbooks and one reference book. He has published 22 research articles in Scopus indexed refereed journals and has attended/presented numbers at various national/international conferences. His research interests include nanomaterials, green synthesis, thin films. Currently, he is working as Head of Department of Physics at YP Science College. He is a life member of ISTE (Indian Society for Technical Education). He has been editor of national and international conferences proceedings.

*3rd International e-Conference on Frontiers in Mechanical Engineering and nanoTechnology [ICFMET]* has been successfully organised on 27–28 November, 2020. The whole world was suffering through the pandemic, but could not much affect the scientific temperament of the researchers. The research in medical sciences geared-up and there was time to rethink and revise their research profiles and further plans. This special issue as Advances in Engineering and Nanotechnology consists of 10 papers from ICFMET-2020. The invited talks were delivered by eminent experts from IIT Indore, IIT Delhi, IIT Roorkee, IIT Jammu and Sungkykwan University and Yeungnam University South Korea. The objective of this conference was to share and exchange the ideas, knowledge and experiences in the field of mechanical engineering and nanotechnology.

The ICFMET-2020 received 118 abstracts out of which only half of them were invited to submit the full manuscripts. The guest editors of this special issue have picked the ten manuscripts for this special issue. The technical committee have thoroughly checked the suitability and fitting with journal's guidelines. We also appreciate the willingness of the authors in this regard. All the selected manuscripts went through single blind peer review. We hope that readers will enjoy this special issue.

The first paper concludes that optical methods cannot be used in sedimentation study of magnetorheological fluids (MRFs) specifically with higher concentration of particles. MRFs are class of smart materials. The second paper focuses on the Taguchi-GRA-PCA methodology for the optimisation of stiffness and deflection behaviour process variables for a technical way to control the limitations of single objective techniques in multiple performance characteristics problems. Third paper focuses on experimental investigations on direct absorption solar flat plate collector using $Al_2O_3$ nanofluid. Fourth paper investigates the influence of the hardness, sliding distance and time on the surface roughness during the sliding process. Fifth paper deals with the extraction, characterisation and consumption of waste plastic oil (WPO) extracted through pyrolysis process of mixed plastic waste in single cylinder diesel engine. Sixth paper focuses on performance improvement of variable compression ratio diesel engine using $H_2O_2$ as fuel additive. The seventh paper is about shape and the size of nanoparticles which are the crucial parameters of nanostructure that need to be securely controlled, owing to their versatility for tailoring the properties and functions of nanostructures towards a variety of applications. This paper reviews shape based surface plasmon resonance (SPR) of silver nanostructures. The eighth paper aims to utilise the experimental approach to perform the optimisation of processing parameters affecting the bio-oil yield in fast pyrolysis. In the modern industrial world, steam is widely used to generate electricity, and for power transmission and heating purposes where direct heating is not possible as in petroleum, food, paper and other industries. The ninth paper deals with design of vertical fire tube boiler using IBR code and FEA analysis. Tenth paper discuss the simulation based study on the disc brake temperature distribution for optimising hole geometry.

We are thankful to [1] Dr. Ashok D. Chougale, The New College, Kolhapur; [2] Dr. J.B. Yadav and Professor (Dr.) A.V. Ghule, Professor (Dr.) R.K. Kamat, Shivaji University, Kolhapur for their cooperation for scientific assessment and evaluation. Besides, we are thankful to Chairman of SETI (Honourable P.R. Bhosale) and YPSC (Honourable R.Y. Patil), Principals of SETI (Dr. M.B. Vanrotti) and YPSC (Dr. G.G. Chougale) for encouraging to organise such an scientific event. Also we are thankful to all the committee members and students. The guest editors would finally like to extend their thanks to all authors who contributed to this special issue.

We would like to express our gratitude to the editorial board of the *International Journal of Nanotechnology* (*IJNT*) and especially to Dr. Lionel Vayssieres, the Editor-in-Chief of the IJNT, for his kind cooperation towards this fruitful output.

# INDIAN INSTITUTE OF TECHNOLOGY KANPUR

## Centre for Continuing Education

## Participation Certificate

This is to certify that **Vinod Vasantrao Vanmore** from **Sanjeevan Engineering & Technology Institute Panhala, Kolhapur MH** attended QIP Short Term Course (online) on "**Multiscale Modeling and Simulation Techniques for 3D Printing**" conducted by the Department of Mechanical Engineering, IIT Kanpur from 8-13 March 2021.

Arvind Kumar
Course Coordinator

Rajesh M Hegde
Head, CCE/QIP

# INDIAN INSTITUTE OF TECHNOLOGY KANPUR

## Centre for Continuing Education

Participation Certificate

This is to certify that **VINOD VASANTRAO VANMORE** from **SANJEEVAN ENGINEERING AND TECHNOLOGY INSTITUTE PANHALA** attended QIP Short Term Course (online) on "**Mechanical Behaviour of Materials"** conducted by the Department of Materials Science and Engineering, IIT Kanpur from *15-20 March 2021*.

| | | | |
|---|---|---|---|
| Nilesh Prakash Gurao | Shashank Shekhar | Sudhanshu Shekhar Singh | Rajesh M Hegde |
| **Course Coordinator** | **Course Co-Coordinator** | **Course Co-Coordinator** | **Head, CCE/QIP** |

No:ATAL/2020/1601829134

# ALL INDIA COUNCIL FOR TECHNICAL EDUCATION

**Nelson Mandela Marg, Vasant Kunj, New Delhi – 110 070**

## AICTE Training And Learning (ATAL) Academy

## *Certificate*

This is certified that **Vinod Vasantrao Vanmore**, **Assistant Professor** of **Sanjeevan Engineering and Technology Institute (SETI, Panhala), Kolhapur** participated & completed successfully AICTE Training And Learning (ATAL) Academy **Online** FDP on "**Micro-electromechanical Systems**" from **2020-11-23** to **2020-11-27** at **SARDAR PATEL COLLEGE OF ENGINEERING**.

Director ATAL Academies

Coordinator

## Dr. Babasaheb Ambedkar Technological University, Lonere
## &
## Sharad Institute of Technology College of Engineering, Yadrav

# Certificate of Participation

This is to certify that **Vinod V. Vanmore** from SETI Panhala Kolhapur has participated in the online faculty development Programme on **'Nearly Zero Energy Building (nZEB)'** from 10$^{th}$ to 14$^{th}$ August 2020.

**Dr. V. S. Hajare**
Co-ordinator
HoD Mechanical Engg.

**Dr. S. A. Khot**
Associate Dean (Academic)
DBATU Lonere
Principal

**Hon. Mr. Anil Bagane**
Executive Director

Sharad Institute of Technology College of Engineering, Yadrav

Certificate No. SIT19847

Certificate No. ECA/MECH/STTP/2021/093

# Engineering College Ajmer
# &
# VJTI Mumbai

## CERTIFICATE

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***In One Week, Short-Term Training Program on***

***"INDUSTRY 4.0 & CONDITION MONITORING"***

***From 15th to 19th March, 2021***

*This is to certify that Vinod Vasantrao Vanmore of Sanjeevan Engineering And Technology Institute Panhala Kolhapur Mh has completed the course successfully.*

| | | | |
|---|---|---|---|
| **Dr. Rekha Mehra** | **Dr. Alok Khatri** | **Dr. Vikas M. Phalle** | **Mr. Vinod K. Verma** |
| Principal, ECA | Coordinator | Coordinator | Coordinator |

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# Certificate
## OF PARTICIPATION

D Y PATIL
COLLEGE of
ENGINEERING & TECHNOLOGY
KASABA BAWADA, KOLHAPUR
(An Autonomous Institute)

This Certificate is hereby awarded to

Vinod Vasantrao Vanmore

Sanjeevan Engineering and Technology Institute Panhala

for proactively participating in the one week online Faculty Development Program on **"Advances in Manufacturing and Materials"** organized by the Department of Mechanical Engineering, **D. Y. Patil College of Engineering & Technology (An Autonomous Institute), Kasaba Bawada, Kolhapur** in association with Indian Society for Technical Education (ISTE), New Delhi during Tuesday, 20th April, 2021 to Saturday, 24th April 2021.

| | | |
|---|---|---|
| **Dr. Sunil J. Raykar** | **Dr. Mahadeo M. Narke** | **Dr. Santosh D. Chede** |
| Convener and Head of Department | Executive Council Member-ISTE | Principal |

No:ATAL/2021/1621835427

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This is certified that **Vinod Vasantrao Vanmore**, **Assistant Professor** of **Sanjeevan Engineering and Technology Institute (SETI, Panhala), Kolhapur** participated & completed successfully AICTE Training And Learning (ATAL) Academy **Online Elementary** FDP on "**Emerging Technologies in Product Design & Development**" from **2021-06-14** to **2021-06-18** at **GOVERNMENT COLLEGE OF ENGINEERING CHANDRAPUR**.

Director ATAL Academies

Coordinator

No:ATAL/2021/1621835293

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**Nelson Mandela Marg, Vasant Kunj, New Delhi – 110 070**

## AICTE Training And Learning (ATAL) Academy

## *Certificate*

This is certified that **Vinod Vasantrao Vanmore**, **Assistant Professor** of **Sanjeevan Engineering and Technology Institute (SETI, Panhala), Kolhapur** participated & completed successfully AICTE Training And Learning (ATAL) Academy **Online Elementary** FDP on "**3D Printing & Design for Innovative Medical Devices**" from **2021-06-28** to **2021-07-02** at **Malaviya National Institute of Technology Jaipur**.

Adviser-I, ATAL Academy

Coordinator

## Faculty Achievement

| | | **Name of Department** | **Mechanical Engineering** | | **Year 2020-21** | |
|---|---|---|---|---|---|---|
| **Sr. No.** | **year** | **Name of the Faculty** | **Event Name** | **Title** | **Journal/college/university Name** | **Date** |
| 1 | 2020-21 | Mr. Rahul Uday Urunkar | National Level Workshop | Digital Transformation & Pedagogies | Government College of Engineering, Karad & Walchand College of Engineering, Sangli | 10/08/2020 to 14/08/2020 |
| 2 | | | Journal paper Publication | Enhancement of heat and mass transfer characteristics of metal hydride reactor for hydrogen storage using various nanofluids | International Journal of Hydrogen Energy | April 2021 |
| 3 | | | Workshop | Disruptive Entrepreneurship-2021 | Karmaveer Adv. Baburao Ganpatrao Thakare College of Engineering, Nashik | 27/05/2021 30/05/2021 |
| 4 | | | Reviwer for SCOPUS Journal | Tech Science Press | Energy Engineering | June 2021 |
| 5 | | | Faculty Develoment Program | Augmented Reality & Virtual Reality | All India Shri Shivaji Memorial Society, College of Engineering, Pune | 21/06/2021 to 25/06/2021 |
| 6 | | | Short Term Training Program | Innovative & Inventive Problem Solving | All India Shri Shivaji Memorial Society, College of Engineering, Pune | 29/06/2021 to 04/07/2021 |

# Government College of Engineering, Karad (Satara) MS
# & Walchand College of Engineering, Sangli, MS

## One Week National Level Workshop on

## "DIGITAL TRANSFORMATION & PEDAGOGIES"

## Sponsored by AICTE, New Delhi & TEQIP III

# CERTIFICATE

This is to certify that Rahul Uday Urunkar of Sanjeevan Engineering and Technology Institute has attended One Week National Level Workshop on "Digital Transformation & Pedagogies" organized during August 10-14, 2020, by Government College of Engineering, Karad & Walchand College of Engineering, Sangli, Sponsored by AICTE, New Delhi & TEQIP III

| Dr. S. P. Deshmukh | Dr. B. S. Gawali | Dr. K. H. Inamdar | Dr. V. B. Dharmadhikari | Dr. A. T. Pise |
|---|---|---|---|---|
| Convener, GCE | Convener, WCE | HoD, MED, WCE | TEQIP Coordinator, WCE | Principal, GCE |

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# Enhancement of heat and mass transfer characteristics of metal hydride reactor for hydrogen storage using various nanofluids

*Rahul U. Urunkar**, *Sharad D. Patil*

*Department of Mechanical Engineering, RIT, Rajaramnagar, Affiliated to Shivaji University, Kolhapur, Maharashtra, India*

## HIGHLIGHTS

- Developed and validated numerical model of metal hydride reactor for hydrogen storage.
- Selected various nanofluids for heat and mass transfer enhancement.
- Presented performance for $Al_2O_3/H_2O$, $CuO/H_2O$ and $MgO/H_2O$ nanofluid.
- Reported 10% improvement in the heat transfer rate for $CuO/H_2O$ nanofluid.
- Absorption time is lowered by 9.5% for given conditions.

## ARTICLE INFO

*Article history:*
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Received in revised form
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Hydrogen
Metal hydride
$MmNi_{4.6}Al_{0.4}$
Nanofluid
Heat transfer

## ABSTRACT

The execution of metal hydride reactor (MHR) for storage of hydrogen is greatly affected by thermal effects occurred throughout the sorption of hydrogen. In this paper, based on different governing equations, a numerical model of MHR filled by $MmNi_{4.6}Al_{0.4}$ is formed using ANSYS Fluent for hydrogen absorption process. The validation of model is done by relating its simulation outcomes with published experimental results and found a good agreement with a deviation of less than 5%; hence present model accuracy is considered to be more than 95%. For extraction or supply of heat, water or oil is extensively used in MHR during the absorption or the desorption process so as to improve the competency of the system. Since nanofluid (mixture of base fluid and nanoparticles) has a higher heat transfer characteristics, in this paper the nanofluid is used in place of the conventional heat transfer fluid in MHR. Further the numerical model of MHR is modified with nanofluid as heat extraction fluid and results are presented. The $Al_2O_3/H_2O$, $CuO/H_2O$ and $MgO/H_2O$ nanofluids are selected and simulations are carried out. The results are obtained for different parameters like nanoparticle material, hydrogen concentration, supply pressure and cooling fluid temperature. It is seen that 5 vol% $CuO/H_2O$ nanofluid is thermally superior to $Al_2O_3/H_2O$ and $MgO/H_2O$ nanofluid. The heat transfer rate improves by the increment in the supply pressure of hydrogen as well as decrement in temperature of nanofluid. The $CuO/H_2O$ nanofluid increases the heat transfer rate of MHR up to 10% and the hydrogen absorption time is improved by 9.5%. Thus it is advantageous to use the nanofluid as a heat transfer cooling fluid for the MHR to store hydrogen.



* *Corresponding author.*
E-mail addresses: rahul.urunkar1991@gmail.com (R.U. Urunkar), sharad.patil@ritindia.edu, p2sharad@yahoo.com (S.D. Patil).
https://doi.org/10.1016/j.ijhydene.2021.03.090

Maratha Vidya Prasarak Samaj's

# Karmaveer Adv. Baburao Ganpatrao Thakare College of Engineering, Nashik

KBTCOE

ACCREDITED WITH GRADE A NAAC

## Department of Master of Business Administration (MBA)

in association with

## ED Cell and Internal Quality Assurance Cell

## Certificate of Participation

# Mr. Rahul Uday Urunkar

of

*Sanjeevan engineering and technology Institute*

is awarded with certificate for active participation in 4 days online workshop on **'Disruptive Entrepreneurship-2021'** conducted on **27th May 2021 to 30th May 2021.**

| | | | |
|---|---|---|---|
| **Mr. D. D. Kulkarni**<br>**IQAC Coordinator** | **Dr. D. T. Khairnar**<br>**Head of Department (MBA)** | **Prof N. B. Desale**<br>**Vice-Principal** | **Dr. S.R. Devane**<br>**Principal** |

Gmail

Rahul Urunkar <rahul.urunkar1991@gmail.com>

## [energy] Registration as Reviewer with Energy Engineering

1 message

**Energy Engineering** <admin1@tspsubmission.com> Wed, Jun 2, 2021 at 2:33 AM
To: "Rahul U. Urunkar" <rahul.urunkar1991@gmail.com>

Dear Rahul U. Urunkar,

In light of your expertise, we have taken the liberty of registering your name in the reviewer database for Energy Engineering. This does not entail any form of commitment on your part, but simply enables us to approach you with a submission to possibly review. On being invited to review, you will have an opportunity to see the title and abstract of the paper in question, and you'll always be in a position to accept or decline the invitation. You can also ask at any point to have your name removed from this reviewer list.

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Thank you,

---

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871 Coronado Center Drive, Suite 200,
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Email: Energy@techscience.com

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## DEPARTMENT OF ELECTRONICS AND TELECOMMUNICATION ENGINEERING

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| | | | |
|---|---|---|---|
| Mr.N.P.Mawale | Mr.Arjun Ghule | Dr.D.G.Bhalke | Dr.D.S. Bormane |
| Mr.V.B.Gawai | Director | Convener and | Principal |
| Coordinator(s) | RBG Group | HOD(E&TC) | |

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This is to certify that

**Rahul Uday Urunkar** from **Sanjeevan Engineering and Technology Institute**

has participated in AICTE Quality Improvement Scheme (AQIS) sponsored

one week online Short Term Training Program on

## "Innovative & Inventive Problem Solving"

organised by Department of Production Engineering, AISSMS COE, Pune during 29th June to 04th July 2021.

STTP-IIPS-P2-2021000162

Dr S H Wankhade
Head, Department of
Production Engineering

AISSMS COLLEGE OF ENGINEERING PUNE

Dr D S Bormane
Principal
AISSMS COE, Pune

## Faculty Achievement

| | | Name of Department | Mechanical Engineering | | Year 2020-21 | |
|---|---|---|---|---|---|---|
| **Sr. No.** | **year** | **Name of the Faculty** | **Event Name** | **Title** | **Journal/college/university Name** | **Date** |
| 1 | 2020-21 | Mr. Deshmukh Sardar Balaso | Faculty Develoment Program | Research in Energy Technologies | Bharati Vidyapith College of Engineering, Pune | 06-07-2020 to 11-07-2020 |
| 2 | 2020-21 | Mr. Deshmukh Sardar Balaso | Faculty Develoment Program | Recent trends in heat exchangers (RTHX 2020) | Walchand College of Engineering, Sangli | 13-07-2020 to 18-07-2020 |
| 3 | 2020-21 | Mr. Deshmukh Sardar Balaso | Faculty Develoment Program | Electro-Mechanical Systems | Walchand College of Engineering, Sangli | 20-07-2020 to 25-07-2020 |
| 4 | 2020-21 | Mr. Deshmukh Sardar Balaso | Workshop | Digital Transformation & Pedagogies | Government College of Engineering, Karad & Walchand College of Engineering, Sangli. | 10-08-2020 to 14-08-2020 |
| 5 | 2020-21 | Mr. Deshmukh Sardar Balaso | Faculty Develoment Program | Blended Learning and Flipped Classroom | National Institute of Technical Teachers Training & Research, Chandigarh | 31-08-2020 to 04-09-2020 |
| 6 | 2020-21 | Mr. Deshmukh Sardar Balaso | Short Term Training Program | Teaching Learning Pedagogies | A. G. Patil Polytechnic, Solapur | 07-09-2020 to 12-09-2020 |
| 7 | 2020-21 | Mr. Deshmukh Sardar Balaso | Faculty Develoment Program | Alternate Fuels | Don Bosco Institute of Technology | 21-09-2020 to 25-09-2020 |
| 8 | 2020-21 | Mr. Deshmukh Sardar Balaso | Faculty Develoment Program | Emotional Intelligence | Motilal Nehru Institute of Technology Allahabad | 18-01-2021 to 22-01-2021 |
| 9 | 2020-21 | Mr. Deshmukh Sardar Balaso | Faculty Develoment Program | Research at A Glance | Sinhgad Institutes, Pune | 18-01-2021 to 23-01-2021 |
| 10 | 2020-21 | Mr. Deshmukh Sardar Balaso | Faculty Develoment Program | Outcome Based Education (OBE) and Accreditation Process | Government Residence Women Polytechnic Tasgaon | 14-06-2021 to 18-06-2021 |
| 11 | 2020-21 | Mr. Deshmukh Sardar Balaso | Faculty Develoment Program | Applications of Artificial Intelligence in Mechanical Engineering | K. Ramakrishnan College of Engineering | 02-08-2021 to 08-08-2021 |

# BHARATI VIDYAPEETH
# (DEEMED TO BE UNIVERSITY),
# COLLEGE OF ENGINEERING, PUNE

## Department of Mechanical Engineering

# *CERTIFICATE OF PARTICIPATION*

This is to certify that **Prof. Sardar Balaso Deshmukh** from **Sanjeevan Engineering & Technology Institute, Panhala** has participated and completed ***One week Faculty Development Programme on 'Research in Energy Technologies'*** from *6$^{th}$ July, 2020 to 11$^{th}$ July, 2020* organized by Department of Mechanical Engineering.

**Dr. D. G. Kumbhar**
**Convener, FDP**
**Professor**

**Dr. Kailasnath Sutar**
**Co- Chairman, FDP**
**Head of Department**

**Dr. Anand Bhalerao**
**Chairman, FDP**
**Principal, BV(DU)COEP**

# WALCHAND COLLEGE OF ENGINEERING, SANGLI

## ONE WEEK FACULTY DEVELOPMENT PROGRAM ON
## "RECENT TRENDS IN HEAT EXCHANGERS (RTHX 2020)"
## IN A DISTANCE MODE UNDER TEQIP III

# CERTIFICATE

This is to certify that **Prof. Sardar Balaso Deshmukh** of **Sanjeevan Engineering & Technology Institute, Panhala** has participated in one week faculty development program on "Recent trends in heat exchangers (RTHX 2020) " in a distance mode from 13/07/2020 to 18/07/2020, organized by Department of Mechanical Engineering, Walchand College of Engineering, Sangli.

| | | |
|---|---|---|
| Prof. Dr. B. S. Gawali<br>Co-ordinator, RTHX 2020 | Dr. K. H. Inamdar<br>HOD | Director<br>WCE, Sangli |

# WALCHAND COLLEGE OF ENGINEERING, SANGLI

One Week Faculty Development Program On

## "Electro-Mechanical Systems"

in a distance mode under TEQIP III

TEQIP III

# CERTIFICATE

This is to certify that **Prof. Sardar Balaso Deshmukh** of **Sanjeevan Engineering & Technology Institute, Panhala** has participated in One Week Faculty Development Program on "Electro-Mechanical Systems " in a distance mode, organized during July 20-25, 2020, by Department of Mechanical Engineering, Walchand College of Engineering, Sangli - 416 415.

| | | |
|---|---|---|
| **Prof. Dr. B. S. Gawali** | **Dr. K. H. Inamdar** | **Dr. V. B. Dharmadhikari** |
| Co-ordinator | HOD, Mechanical Engg. Dept. | TEQIP Co-ordinator |

# Government College of Engineering, Karad (Satara) MS
# & Walchand College of Engineering, Sangli, MS

One Week National Level Workshop on

## “DIGITAL TRANSFORMATION & PEDAGOGIES”

Sponsored by AICTE, New Delhi & TEQIP III

# CERTIFICATE

This is to certify that Prof. Sardar Balaso Deshmukh of Sanjeevan Engineering & Technology Institute, Panhala has attended One Week National Level Workshop on "Digital Transformation & Pedagogies” organized during August 10-14, 2020, by Government College of Engineering, Karad & Walchand College of Engineering, Sangli, Sponsored by AICTE, New Delhi & TEQIP III

TEQIP III

| Dr. S. P. Deshmukh | Dr. B. S. Gawali | Dr. K. H. Inamdar | Dr. V. B. Dharmadhikari | Dr. A. T. Pise |
|---|---|---|---|---|
| Convener, GCE | Convener, WCE | HoD, MED, WCE | TEQIP Coordinator, WCE | Principal, GCE |

No:ATAL/2020/1596434148

# ALL INDIA COUNCIL FOR TECHNICAL EDUCATION

Nelson Mandela Marg, Vasant Kunj, New Delhi – 110 070

## AICTE Training And Learning (ATAL) Academy

## *Certificate*

This is certified that **Sardar Balaso Deshmukh**, **Assistant Professor** of **Sanjeevan Engineering & Technology Institute, Panhala** participated & completed successfully AICTE Training And Learning (ATAL) Academy **Online** FDP on "**Blended Learning and Flipped Classroom**" from **2020-8-31** to **2020-9-4** at **National Institute of Technical Teachers Training & Research, Chandigarh**.

Director ATAL Academies

Coordinator

Shanti Education Society's

# A. G. Patil Polytechnic Institute, Solapur

Opp. SRP Camp, Vijapur road, Solapur-413 008 (Maharashtra)

(All Programs NBA Accredited)

# Certificate of Completion

This is to certify that

## Mr. DESHMUKH SARDAR BALASO

(Sanjeevan Engineering & Technology Institute, Panhala)

has successfully completed one week online STTP on "Teaching Learning Pedagogies" Approved & Funded by All India Council for Technical Education, New Delhi - Quality Improvement Scheme (AQIS), conducted by Department of Mechanical Engineering from 7th Sept to 12th Sept 2020.

*AICTE Approval No.34-65/12/RIFD/STTP/Policy-1/2018-19 dated 01 June 2020*

| | | |
|---|---|---|
| Mr. S. K. Mohite | Mr. J. M. Jaketia | Dr. M. A. Chougule |
| Coordinator-STTP | Vice Principal | Principal |

No:ATAL/2020/1600015215

# ALL INDIA COUNCIL FOR TECHNICAL EDUCATION

**Nelson Mandela Marg, Vasant Kunj, New Delhi – 110 070**

## AICTE Training And Learning (ATAL) Academy

## *Certificate*

This is certified that **Sardar Balaso Deshmukh**, **Assistant Professor** of **Sanjeevan Engineering & Technology Institute, Panhala** participated & completed successfully AICTE Training And Learning (ATAL) Academy **Online** FDP on "**Alternate Fuels**" from **2020-9-21** to **2020-9-25** at **DON BOSCO INSTITUTE OF TECHNOLOGY**.

Director ATAL Academies

Coordinator

No:ATAL/2021/1609922979

# ALL INDIA COUNCIL FOR TECHNICAL EDUCATION

Nelson Mandela Marg, Vasant Kunj, New Delhi – 110 070

## AICTE Training And Learning (ATAL) Academy

## *Certificate*

This is certified that **Sardar Balaso Deshmukh**, **Assistant Professor** of **Sanjeevan Engineering & Technology Institute, Panhala** participated & completed successfully AICTE Training And Learning (ATAL) Academy **Online** FDP on "**Emotional Intelligence**" from **2021-1-18** to **2021-1-22** at **Motilal Nehru Institute of Technology Allahabad**.

Director ATAL Academies

Coordinator

LET'S LEARN AND GROW TOGETHER

# CERTIFICATE

OF APPRECIATION

SINHGAD TECHNICAL EDUCATION SOCIETY, PUNE

तमसो मा ज्योतिर्गमय

Sinhgad Institutes

**THIS CERTIFICATE IS PROUDLY PRESENTED TO**

## Mr. Sardar B. Deshmukh

of

## SETI, Panhala

**For attending 6 Days FDP on "Research at A Glance: Current Protocols" For the Period of 18th to 23rd January, 2021.**

Head, Mech. Engg. Dept.

Principal, SIT, Lonavala

Dattatraya Khodake

Team LLAGT

Certificate ID: WVEPTM-CE000168

6 Days FDP on "Research at a Glance: Current Protocols | LLAGT

No:ATAL/2021/1620636308

# ALL INDIA COUNCIL FOR TECHNICAL EDUCATION

Nelson Mandela Marg, Vasant Kunj, New Delhi – 110 070

## AICTE Training And Learning (ATAL) Academy

## *Certificate*

This is certified that **Sardar Balaso Deshmukh**, **Assistant Professor** of **Sanjeevan Engineering & Technology Institute, Panhala** participated & completed successfully AICTE Training And Learning (ATAL) Academy **Online Elementary** FDP on "**Outcome Based Education (OBE) and Accreditation Process**" from **2021-06-14** to **2021-06-18** at **Government Residence Women Polytechnic Tasgaon**.

Director ATAL Academies

Coordinator

No:ATAL/2021/1626247574

# ALL INDIA COUNCIL FOR TECHNICAL EDUCATION

Nelson Mandela Marg, Vasant Kunj, New Delhi – 110 070

## AICTE Training And Learning (ATAL) Academy

## *Certificate*

This is certified that **Sardar Balaso Deshmukh**, **Assistant Professor** of **Sanjeevan Engineering & Technology Institute, Panhala** participated & completed successfully AICTE Training And Learning (ATAL) Academy **Online Elementary** FDP on "**Applications of Artificial Intelligence in Mechanical Engineering**" from **2021-8-2** to **2021-8-6** at **K. RAMAKRISHNAN COLLEGE OF ENGINEERING**.

Adviser-I, ATAL Academy

Coordinator

## Faculty Achievement

| | | Name of Department | Mechanical Engineering | | Year 2020-21 | |
|---|---|---|---|---|---|---|
| **Sr. No.** | **year** | **Name of the Faculty** | **Event Name** | **Title** | **Journal/college/university Name** | **Date** |
| 1 | 2020-21 | Mr. Dhananjay Vasantrao Patil | Webinar | Numerical Investigation of flow and heat transfer using nanofluids | Francis Xavier Engineering College | 7/4/2020 |
| 2 | | | Faculty Develoment Program | Role of national education policy for national development | Karmayogi Engineering College, Shelve Pandharpur | 30/03/2021 |
| 3 | | | Faculty Develoment Program | Advances in manufacturing & materials | D.Y.Patil college of engineering and technology, kolhapur. | 20/04/2021 to 24/04/2021 |

FRANCIS XAVIER ENGINEERING COLLEGE

AN AUTONOMOUS INSTITUTION

ACCREDITED BY NBA

ISO 9001:2015 Certified | DST-FIST Supported Institution

Recognized under Section 2(f) & 12(B) of the UGC Act, 1956

Vannarpettai, Tirunelveli - 627003, Tamil Nadu

INSTITUTION'S INNOVATION COUNCIL

(Ministry of HRD Initiative)

# *Certificate of Participation*

This is to certify that **DHANANJAY PATIL** has actively participated in the webinar **"Numerical Investigation of flow and heat transfer using Nanofluids"**, presented by **Dr.David Santosh Christopher, Associate Professor,Department Of Mechanical Engineering, Wolaita Sodo University,Ethiopia** which was organized by Department of Mechanical Engineering, Francis Xavier Engineering College, Tirunelveli on 04.07.2020.

| | | |
|---|---|---|
| **Mr. M.Muthu kumar** | **Dr.S.Joe patrick** | **Dr.V.Velmurugan** |
| **CONVENOR/MECH** | **HOD/MECH,FXEC** | **PRINCIPAL, FXEC** |

Shri Pandurang Pratishthan Pandharpur's

# Karmayogi Engineering College, Shelve Pandharpur

Approved by AICTE, New Delhi, Recognised by Govt. Maharashtra and Director of Technical Education, Mumbai
Affiliated to Dr. Babasaheb Ambedkar Technological University, Lonere
Accredited with B++ Grade by NAAC

TEQIP III

## Certificate of Participation

This certificate declares that,

**Patil Dhananjay Vasantrao**

has participated in One day Online Faculty Development Program on the "**Role of National Education Policy for National Development**" organized by **Karmayogi Engineering College, Shelve Pandharpur** on 30 March 2021 sponsored by DBATU, Lonere TEQIP-III.

| | | | | |
|---|---|---|---|---|
| **Mr. D. V. Bhosale**<br>Convener | **Mr. J. L. Mudegaonkar**<br>Convener | **Dr. S. P. Patil**<br>Principal | **Dr. S. B. Deosarkar**<br>Institute Project Director<br>TEQIP-III, DBATU Lonere | **Mr. Rohan Paricharak**<br>Trustee, SPP |

YouTube Karmayogi Engineering
www.karmayogiengg.com

D Y PATIL
COLLEGE of ENGINEERING & TECHNOLOGY
KASABA BAWADA, KOLHAPUR
(An Autonomous Institute)

# Certificate
## OF PARTICIPATION

This Certificate is hereby awarded to

Mr. Dhananjay Vasantrao Patil

Sanjeevan Engineering and Technology Institute,Panhala.

for proactively participating in the one week online Faculty Development Program on **"Advances in Manufacturing and Materials"** organized by the Department of Mechanical Engineering, **D. Y. Patil College of Engineering & Technology** (An Autonomous Institute), Kasaba Bawada, Kolhapur in association with Indian Society for Technical Education (ISTE), New Delhi during Tuesday, 20th April, 2021 to Saturday, 24th April 2021.

| Dr. Sunil J. Raykar | Dr. Mahadeo M. Narke | Dr. Santosh D. Chede |
|---|---|---|
| Convener and Head of Department | Executive Council Member-ISTE | Principal |

| Faculty Achievement | | | | | | |
|---|---|---|---|---|---|---|
| | | Name of Department | Mechanical Engineering | | Year 2020-21 | |
| Sr. No. | year | Name of the Faculty | Event Name | Title | Journal/college/university Name | Date |
| 1 | 2020-21 | Mr. Praveen Shivaji Atigre | Faculty Development Program | Research at A Glance: Current Protocols | SIT, Lonavala | 18/01/2021 to 23/01/2021 |

LET'S LEARN AND GROW TOGETHER

Sinhgad Technical Education Society, Pune
तमसो मा ज्योतिर्गमय
Sinhgad Institutes

# CERTIFICATE

## OF APPRECIATION

**THIS CERTIFICATE IS PROUDLY PRESENTED TO**

**Mr. Praveen Shivaji Atigre**

**of**

**Sanjeevan Engineering and Technology Institute Panhala**

**For attending 6 Days FDP on**

**"Research at A Glance: Current Protocols"**

**For the Period of 18th to 23rd January, 2021.**

Head, Mech. Engg. Dept.

Principal, SIT, Lonavala

Team LLAGT

Certificate ID: WVEPTM-CE000130

6 Days FDP on "Research at a Glance: Current Protocols | LLAGT