Agility through Product design in the era of Industry 4.0

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Abstract: Industry 4.0 demands the aggressive implementation of IT and communication devices and infrastructure to integrate machines in the factories so as to execute the operations with the characteristics namely interoperability and flexibility at unimaginable high speed. This kind of facility will enable companies to design and manufacture products for supplying to the individual customers. By implementing industry 4.0 enablers, mass customization is achieved. Mass customization is an outcome of implementing agile manufacturing paradigm. Obviously, this derivation implies that application of Industry 4.0 will enable the companies to implement agile manufacturing paradigm by acquiring agility. Though accomplishment of this goal is going to help the industries to flourish, attaining this goal is going to be a challenge. The major challenge is that the designing of products has to be carried out to tune with the requirements of the Industry 4.0 requirements. This challenge is addressed in this article by indicating the actions to be executed for this purpose and presenting a case study.

Keywords: Agile Manufacturing; Industry 4.0; Mass customization; Craft Production; Automation; Pump manufacturing

INTRODUCTION

Right from the days when man became engineer, product design has been playing a crucial role in changing the behavioral patterns of factories, humans and societies [9]. Product design would have been the first design of any manufacturing activity [10,11,12]. One of the earliest product design activity might be the changing of the shape of the stones to develop weapons to kill animals as prey for humans. As soon as the designing of this stone made weapon would have been completed, humans would have started the manufacturing of such stone made weapons [13,14,15,16]. After manufacturing those weapons, the productivity and quality of catching preys by the humans would have been increased [17- 19]. This act would have changed the behavioral pattern of hunting for preys and eating habits of the humans who used those preys [21-32]. This phenomenon has been happening in the world through all the centuries that have passed after humans became designers. During these many centuries, the man designed millions of products which changed the behavioral patterns of factories, humans and societies [33-42]. This kind of situation began to change when the world witnessed the intensification of competition. Because of this situation, the behavioral patterns of factories, humans and societies changed. This development indicated that the products need to be designed to suit the behavioral pattern of not only the factories but also the humans and societies [43-51]. In other words, the product design should be compatible with the various paradigms that have been emerging in the world to meet different kinds of customer requirements [52-61].

A study of the history indicates that the world witnessed the emergence of different paradigms due to the appearance of four industrial revolutions. During the first industrial revolution, machines were produced to manufacture products. During the second industrial revolution, steam engines were produced to run machines and produce the products. During the third industrial revolution, electrical motors were used to drive machines for manufacturing products [62-69]. During the fourth industrial revolution, Information Technology (IT) was infused in manufacturing field. This fourth industrial revolution began from the beginning of this 21st century. Industry 4.0 demands the aggressive implementation of IT and communication devices and infrastructure to integrate machines in the factories so as to execute the operations with the characteristics namely interoperability and flexibility at unimaginable high speed. This kind of facility will enable companies to design and manufacture products for supplying to the individual customers [70-84]. Thus, on applying industry 4.0 enablers the outcomes of craft manufacturing can be obtained but by spending least resources (Buer et al 2018). In other words, by implementing industry 4.0 enablers, mass customization is achieved. Mass customization is an outcome of implementing agile manufacturing paradigm. Obviously, this derivation implies that application of Industry 4.0 will enable the companies to implement agile manufacturing paradigm by acquiring agility.

PRODUCT DESIGN FOR AGILITY

As mentioned in the previous section, agility is a set of characteristics that would enable an organization t react quickly in accordance with the dynamic demands of the customers without compromising profitabilit Agility is infused in organization through the implementation of agile manufacturing paradigm [85-89]. I order to enable an organization to exhibit agility, the product should be designed in such a way that it ca be reconFigd and modified to suit the requirements of customers. One way of carrying out this task is b choosing several components whose functions are same. For example, while designing a gear box, provisio should be made to assemble either cast iron gear or plastic gear. Another way is to design the product i such a way that it can be reconFigd by applying CAD technology and manufactured by applying eith Cyber Physical system (CPS) or additive manufacturing technologies. Thus, the design engineers have t apply these approaches either separately or in combined form, to facilitate the acquirement of agility throug product design.

Industry 4.0

As the competition is becoming very intensive, in order to design a product to suit agility, the Information Communication and Technology (ICT) devices are required to be exploited. Meanwhile, it is necessary to design products to suit their manufacturing under Industry 4.0 environment. As mentioned earlier, Industry 4.0 stipulates the linking of machines and thereby establishing communication among them to achieve interoperation ability and flexibility in manufacturing. The three main enablers of Industry 4.0 are Internet of things (IoT), CPS and Cloud manufacturing (Fatorachian and Kazemi, 2018). IoT refers to the practice of using internet as the central medium for exchanging data and information among the machines and supporting devices. CPS refers to the practice of fixing necessary devices in the machines so that communication is established among the machines and hence any changes to be carried out are executed by the machine itself. Cloud manufacturing refers to the utilization of cloud computing to store data by the organization in the cloud systems and carry out the operations by availing the services available in those systems.

Besides the three enablers mentioned above, few other enablers like additive manufacturing, big data analytics and machine learning are also required to be executed when need arises in Industry 4.0 environment. Some of the devices used while executing these enablers are Radio Frequency Identification (RFID), actuators and sensors. After the release of Industry 4.0, the products to be used under Industry 4.0 requirement are required to be designed in such a way that, they facilitate the establishment of communication and flexibility by making used of all these enablers and devices. Abundant theoretical works on Industry 4.0 have been reported by the researchers. However very little application oriented works on Industry 4.0 have been reported by the researchers. Further, the practice of designing products to suit Industry 4.0 requirements is yet to be addressed. On noticing this gap, a work on integrating IoT with designing of a centrifugal pump which was carried out about two years back as part of a Ph.D. work is reported in the next section.

CASE STUDY

The construction of a centrifugal monoblock pump is shown in Fig 1. As shown a centrifugal monoblock pump consists of two units. One unit is the electrical motor and the other unit is pump unit. Normally induction type electrical motors are used in the centrifugal monoblock pump. The electrical motor consists of a stator and rotor. The stator unit is made by winding copper coils. The rotor unit is connected to the drive shaft. The drive shaft extends to the pump unit. At the end of drive shaft, impeller is connected. The impeller connected to the drive shaft is enclosed inside the volute casting of the pump unit.

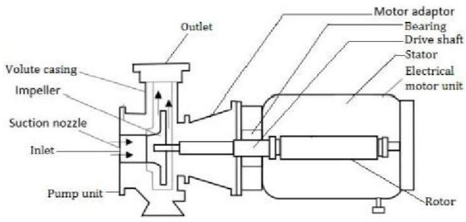

Fig 1-Construction of centrifugal monoblock pump

The efficiency of the performance of the centrifugal pump is dependent on the performance of electrical motor, volute casing and impeller. In the pump unit, there are two openings which are called as inlet and outlet. The inlet is connected to a pipe through which the liquid at the lower altitude enters into the volute casing. The outlet is connected to the pipe through which the liquid entered into the volute casing is pumped to a location at a higher altitude. The impeller is made in the form of blades. This blade has to be made in the form of a curve. This curve is made in such a way that the air is sucked from the inlet and delivered at the outlet. The volute casing should be designed and manufactured in such a way that air and liquid entered into it do not leak from it. The driver shaft is required to transfer power from the electrical motor unit without any loss. Besides the driver shaft should be fixed between bearings in such a way that it is run at high speed.

When the electrical connection is switched on, the electrical motor rotates the driver shaft. Hence in the volute casing, the impeller rotates. Due to the rotation of impeller in the volute casing, the air present in it is driven through outlet. This process creates vacuum in the volute casing. In order to fill this vacuum, air tries to enter into the inlet. When inlet is connected to a liquid source through pipe, due to the vacuum created in the volute casting and in the absence of air, the water enters into the volute casing. As there is no more air present tin the volute casing, the continued impeller rotation causes the liquid to flow out through the outlet.

As the pumping of liquid in volute casing is carried out through a simple process and hence, minimum maintenance is required to ensure the defect free and interruption free operation of the centrifugal monoblock pump. Because of this merit, from 1950s onwards, several manufacturers in the world began to manufacture portable centrifugal pump. Due to the same reason, people from different parts of world also began to use portable centrifugal pump. For example, people living in single storey houses began to use portable centrifugal pump to pump water from sump to the overhead tank. The centrifugal pumps are also used largely in manufacturing companies to pump water from tanks and wells to the different locations. Because of the wide usage of the centrifugal pumps, many companies manufacturing centrifugal pumps were started in many countries of the world from 1950 onwards. These companies aided the countries to generate significant wealth and employment opportunities.

When the world community began to use centrifugal pumps, the design was not good enough to perform these pumps at high efficiency. In the field of pump manufacturing, it has been a challenge to design and produce portable centrifugal pump whose efficiencies are about 60%. Those olden day pumps were designed and manufactured in two separate units namely the electrical motor and pump. Those units were heavy and sturdy. These features of design prevented the olden day's centrifugal pumps to be portable enough for easy handling to install them in different locations. Moreover, in those olden days, the design of the blades of the

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impellers of centrifugal pumps were not optimised. Because the design of blades was not optimised, the delivery of liquid per unit time was very less in comparison to that is observed in modern day pumps. In order to overcome these deficiencies, researchers and practitioners concentrated on improving the design of centrifugal pumps.

In order to reduce the size and weight of pumps, the designers began to develop pump and motor units as an integral unit. Further, works were carried out to use material with low density for developing portable centrifugal pump. This kind of development took place till 1980s. However, after 1980s, the pace of emergence of new designs in pump manufacturing arena became slow. During this period, the growth of pump Industry in terms of the volume of pumps sold and revenue generation began to decline. This is due to the reason that the changing taste of the customers and increasing competition through the entry of numerous competitors into the market enabled the customers to demand value addition in the form of incorporation of innovative features in the products. Since, researchers and practitioners associated with the pump industry have been failing to react to this kind of customers' expectations and aspirations, the pump industry has been exhibiting declined growth in the past little more than a decade (Zhong et al 2018). The need of the hour is to evolve solutions that would overcome this deficient situation so as to brighten the future of pump Industry. This solution lies in infusing agility characteristics in the case of designing, developing and manufacturing portable centrifugal pumps. Such a solution is presented in the following subsections.

A. Modelling of the individual components of the centrifugal monoblock pump by using CAD packages

In order to digitize the design, the three dimensional (3D) models of the components of a centrifugal monoblock pump were modelled in Creo 3.0. The 3D models thus developed are shown in the Figs 2-6.

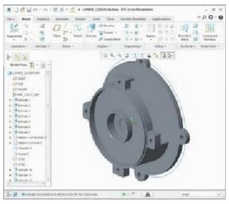


Fig 1 3D model of adaptor

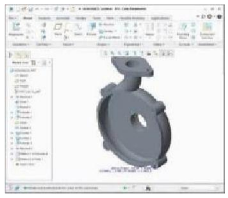


Fig 2 3D model of pump casing

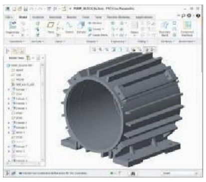


Fig 3-3D model of stator

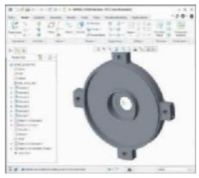
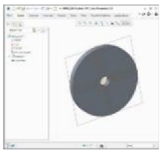


Fig 4-3D model of lower cover



Fige 6-3D model of impeller

B. Assembling the CAD models of the components to digitize the centrifugal monoblock pump

The 3D models of the components of centrifugal monoblock pump were assembled by using the assemble option in PTC Creo 3.0. The creation of the 3D model of the assembled chosen centrifugal monoblock pump was carried out in Creo 3.0 by following the steps presented in Table 1.

Table 1-Steps followed to assemble the centrifugal monoblock pump

Step Number	**Components and subassemblies assembled**	**Constraints considered**
1	Stator	Default constraint-Assembles stator component at default location
2	Upper cover	Coincident constraint- stator component reference coincident to the assembly reference
3	Pump casing	Automatic constraint- upper cover to component reference automatic the assembly reference

4	Impeller	Coincident constraint- pump casing to component reference coincident the assembly reference
5	Lower cover	Coincident constraint- stator component reference coincident to the assembly reference

The 3D model of the assembled chosen centrifugal monoblock pump is shown in Fig 7.

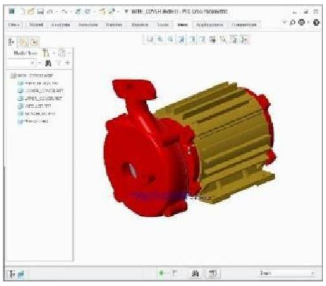


Fig 5-Assembled digitized version of the centrifugal monoblock pump

The creation of models of components and assembled chosen centrifugal monoblock pump marked the digitization of the chosen centrifugal monoblock pump. Subsequently, the 2D drawings of the 3D models were extracted by using the facility called 'drawing' in PTC Creo 3.0.

C. Functional agility through digitization

The centrifugal monoblock pumps are most commonly used in houses. Generally a centrifugal monoblock pump is placed outside the house. In order to switch on or switch off the pump, the user has to come out of the house. In this modern era, users like devices which can be operated by using remote controlling devices. Modern customers buy products like TV, audio system and air conditioning only when are incorporated with remote controlling facility. Considering this customer preference as the functional agility feature, it was decided to accommodate remote controlling features in the centrifugal monoblock pump being manufactured in Jay Pumps.

Instead of designing a new remote control, it was decided to use a smart mobile phone as the remote controlling device. In order to support the use of mobile phone for remotely controlling the centrifugal monoblock pump, one hardware unit and software unit had to be developed. This hardware unit is named as 'smart pump system' and fixed in the centrifugal monoblock pump. The software unit had to be developed as an 'app' and installed in the smart mobile phone. This 'app' is given the name 'smart monoblock pump app'. The smart pump system and 'smart monoblock pump app' are connected wirelessly by using Bluetooth technology. The construction and working of this smart pump system and smart centrifugal monoblock pump system are described in the following two subsections.

SMART PUMP SYSTEM

In order to check the feasibility of this smart pump system, initially a virtual simulation of the schematic design was carried out in Proteus Software. Proteus can be used to simulate the microcontrollers based designs during the design phase. The schematic layout of smart pump system designed by using Proteus is shown in Fig 8. As shown, this schematic circuit is incorporated with Acorn RISC (Reduced Instruction Set Computing) Machine (ARM) microcontroller, Liquid Crystal Display (LCD) screen for displaying the output and six sensors. The ARM microcontroller in this schematic layout was conFigd by using the Keilμvision 4 (hereafter referred to as Keil). In order to carry out this configuration, the commands were written by using C language. This C program was entered in Keil. This entering of C program is shown in Fig 9. Then this program was mapped with the ARM microcontroller in the schematic layout deigned by using Proteus. The results of simulation runs of the schematic layout were observed. These results indicated that the smart pump system will work without any flaws.

By referring to the schematic layout, the prototype of the smart pump system was developed. This prototype is shown in Fig 10. As shown in Fig 10, the main components of this prototype circuit were ARM microcontroller, Bluetooth module, sensors and relay switches. The ARM microcontroller will carry out all the operations in accordance with the commands of the C program coded earlier in the Keil. The Bluetooth module in the smart pump system will enable the ARM microcontroller to receive and send the signals to the mobile phone device. The signals are received from the mobile phone through the Bluetooth module present in the system. The received signal will be processed in the ARM microcontroller and the corresponding operation will be carried out. This smart pump system will have to be installed in the centrifugal monoblock pump.

In order to control the smart pump system, an android app named 'smart monoblock pump app' was developed. The android operating system was chosen as it is the most commonly installed operating system in many smart phones used all over the world (Webopedia, 2015). The android applications are generally written in Java programing language in the Eclipse Software Development

Kit (SDK) (Androidauthority, 2015). This Eclipse SDK package is incorporated with sample codes, tutorials, debugger and also handset emulator. The handset emulator in the SDK package will enable the android developer to virtually test the developed application in different mobile phone models. The 'smart monoblock pump app' was developed by coding using java language. This program was tested by running and debugging its codes in the Eclipse software. Then the developed android application was installed in a smart mobile phone device. Subsequently, this 'smart monoblock pump app' was paired with the Bluetooth module in the smart pump system in order to transmit signals among them.

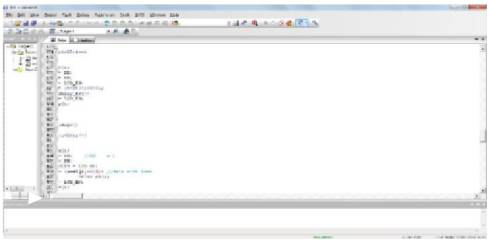


Fig 1-Simulation of the circuit in Proteus software

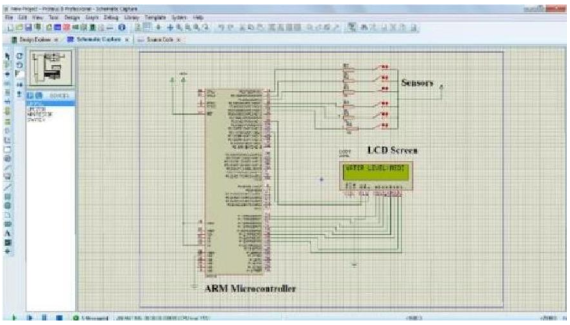


Fig 2-C program coded and tested in Keil µvision 4 software

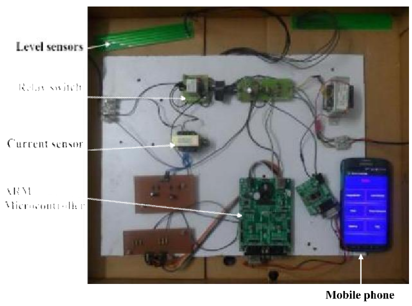
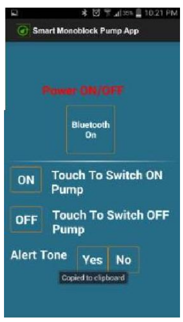


Fig 3-Smart pump system for controlling and monitoring the centrifugal monoblock pump

The home screen of the 'smart monoblock pump app' is shown in Fig 11. As shown, this app is incorporated with the facilities for switching on and off the centrifugal monoblock pump, timing the operation of the centrifugal monoblock pump, indicating the level in the sump and overhead tank, and trouble shooting for solving the problems encountered while operating the centrifugal monoblock pump. These facilities of smart monoblock pump app are described in the following subsections.

Fig 12-Pump on and off

Fig 11-Home screen of the smart monoblock pump app



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D. Pump on/off

The 'smart monoblock pump app' will enable the user to switch on and off the pump remotely by using the mobile phone through its Bluetooth device. The smart monoblock pump system installed along with the pump will have a Bluetooth receiver module. The pump ON/OFF screen in the smart monoblock pump app is shown in the Fig 12. When the ON button is pressed in the smart monoblock pump app, a Bluetooth signal will be transmitted to the Bluetooth receiver in the 'smart monoblock pump system'. The received signal will be processed by the ARM microcontroller in the smart pump system. The ARM microcontroller will switch on the relay switch, which will in turn switch on the pump. An alert tone can also be switched on to notify the user that the pump is on. Thus the pump can be switched on and off remotely by using the mobile phone.

E. Timer controlled on/off

The timer control option in the smart monoblock pump app will enable the user to operate the centrifugal monoblock pump for a pre-set time. When the user presses the timer button in the home screen, the timer facility shown in Fig 13 will be opened. When the user sets the duration of operation in minutes, then a signal will be transmitted from the Bluetooth module of the mobile phone to the smart pump system installed in the centrifugal monoblock pump. The received signal will be processed by the ARM microcontroller and it will be switching on the pump. Once the pre-set duration of operation of the pump is completed, the mobile phone will send another signal to the smart pump system which will switch off the pump. The user can set up the running time as 1,2,3,5 upto 30 minutes by using the smart monoblock pump app.

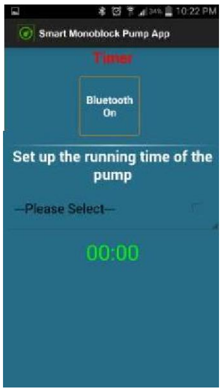

Fig 13-Timer controlled on/off

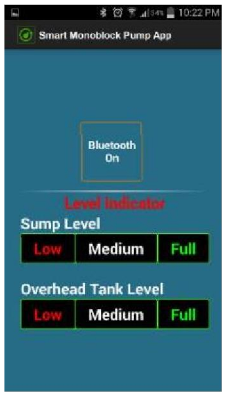

Fig 14-Water level indicator

F. Checking the water levels

The smart monoblock pump app will aid the user to monitor the water level in the overhead tank and the sump. When the user presses the level indicator button in the home screen of the mobile phone, the level indicator screen as shown in Fig 14 will open. When this button is pressed, it will send a signal to the Bluetooth receiver in the smart pump system. This signal will be processed in the ARM microcontroller of the smart pump system. The ARM microcontroller will in turn gather data form the sensors. The sensors are fixed at three different levels of the overhead tank and sump. The measured water level data will be sent to the mobile phone which will be displayed in the smart monoblock pump system.

The users can switch on and off the centrifugal monoblock pump by monitoring the water levels of the sump and overhead tank.

G. Metering the amount of water discharged

The smart monoblock pump app can be used to measure the amount of water discharged by the centrifugal monoblock pump. The screen which displays the amount of water discharged is shown in Fig
15. The flow sensor can be used to execute this metering application. The flow sensor placed in the pump will send the measured data to the smart pump system which will transmit the data to the mobile phone through the Bluetooth. The smart monoblock pump app will display the amount of water discharged during that operation. The total amount of water over a period of time discharged by the centrifugal monoblock pump can also be monitored by using this facility.

H. Power consumption

The smart monoblock pump app enables the users to monitor the power consumed by the centrifugal monoblock pump. The current sensor incorporated in the smart pump system will sense the amount of power consumed during the pumping operation of the centrifugal monoblock pump and send the data to the ARM microcontroller. These data will be sent to the mobile phone through Bluetooth. The smart monoblock pump app displaying the power consumed during an operation in its screen is shown in Fig 16.

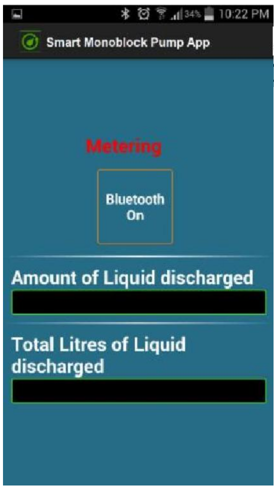

Fig 15-Metering the liquid discharge

Fig 16-Screen displaying the power consumption

I. *Help screen*

This facility in the 'smart monoblock pump app' will aid the user to contact the customer care centre of Jay Pumps. In case of any breakdowns, the user can refer the trouble shooting solutions which are incorporated in 'smart monoblock pump app'. The smart monoblock pump app will be loaded with basic trouble shooting videos. The users can also contact the customer care executive by pressing the customer care button shown in the Fig 17. This facility of the smart monoblock pump app will enable the executives and employees of Jay Pumps to provide a better customer service.

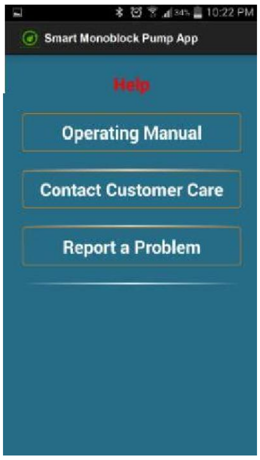

Fig 17- Help screen

The facilities of the 'smart monoblock pump app' which are described above will infuse agility in the centrifugal monoblock pumps manufactured in Jay Pumps.

Ergonomic agility through digitization

After developing 'smart monoblock pump', the agility in the centrifugal monoblock pump was infused by improving its ergonomic features. While initiating this task, the propensities of improving the ergonomics of the centrifugal monoblock pump were analysed. In this direction, an idea of eliminating the noise while operating the centrifugal monoblock pump by reducing the vibrations was conceived. This type of pumps is coined here the name 'silent pumps'. The rationale behind developing the silent pumps is explained in the following sub-section.

J. *Silent pumps*

The average noise generated in a centrifugal monbolock pump is from 60 db-80db (Pump handbook, 2015). This noise will be disturbing the environment. The major noise that arise in the centrifugal monoblock pump is caused due to vibration. The reduction of vibration will lead to the silent operation of the pump. The vibration can be reduced by installing vibration isolation pads under the centrifugal monoblock pump while installing them. These vibration isolator pads will eliminate the transmission of vibration from the pump to the floor. This arrangement will control the vibration and reduce the noise generated during the operation of the centrifugal monoblock pump.

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The fixing of vibration isolation pads will also add life to centrifugal monoblock pump and reduce the maintenance costs. The vibration isolation pads which are made up of visco elastic polymer materials are found to be most suitable for eliminating the transmission of vibration from pump to the floor (Sorbothane, 2015).

While carrying out the doctoral work being reported here, the CAD model of centrifugal monoblock pump with vibration isolation pad was developed. In order to develop this CAD model, PTC Creo 3.0 package was used. Initially the digitized version of the centrifugal monoblock pump was referred. The exterior dimensions of the centrifugal monoblock pump were measured. By referring to these measurements, the vibration isolation pads were modelled in PTC Creo 3.0 software package. By using the part modelling facility of PTC Creo 3.0 software package, a rectangular section was drawn by using the sketch option. Then the rectangular surface was chosen and extruded. In the next step the surface of the extruded part was chosen and a rectangular was drawn by using the sketch facility. Then this section was extruded. After extruding, similar rectangular sections were created by using the pattern facility available in the PTC Creo 3 software package. Then this 3D model of the vibration isolation pad was added in the assembly section of the centrifugal monoblock pump. The vibration isolation pad was assembled with the centrifugal monoblock pump in PTC Creo 3.0 software environment by using the automatic constraint.

The assembled CAD model of centrifugal monoblock pump with the vibration isolation pad thus developed by using PTC Creo 3 software package is shown in Fig 18. The simulation of this CAD model can be carried out by using Computer Aided Analysis software packages. However, the simulation was not carried out due to the non-availability of acoustic simulation software package with the authors of this article. In future, the results obtained by conducting simulation runs can be compared with the experimental results. The results of this comparison can be used to design vibration isolation pads that will completely eliminate the noise during the operation of centrifugal monoblock pumps. This effort will lead to the development of silent centrifugal monoblock pumps.

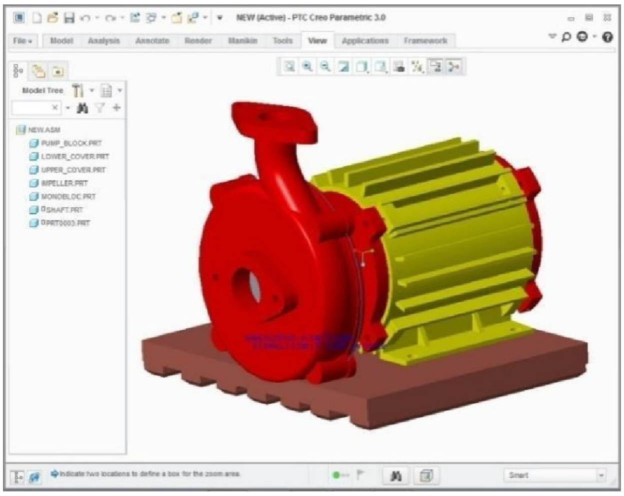

Fig 18-Centrifugal monoblock pump with the vibration isolation pad

Thus the ergonomic feature of the centrifugal monoblock pump can be improved to infuse agility in Jay Pumps.

CONCLUSION

As mentioned in the beginning, ‘product design’ had been driving and facilitating the execution of manufacturing paradigms and industrial revolutions. Currently, Industry 4.0 is revolutionizing the organizations and societies. The researchers have been pointing out that various ICT devices are required to be embedded in practice to carry out the enablers of Industry 4.0. In line to this appraisals, several digitization activities are carried out. Enabling the fund transfer, booking air reservations, purchasing products using internet apps is the example of implementing Industry 4.0. This kind of implementation of Industry 4.0 is occurring at fast pace in Germany. In other parts of the world, Industry 4.0 is occurring at slow pace. This is due to the reason that implementing Industry 4.0 in organizations has to happen by overcoming several hurdles. One such hurdle is the contemporary product design which is incompatible for adoption to manufacture under Industry 4.0 compatible organizations. In order to overcome this hurdle, the contemporary products should be redesigned with the incorporation of the appropriate Industry 4.0 compatible technologies and devices. In order to provide a solution in this regard, a case study was carried out to design a centrifugal monoblock pump incorporated with Industry 4.0 comparative technologies and devices. After explaining about agile manufacturing and Industry 4.0, this case study has been reported in this article. This Industry 4.0 compatible centrifugal monoblock pump will meet the stipulations of agile manufacturing to the extent of providing innovative functional, ergonomical and aesthetic features. This article is concluded by claiming that the pursuance of product design with the focus to infuse agility in products by adopting Industry 4.0 compatible technologies and devices will bring out the fourth industrial revolution in organizations.

References

1. Androidauthority 2015, Available from: https://www.androidauthority.com [August 5, 2015]
2. Blijlevens, J, Creusen, MEH & Schoormans, JPL 2009 How Consumers Perceive Product Appearance: The Identification of

Three Product Appearance Attributes, International Journal of Design, vol.3, no.3.

3. Karassik, IJ, Messina, JP, Cooper, P & Heald, CC 2001, Pump Handbook, McGraw-Hill Ltd.
4. Sorbothane, 2015, Available from: http://www.sorbothane.com/about-sorbothane-vibration- isolation-mounts.aspx [August 6, 2015]
5. Thermochromism, 2015, Available from: https://en.wikipedia.org/wiki/Thermochromism [October 25,2015]
6. Webopedia, 2015, Available from: https://www.webopedia.com [August 6, 2015]
7. Fatorachian, H & Kazemi, H (2018) A critical investigation of Industry 4.0 in manufacturing: theoretical operationalisation framework, Production Planning & Control, vol. 29, issue 8, pp.633-644.
8. Buer, S.V, Strandhagen J.O. and Chan F.T.S. (2018) The link between Industry 4.0 and lean manufacturing: mapping current research and establishing a research agenda, International Journal of Production Research, vol. 56, issue 8, pp. 2924-2940.
9. B.K. Patle, G. Babu L, A. Pandey, D.R.K. Parhi, A. Jagadeesh, A review: On path planning strategies for navigation of mobile robot, Def. Technol. 15 (2019) 582– 606. https://doi.org/10.1016/j.dt.2019.04.011.
10. Dr.A.Senthil Kumar, Dr.G.Suresh, Dr.S.Lekashri, Mr.L.Ganesh Babu, Dr. R.Manikandan. (2021). Smart Agriculture System With E – Carbage Using Iot. International Journal of Modern Agriculture, 10(1), 928 - 931. Retrieved from http://www.modern-journals.com/index.php/ijma/article/view/690
11. Manoharan S, Sai Krishnan G, Babu L G, Vijay R and Singaravelu D L 2019 Synergistic effect of red mud-iron sulfide particles on faderecovery characteristics of non-asbestos organic brake friction composites Mater. Res. Express 6 105311.
12. Lokesh, P.; Kumari, T.S.; Gopi, R.; Loganathan, G.B. A study on mechanical properties of bamboo fiber reinforced polymer composite. Mater. Today Proc. 2020, 22, 897–903.
13. Sai Krishnan G, Jayakumari L S, Babu L G and Suresh G 2019 Investigation on the physical, mechanical and tribological properties of areca sheath fibers for brake pad applications Mater. Res. Express 6 085109.
14. Ganesh Babu L 2019 Influence of benzoyl chloride treatment on the tribological characteristicsof Cyperus pangorei fibers based nonasbestos brake friction composites Mater. Res. Express 7 015303.
15. Devaraju, P. Sivasamy, Ganesh Babu Loganathan, “Mechanical properties of polymer composites with ZnO nano-particle”, Materials Today: Proceedings (2020), Volume 22, Part 3, Pages 531- 534.
16. Ganesh Babu Loganathan, Dr. E.Mohan, R.Siva Kumar, “ Iot Based Water And Soil Quality Monitoring System”, International Journal of Mechanical Engineering and Technology (IJMET)(2019), Vol.10 Issue No.2, P.No. 537-541.
17. Krishnan GS et al (2020) Investigation of Caryota urens fibers on physical, chemical, mechanical and tribological properties for brake pad applications. Mater Res Exp 7:015310.
18. Dr. A. Senthil Kumar; Dr. Venmathi A R; L. Ganesh Babu; Dr. G. Suresh. "Smart Agriculture Robo with Leaf Diseases Detection using IOT". European Journal of Molecular & Clinical Medicine, 7, 11, 2022, 2462-2469.
19. Mohammed Abdulghani Taha and Ganesh Babu Loganathan, “Hybrid algorithms for spectral noise removal in hyper spectral images” AIP Conference Proceedings (2020), Volume 2271, Issue 1, pp 030013.
20. Ganesh Babu Loganathan, “Can Based Automated Vehicle Security System”, International Journal of Mechanical Engineering and Technology (IJMET)(2019), Vol.10 Issue No.07, P.No. 46-51.
21. Suganthi K, Idris Hadi Salih, Ganesh Babu Loganathan, and Sundararaman K, “A Single Switch Bipolar Triple Output Converter with Fuzzy Control”, International Journal of Advanced Science and Technology, (2020), Vol. 29, No. 5, (2020), P.No.. 2386 – 2400.
22. Ellappan Mohan, Arunachalam Rajesh, Gurram Sunitha, Reddy Madhavi Konduru, Janagaraj Avanija, Loganathan Ganesh Babu, “A deep neural network learning-based speckle noise removal technique for enhancing the quality of synthetic-aperture radar images”, Concurrency and Computation-Practice & Experience, https://doi.org/10.1002/cpe.6239.
23. Ganesh Babu Loganathan “Design and analysis of high gain Re Boost-Luo converter for high power DC application”, Materials Today: Proceedings (2020), Volume 33, Part 1, PP 13-22.
24. C. Sivakandhan, Ganesh Babu Loganathan, Material characterization and unconventional machining on synthesized Niobium metal matrix Mater, Res. Exp. 7 (2020) 015018.
25. Dr. Idris Hadi Salih, Ganesh Babu Loganathan, “Induction motor fault monitoring and fault classification using deep learning probablistic neural network” Solid State Technology (2020), Volume 63, Issue 6, 2196-2213..
26. P Sivasamy, S Harikrishnan, L Ganesh Babu, S Imran Hussain, S Kalaiselvam, “Improved thermal characteristics of Ag nanoparticles dispersed myristic acid as composite for low temperature thermal energy storage” Materials Research Express, ISSN: 2053-1591, Volume-6, Issue-8, May 2019, P.No 085066.
27. Sundar Singh Sivam S P, Umasekar V G, Loganathan G B, Kumaran D and Rajendrakumar S 2019 Multi response optimization of setting process variables in face milling of ZE41 magnesium alloy using ranking algorithms and ANOVA International Journal of Vehicle Structures & Systems 5 47–56.
28. S.P.S.S. Sivam, G.B. Loganathan, K. Saravanan, V.G. Umasekar and S. Rajendrakumar. 2019. Numerical Evaluation and Influence of Product Quality and its Defects Measures on the Drawing of Stainless Steel Cross Member for Automobiles Int. J. Vehicle Structures & Systems, 11(1), 107- 112. doi:10.4273/ijvss.11.1.19.

29. Qaysar Salih Mahdi, Idris Hadi Saleh, Ghani Hashim, Ganesh Babu Loganathan, "Evaluation of Robot Professor Technology in Teaching and Business", Information Technology in Industry, Volume 09, Issue 01, PP 1182 -1194.
30. Sivam Sundarlingam Paramasivam, S., Loganathan, G., Kumaran, D., Saravanan, K. et al., "Function of Taguchi Grey Relation Analysis for Influencing the Process Parameter for Getting Better Product Quality and Minimize the Industrial Pollution by Coolants in Turning of Ti-6Al- 4V Alloy," SAE Technical Paper 2019-28-0065, 2019, https://doi.org/10.4271/2019-28-0065.
31. Sivam SPSS, Loganathan GB, Umasekar VG, Suresh Kumar PS, Raja S (2019) Study on micro structural characteristics and mechanical behaviour of AISI1050 steel under various heat treatments. Int J Veh Struct Syst 11(1):15–20. https://doi.org/10.4273/ijvss.11.1.04.
32. Sivam S.P.S.S., Loganathan G.B., Saravanan K., Dinesh Guhan S., Banerjee A. (2021) Effects of Drilling Process Parameters Using ANOVA and Graphical Methods. In: Kumaresan G., Shanmugam N.S., Dhinakaran V. (eds) Advances in Materials Research. Spring
33. G Suresh, S Vivek, L Ganesh Babu, S Stephen Bernard, R M Akash, "Evaluation of mechanical behaviour of carbon fiber reinforced nanoclay filled IPN matrix composite, Materials Research Express 2019, 6 (12). https://doi.org/10.1088/2053-1591/ab54ec.
34. Mr.Vishwa Deepak, S.Nithish, D. V. B. M. B. L. M. (2021). Static Stress Analysis of an Addendum Modified Spur Gear Pair using FRP Material. Design Engineering, 3562-3573. Retrieved from http://thedesignengineering.com/index.php/DE/article/view/5301. ISSN 0011- 9342,
35. Ganesh Babu Loganathan, K. I. M. G. (2021). Crowd Control Robot for Congestion Control. Design Engineering, 3377- 3391. Retrieved from http://thedesignengineering.com/index.php/DE/article/view/5286. ISSN 0011-9342,
36. Manikandan Ganesan, Ganesh Babu Loganathan, J.Dhanasekar, K. R. Ishwarya, Dr.V.Balambica. (2021). Implementing Industrial Robotics Arms for Material Holding Process in Industries. Harbin Gongye Daxue Xuebao/Journal of Harbin Institute of Technology, 53(9), 17–27. Retrieved from http://hebgydxxb.periodicales.com/index.php/JHIT/article/view/704.
37. Ahmed Ameer Arsalan Hadi , Karam Dheyaa Jirjees, G. B. L. I. H. S. (2021). An Analysis of Topology Optimization On Robot By Finite Component. Design Engineering, 7336-7351. Retrieved from http://www.thedesignengineering.com/index.php/DE/article/view/3246. ISSN 0011-9342,
38. Dr.Qaysar Salih Mahdi, Mr.Ganesh Babu Loganathan, "Classification of Web Page by Using Neural Networks", Efflatounia, Volume: 5 Issue 2, Pages: 650 – 663, ISSN: 1110-8703.
39. Dr.Qaysar Salih Mahdi, Mr.Ganesh Babu Loganathan, "Modelling ofRadar Targets and Radar Cross Section For Air TrafficControl Radars", Efflatounia, Volume: 5 Issue 2, Pages: 664–674, ISSN: 1110-8703.
40. Ganesh Babu Loganathan, Dr. Mohammad M. Othman, Elham Tahsin Yasin, "*An Analysis on Garbage Removal Process by WSN thorugh Global System for Mobile Communication Media.*" REVISTA GEINTEC-GESTAO INOVACAO E TECNOLOGIAS, 11 (3). pp. 493-505. ISSN 2237-0722.
41. Manikandan Ganesan, KR Ishwarya, Demos Lisanework, Ganesh Babu Loganathan, *Design and Implementation of Single Phase to Three Phase Drive System Using Space Vector Modulation.* REVISTA GEINTEC-GESTAO INOVACAO E TECNOLOGIAS, 11 (2). pp. 2221- 2239. ISSN 2237-0722.
42. BABU, L. G. (2021). Microstructure and Wear Behaviour Of A356-TIB2 Novel Metal Matrix Composites. In Journal of the Balkan Tribological Association (Vol. 27, Issue 3, pp. 417–425). ISSN:1310-4772
43. Muthukumaran, S., Ganesan, M., Dhanasekar, J. and Loganathan, G.B. (2021). Path Planning Optimization for Agricultural Spraying Robots Using Hybrid Dragonfly – Cuckoo Search Algorithm. Alinteri Journal of Agriculture Sciences, 36(1): 412-419. -ISSN: 2587-2249. doi: 10.47059/alinteri/V36I1/AJAS21062.
44. S. Priyadharsini, T. S. Balaji Damodhar, C. Kannan, & L. Ganesh Babu. (2021). Improved Performance of Photovoltaic Based Embedded Dual Power Source SL-Quasi Z Source Inverter For IM Drive. EPRA International Journal of Research & Development, 6(6), 266–273. Retrieved from https://eprajournals.org/index.php/IJRD/article/view/248.
45. Dr. Othman, M.M., Ishwarya, K.R., Ganesan, M. and Babu Loganathan, G. (2021).," A Study on Data Analysis and Electronic Application for the Growth of Smart Farming". Alinteri Journal of Agriculture Sciences, 36(1): 209-218. doi: 10.47059/alinteri/V36I1/AJAS21031.
46. Ganesh Babu Loganathan, Idris Hadi Salih, A.Karthikayen, N. Satheesh Kumar, Udayakumar Durairaj. (2021). EERP: Intelligent Cluster based Energy Enhanced Routing Protocol Design over Wireless Sensor Network Environment. International Journal of Modern Agriculture, 10(2), 1725 - 1736. Retrieved from http://www.modern-journals.com/index.php/ijma/article/view/908.
47. Qaysar Salih Mahdi, Idris Hadi Saleh, Ghani Hashim, Ganesh Babu Loganathan, "Evaluation of Robot Professor Technology in Teaching and Business", Information Technology in Industry, Volume 09, Issue 01, PP 1182-1194.
48. Sivama, S., Loganathanb, G., Harshavardhanaa, N., Kumarana, D., & Prasannaa, P. (2020). A comparative study of experimental and adaptive neuro fuzzy inference system based prediction model of machined AM60 magnesium alloy and its parameter effects. Materials Today: Proceedings, Volume 45, Part 2, 2021, Pages 1055-1062.
49. G.Sai Krishnan, K.Ilayaperumal, L.Ganesh Babu, S.Kumar, B.Sathish, R.Sanjana, "Investigation on the physical and mechanical

characteristics of demostachya bipinnata reinforced with polyester composites" , Materials Today: Proceedings, Volume 45, Part 2, 2021, Pages 1134-1137.

50. G Shanmugasundar , M Vanitha , L Ganesh Babu , P Suresh , P Mathiyalagan , G Sai Krishnan and Mebratu Makos, "Fabrication and analysis of mechanical properties of PVC/Glass fiber/graphene nano composite pipes", Materials Research Express, ISSN: 2053-1591, Volume-7, Issue-11, May 2020, P.No 115303.
51. Babu, L.G. (2020). Influence on the tribological performance of the pure synthetic hydrated calcium silicate with cellulose fiber. In Journal of the Balkan Tribological Association, 26(4), 747– 754.
52. Mohammed Abdulghani Taha and Ganesh Babu Loganathan, "Hybrid algorithms for spectral noise removal in hyper spectral images" AIP Conference Proceedings (2020), 2271(1), 030013.
53. Muhammad Abdulghani Taha , Melike Şah and Cem Direkoğlu , Ganesh Babu Loganathan, "*Adaptive Wiener Filter And Non Linera Diffusion Based Deblurring And Denoising Images".* Journal of critical reviews, 7 (3). pp. 908-915. ISSN 2394-5125.
54. J. Aravind Kumar, D. Joshua Amarnath, A. Annam Renita and Ganesh Babu, "*Activated Carbon Production From Biowaste Materials - Properties and Applications: A Review".* Indian Journal of Environmental Protection, 40 (5). pp. 507-511.
55. P.Ramesh, G.Sai Krishnan, J.Pravin Kumar, M.Bakkiyaraj, Raghuram Pradhan, L.Ganesh babu, "A critical investigation on viscosity and tribological properties of molybdenum disulfide nano particles on diesel oil" , Materials Today: Proceedings, Volume 43, Part 2, 2021, Pages 1830-1833.
56. K. Rajendra Prasad, V. Manoj Kumar, G.Swaminathan, Ganesh Babu Loganathan, "Computational investigation and design optimization of a duct augmented wind turbine (DAWT)", Materials Today: Proceedings, Volume 22, Part 3, 2020, Pages 1186-1191.
57. Selvam, R., & Loganathan, G. B. (2019). Product detail and analysis of hydraulic quick releasing coupling. Materials Today: Proceedings, 22, 751–755. https://doi.org/10.1016/j.matpr.2019.10.081.
58. T. Muthuramalingam, S. Vasanth, L. G. Babu, D. Saravanakumar and P. Karthikeyan, "Flushing Pressure Automation for Efficient Machining in EDM Process," 2019 7th International Conference on Control, Mechatronics and Automation (ICCMA), 2019, pp. 232-236, doi: 10.1109/ICCMA46720.2019.8988592.
59. Suresh G., Ganesh B.L., Bharani K.S., Rajesh K.K. Influence of water absorption on glass fibre reinforced IPN composite pipes // Polímeros: Ciência e Tecnologia. 2019. Vol. 29 (3). P. 2019– 2038.
60. Ganesh Babu L, Ramesh M and Ravichandran M 2019 Mechanical and tribological characteristics of ZrO2 reinforced Al2014 matrix composites produced via stir casting route Mater. Res. Express 4 115542115542.

61. Sivam Sundarlingam Paramasivam, S., Loganathan, G., Kumaran, D., Saravanan, K. et al.,
"Taguchi Based Vikor Method for Optimization of Cutting Parameters for Improving the
Efficiency in Machining Process by Considering the Effect of Tool Nose Radius," SAE Technical
62. Paper 2019-28-0138, 2019, https://doi.org/10.4271/2019-28-0138.
Loganathan, G., Saravanan, K., Rajendran, R., Sivam Sundarlingam Paramasivam, S. et al.,
"Investigation of Setting Input Process Parameters for Getting Better Product Quality in Machining
63. of AM60 Magnesium Alloy - TOPSIS and ANOVA Approach," SAE Technical Paper 2019-28-
0136, 2019, https://doi.org/10.4271/2019-28-0136.
oganathan, G., Kumaran, D., Sivam Sundarlingam Paramasivam, S., Saravanan, K. et al.,
64. "Improvement of Mechanical Properties, and Optimization of Process Parameters of AISI 1050
Spheriodized Annealed Steel by Ranking Algorithm," SAE Technical Paper 2019-28-0143,
2019, https://doi.org/10.4271/2019-28-0143.
Sivam Sundarlingam Paramasivam, S., Kumaran, D., Loganathan, G., Saravanan, K. et al.,

Forming of AA 8011 Using Complex Proportional Assessment and ANOVA," SAE Technical Paper 2019-28-0064, 2019, https://doi.org/10.4271/2019-28-0064.

65.. Thangaraj, M., Loganathan, G., Atif, A., and Palanisamy, S., "Multi Response Optimization on Machin -28-0070, 2019, https://doi.org/10.4271/2019-28-0070.

66.. "Experimental Study on Verification of Alloy ASTM A510 High-Speed Micro Turning by 2019, ht Loganathan, G., Sivam Sundarlingam Paramasivam, S., Kumaran, D., Saravanan, K. et al., Parameters Validation through Ranking Algorithm," SAE Technical Paper 2019-28-0071,

Showing Signs of Improvement Product Quality in Drilling $AlSi_7Cu_4$ Utilizing GRA in Taguchi Study on Mechanical Properties and Multi Response Optimization of Process Parameters for Method," SAE Technical Paper 2019-28-0058, 2019, https://doi.org/10.4271/2019-28-0058.
"Optimization of Machining Process Parameters for Minimizing the Waste Stream Response 2019, https://doi.org/10.4271/2019-28-0062.

through Multi-Objective Optimization," SAE Technical Paper 2019-28-0062,

67. S.P.S.S.Sivam G.B. Loganathan and L. Ganesh Babu and D. Kumaran. 2019. Enhancing the Mechanical Properties and Formability of Cold Rolled Closed Annealed Sheet for Automobile Applications Int J. Vehicle Structures & Systems. 11 15-20.
68. Muralikrishna, M.V.V.; Surya Kumari, T.S.A.; Gopi, R.; Loganathan, G.B. Development of mechanical properties in banana fiber composite. Mater. Today Proc. 2020, 22, 541–545.
69. S.P. Sundar Singh Sivam et al.2019 Analysis of Product Quality through Mechanical Properties and Determining Optimal Process Parameters of Untreated and Heat Treated ALSI 1050 Alloy during Turning Operation Mater. Sci. Forum. 969 876-881.
70. L. Ganesh Babu, G. Sai Krishnan & N. Siva Shanmugam, “Microstructural and Corrosion Studies by Immersion IN 3.5wt % NaCl Environment on Mg-6Al-1Zn-XCa ALLOY with Ca Addition and Aged at Different Temperatures”, International Journal of Mechanical and Production Engineering Research and Development (IJMPERD) Vol. 9, Issue 3, Jun 2019, 1553-1562, ISSN (P): 2249-6890; ISSN (E): 2249-8001.
71. G. Sai Krishnan , L. Ganesh Babu & N. Siva Shanmugam “Experimental investigation of wear behaviour of A356-Tib2 metal matrix composites”, International Journal Of Mechanical And Production Engineering Research And Development (IJMPERD) Vol. 9, Issue 3, Jun 2019, 1353- 1362. ISSN (P): 2249-6890; ISSN (E): 2249-8001.
72. Sai Krishnan G and Loganathan G B 2019 Development of superhydrophobic nanocomposite coatings on FRP sheet surface for antiicing and wear-resistance applications(August 5, 2019) Proc. of Int. Conf. on Recent Trends in Computing, Communication & Networking Technologies (ICRTCCNT).
73. Ganesh Babu Loganathan, S. Kalyan Kumar, S.P. Sundar Singh Sivam, K. Saravanan, S. RajendraKumar, “Experimental Investigation and Optimization of Wire Cut EDM Parameters for Performance Measures of Heat Treated SS304: Ranking Algorithm and Anova Approach” International Journal of Recent Technology and Engineering (IJRTE) Volume-7, Issue-6, March 2019, ISSN: 2277-3878.
74. S Dhanraj et al 2019, “An Efficiency Study On Water Extraction From Air Using Thermophoresis Method” IOP Conf. Ser.: Mater. Sci. Eng. 574 012003.
75. Arivazhagan, R.; Prakash, A. S.; Kumaran, P.; Sankar, S.; Loganathan, B. G.; Arivarasan, A., 2020. “Performance analysis of concrete block integrated with PCM for thermal management”, Materials Today: Proceedings 22, 370 – 374.
76. S.P. Sundar Singh Sivam, Ganesh Babu Loganathan, P.R. Shobana Swarna Ratna, G. Balakumaran , “Improvement of Product Quality by Process Parameter Optimization of AISI 1050 by Different Heat Treatment Conditions: Ranking Algorithm and ANOVA”, International Journal of Innovative Technology and Exploring Engineering (IJITEE) Volume-8 Issue-5 March, 2019, PP.30-35, ISSN: 2278-3075.
77. Loganathan, G.B., Mahdi, Q.S., Saleh, I.H., Othman, M.M. (2022). AGRIBOT: Energetic Agricultural Field Monitoring Robot Based on IoT Enabled Artificial Intelligence Logic. In: Liatsis, P., Hussain, A., Mostafa, S.A., Al-Jumeily, D. (eds) Emerging Technology Trends in Internet of Things and Computing. TIOTC 2021. Communications in Computer and Information Science, vol 1548. Springer, Cham. https://doi.org/10.1007/978-3-030-97255-4_2
78. Kanagaraju, T., Babu, L.G., Madhavan, V.M. *et al.* Experimental analysis on drilling of super duplex stainless steel 2507 (SDSS 2507) using cryogenic LCO_2 and MQL process. *Biomass Conv. Bioref.* (2022). https://doi.org/10.1007/s13399-022-02536-8
79. Elham Tahsin Yasin, Nawroz I. Hamadamen, Ganesh Babu Loganathan, Manikandan Ganesan, “Recent Scope for AI in the Food Production Industry Leading to the Fourth Industrial Revolution”, Webology, Volume 18, Issue-Number 2, December, 2021, PP 1066-1080. DOI: 10.14704/WEB/V18I2/WEB18375.
80. Dr V. Balambica, Ganesh Babu Loganathan, Vishwa Deepak, Dr M,Achudhan, “Analysis of an Addendum Modified Fiber Reinforced Composite Spur Gear Pair to Eliminate Noise &

Interference Defects" International Journal of Mechanical Engineering, ISSN: 0974-5823, Volume-7 Issue-15 Jan, 2022, PP. 5464-5478.

81. Dhanasekar J, Manikandan Ganesan, K. R. Ishwarya, Ganesh Babu Loganathan, "An Animatronic Arm Mimicking Human-like Motions", International Journal of Mechanical Engineering, ISSN: 0974-5823, Volume-7 Issue-15 Jan, 2022, PP. 2942- 2950
82. S. Ashok Kumar, Ganesh Babu Loganathan, P.R. Shobana Swarna Ratna, G. Balakumaran, S.P. Sundar Singh Sivam, "Determination of Taguchi Grey Relation Analysis to Influence the Tool Geometry and Cutting Parameters of the Ti-6Al-4V Alloy to Achieve Better Product Quality" , International Journal of Innovative Technology and Exploring Engineering (IJITEE) Volume-8 Issue-5 March, 2019, PP.212-217, ISSN: 2278-3075.
83. A, Shakin Banu and P, Vasuki and Loganathan, Ganesh Babu and V, Srinivasa Raman and A, Yusuf Khan, Sparse Representation Based Despeckling of SAR Images using STDTCWT (August 2, 2019). Proceedings of International Conference on Recent Trends in Computing, Communication & Networking Technologies (ICRTCCNT) 2019, Available at SSRN: https://ssrn.com/abstract=3431020 or http://dx.doi.org/10.2139/ssrn.3431020.
84. S.P. Sundar Singh Sivam, Ganesh Babu Loganathan, K. Saravanan, S. RajendraKumar, "Multi- Response Enhancement of Drilling Process Parameters for AM 60 Magnesium Alloy as per the Quality Characteristics utilizing Taguchi-Ranking Algorithm and ANOVA", International Journal of Innovative Technology and Exploring Engineering (IJITEE) Volume-8 Issue-4, February 2019, PP.437-440, ISSN: 2278-3075.
85. Ganesh Babu Loganathan, "An Identical Machine-Adaptive Algorithm Based Blockchain Process and Predicting Secret Data from Hacking In Computer Numerical Control Applications", International Journal of Mechanical and Production Engineering Research and Development (IJMPERD) Vol. 9, Special Issue 1, Jan 2019, PP.510-522, ISSN(P): 2249-6890; ISSN(E): 2249-8001.
86. S.P. Sundar Singh Sivam, Ganesh BabuLoganathan, K. Saravanan, S. RajendraKumar, "Outcome of the Coating Thickness on the Tool Act and Process Parameters When Dry Turning Ti–6Al–4V Alloy: GRA Taguchi & ANOVA", International Journal of Innovative Technology and Exploring Engineering (IJITEE) ISSN: 2278-3075, Volume-8, Issue-4, February 2019 PP. 419-423.
87. Zhong, R.Y, Xua X, Klotz E, Newmanc, S.T. 'Intelligent Manufacturing in the Context of Industry 4.0: A Review T. Newmanc Engineering 3 (2017) 616–630