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Design and Development of a Special Purpose Machine for Combined Trimming and Drilling Operations on Tail Lamp Bracket Casting of a Motor Cycle

Nikhil J Surwade[a], Vinay K Thute[b]
[a]M.E Student, Shri Sant Gajanan Maharaj College of Engineering, Shegaon and India
[b] Associate Professor, Shri Sant Gajanan Maharaj College of Engineering, Shegaon and India

ABSTRACT:
The paper is focused on the work done on project which was initiated to design and develop a special purpose machine capable of performing trimming and drilling operations altogether on the tail lamp bracket casting of a motor cycle. The purpose of the design is to trim out the flashes generated after pressure die casting process from 14 different areas of the casting and to drill 2 holes on the same casting. The work is undertaken at Global Automation which is located at Pune.

Keywords: Casting, Drilling, Flashes, Trimming.

I. Introduction

Aluminium is a widely used metal, particularly in an automotive industry. To survive in competitive market the major task for automotive industries is to reduce the fuel consumption by reducing the weight of an automobile hence a wide market is open for aluminium [1]. The tail lamp bracket is made of an alloy of aluminium commonly known as Al-Si 132/ADC12. This alloy undergoes the Pressure Die Casting Process. The first high pressure die casting machine was brought to the market by H.H. Doehler in the year 1915. At first zinc die casting were produced and then aluminium [2]. Engineered aluminium alloy products such as motor housing, frames, brackets etc are produced by aluminium pressure die casting process. Pressure die casting is a widely used process for aluminium alloys and about two thirds of all aluminium castings are used in automotive industries. Nowadays to sustain in the competitive market all the industries have to strive for maximum output in stipulated period of time. More the productivity of company more is its profit. The need of development of special purpose machine for the tail lamp bracket casting of the motor cycle is to increase the productivity by automating the post pressure die casting process. Automation is best solution for completing required work in least possible period of time and gives a finished product with negligible chances of rework. Hence the need arises to incorporate the concept of automation in post PDC process of tail lamp bracket casting. The present work addresses the solution for the flashes generated after pressure die casting process and drilling the two holes with centre distance of 36mm. To remove the flashes by manual filing operation and drilling the holes by conventional drilling machine will obviously result in low productivity. Because of this reason the detailed study of the component is done along with tracing out the areas where flashes get generated. Main causes of flash generation are researched and the best suited solution for the existing problem is given in the paper.

II. Detailed Pressure Die Casting Process

Pressure die casting is a manufacturing process capable producing geometrically complex metal parts. The pressure die casting machine involves use of die casting machine, molten metal (aluminium), furnace and die. Mainly used materials are generally non ferrous alloys such as aluminium and zinc. These alloys are melted in the furnace and then injected in to dies in the die casting machine. Die casting machines used in casting industries are of two types- hot chamber machines used for alloys with low melting temperatures, such as zinc and cold chamber machines used for alloys with high melting temperatures such as aluminium.

A. *Cold Chamber Pressure Die Casting Machine*

This machine is used for casting the alloys with high melting temperatures like aluminium. As soon as the molten metal is injected in to the dies, it rapidly cools and we get a casting. The castings that are created in this process can vary greatly in size and weight.

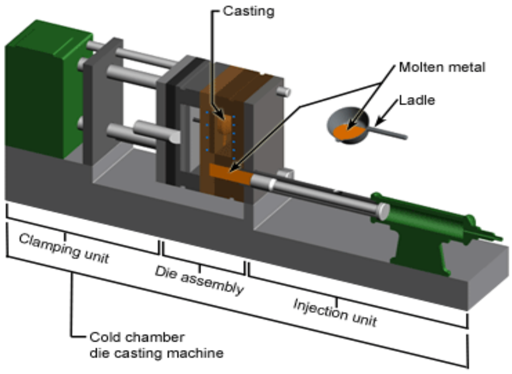

Fig. 1 Cold Chamber Pressure Die Casting Machine

B. Stages in Cold Chamber Pressure Die Casting

The cold chamber pressure die casting process consists of 5 stages as shown in Fig. 2

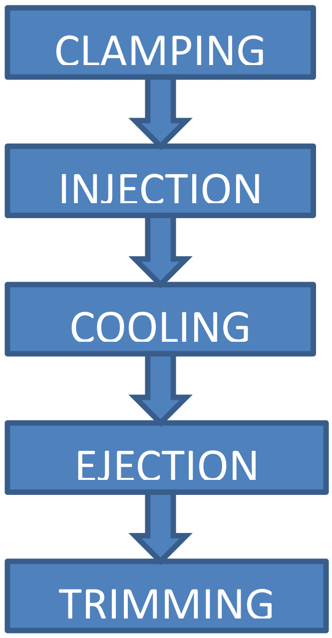

Fig. 2 Stages of Cold Chamber Pressure Die Casting

Clamping-

Die is divided in two parts each die is cleaned and lubricated in order to facilitate the ejection of next casting. Two die halves are securely closed and clamped together with sufficient amount of force. The time required for clamping depends upon the size of machine large the size of machine more is the time required for clamping.

Injection-

The molten metal is transferred into the chamber where it can be injected into the die. Further the molten metal is injected at pressure (1000-20000 psi) into the die. The amount of metal injected into the die is referred as a shot. A greater wall thickness will require more injection time.

Cooling-

Once molten metal enters the die cavity will begin to cool and solidify. The final shape of casting is formed when the entire cavity is filled and molten metal solidifies. The complexity of die, maximum wall thickness and several thermodynamic properties of aluminium alloy decides the cooling time. A longer cooling tome is required for geometrically complex die because it offers additional heat resistance to the flow of heat.

Ejection-

Ejection mechanism pushes the casting out of the die cavity after the specific cooling time. The ejection mechanism must apply some force to eject the part because during cooling the part shrinks and adheres to the die.

Trimming-

Trimming is the post pressure die casting process performed on the component. Need of trimming arises because of solidification of material in the channels of die. Flash is the result of solidified material in the channels of die.

The scrap material which results from this trimming is either discarded or can be reused in the die casting process. The excess material is to be removed either by cutting or filing.

III. PROBLEM IDENTIFICATION

The tail lamp bracket casting needs to meet the surface finish and aesthetic look after the anodizing process. After the survey of complete manufacturing process it is noted that many of the components got rejected because of-

1) Non uniform trimming at required areas.
2) Poor surface finish with filing marks on the component surface.
3) More time required in manual process of removing flashes which doesn't meet the productivity requirements.

For drilling two holes with center distance of 36mm, a conventional drilling machine is used. The problem observed with this process is-

1) A specific center distance of 36mm is not maintained though initial punching is done on the required areas.
2) More time required for setting the location for drilling and manually performing the drilling operation.

Rejection percentage is shown in table.

Table 1.Rejection Percentage

Sr No.	Process	Rejection (%)
1	Trimming	22
2	Drilling	5

So the major problem exists in manual trimming and drilling operations, which results in poor finishing of component along with more time consumption. The existing problem can be solved by introducing automation in the processes. Hence main importance was given to design and develop the special purpose machine which will eliminate all the existing problems associated with trimming and drilling operations, and increases the productivity.

IV. COMBINED TRIMMING AND DRILLING MACHINE DESIGN

Before designing the machine all the operations are divided in two stages, this means all the operations are to be done on two stations. Top diagonally oriented holes are chosen to restrict two degree of freedoms of the component.

Trimming and drilling operations divided in two stations as follows-

STATION NO. 1–

A) Trimming-

1) Top diagonally oriented holes (1, 2)
2) Top small holes (3, 4)
3) Front rectangular windows (5, 6, 7, 8)

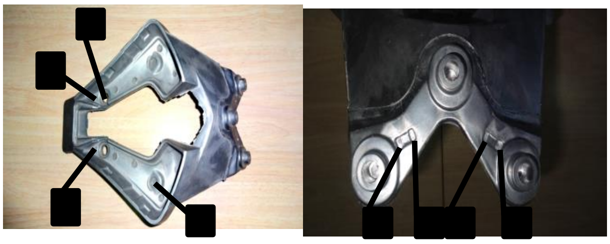

Fig. 3 (a) Trimming Areas of Station No. 1

B) Drilling-

1) Two holes with center distance of 36mm (9, 10)

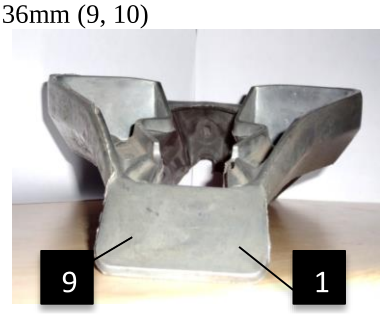

Fig. 3 (b) Drilling Areas of Station No. 1

STATION NO.2-

A) Trimming-

1) Top profile (11)
2) Front round holes (12, 13, 14)

3) LHS hole (15)
4) RHS hole (16)

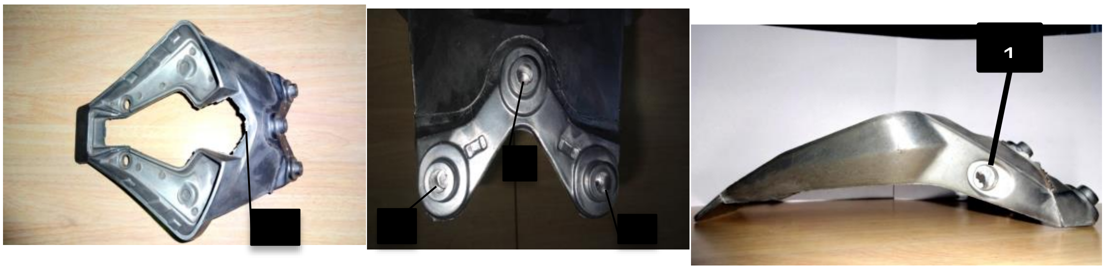

Fig. 4 Trimming Areas of Station No. 2

A. Deciding the Trimming Force

Trimming is the operation of removing the unnecessary flashes from the component. During trimming process when the punch descends to touch the material, it begins to accumulate the trimming force. The trimming force increases with increase of distance. As the material load reaches the highest, the crack on the material enlarges drastically, causing the material sheared off. To get a smooth trimming operation the parameters like size of punch, punch clearance and supporting method of material are considered [3]. The required trimming force is a product of shearing area and the shearing strength.

The trimming force required for the punch can be calculated by using equations as-

$$F = P \text{ x } t \text{ x } \tau s \quad (1)$$

If the hole to be trimmed is round or circular shape then,

$$F = \pi \text{ x } D \text{ x } t \text{ x } \tau s \quad (2)$$

Where,
F = Trimming force (N)
P = Perimeter (m)
t = Thickness of the material (m)
τs = Shearing strength of the material (N/m2)
D = Diameter of hole to be trimmed (m)

Trimming forces of respective areas are calculated by using the formula and punches are designed accordingly. A hydraulic cylinder with specific bore size can be selected by using these force values.

B. Design of Drilling Unit-

The tail lamp bracket casting is designed in such a way that the number plate of bike can be mounted with the help of bolts on it. It is the modification after final design hence these two holes are not included in pressure die casting process. Drilling operation is to be performed at two locations on the same axis with the center distance of 36 mm. To solve this purpose a multi spindle drilling unit consisting of a gear train is to be designed. The holes are to be drilled with diameter of 6.5 mm each.

The cutting speed value was established from equation (3)

$$n = \frac{1000 \text{ v}}{\pi d} \quad (3)$$

Starting from the whole value of spindle speed the corresponding value of cutting speed, drilling force etc calculated. The drilling unit consists of housing, LM Rail, gears, needle bearing and other supporting components.

C. Hydraulic Cylinders and Power Pack Selection-

A hydraulic system is used for performing all the above mentioned operations. The reason for selecting a hydraulic system is the forces required for trimming and drilling exceeds the limit of pneumatic system. The maximum flash thickness observed is 5mm and a pneumatic system fails to trim the flash.

Hydraulic cylinders are selected and designed by considering the trimming and drilling forces. A maximum pressure of 100bar is selected for the operation. To select a proper hydraulic cylinder we must know its bore size and to calculate the bore size of cylinder following basic formula is used-

$$\text{Pressure} = \frac{\text{Force}}{Area} \quad (4)$$

Hence by putting the values of force and maximum pressure, the bore size of hydraulic cylinder are calculated as given below-

Table 2.Specifications of Hydraulic Cylinders [7]

Cylinder No.	Trimming force (N)	Bore Dia. (mm)	Rod Dia. (mm)	Stroke (mm)	Quantity
1	39308	80	45	400	1
2	36000	80	45	50	1
3	391.96	32	18	160	1
4	380000	125	90	400	1
5	38931	80	45	50	1
6	38931	80	45	50	1
7	49197	80	45	50	1

Hydraulic power pack consists of hydraulic motor, pump, direction control valves, pressure relief valves, check valves, filters etc. All the valves are arranged on a single manifold because of which both the stations can be operated on the same power pack. Hydraulic oil used in the power pack is mineral oil HL-P DIN 5254 [7].

D. PLC, HMI and Safety Light Curtain Selection-

A programmable logic controller is a microprocessor based control system and is a control hub for wide variety of automated processes and systems. PLCs are mostly used in industries to communicate with other processes and control components [4]. Groover [5] defines a PLC as: “A microcomputer based controller that uses stored instructions in programmable memory to implement logic, sequencing, timing, counting and arithmetic functions, using digital and analog input/output modules, for controlling machines and processes.” The machine is equipped with PLC of MITSUBISHI MELSEC make with model number FX3U-64M as we have 32 inputs and 32 outputs for the machine.

Human-machine interaction with industrial plants and other dynamic technical systems has nowadays been recognized essential for process safety, quality, and efficiency. It comprises all aspects of interaction and communication between human users and their machines via human machine interfaces [6]. The HMI used for human interface with is SCHNEIDER make which allows safety operation of machine when maintenance is to be carried out.

Safety light curtains are most commonly used in industries to avoid accidents during machine operations. Safety light used for the machine is of P&F make with operating range of 0.3-6m.

E. 3-D CAD Drawings of Combined Trimming and Drilling Machine-

A detailed design of the machine includes design of punches, mounting brackets, springs, various supporting and mounting plates, strippers, locators etc. All the designed elements are drawn, extruded and assembled together in a 3D CAD modeling software named SOLIDEDGE V18. The final design of the machine is given in figs. 5, 6 (a), and 6 (b).

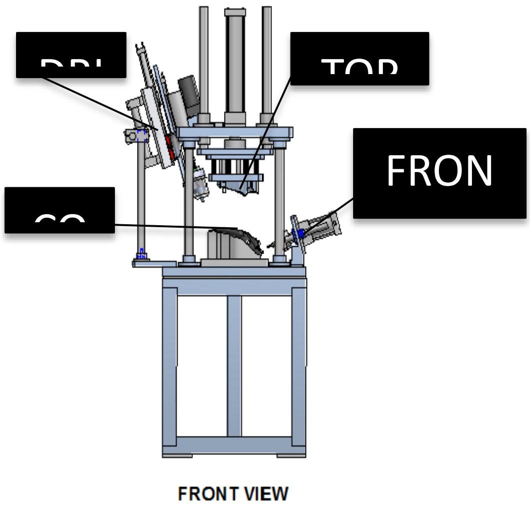

FIG. 5 STATION NO. 1

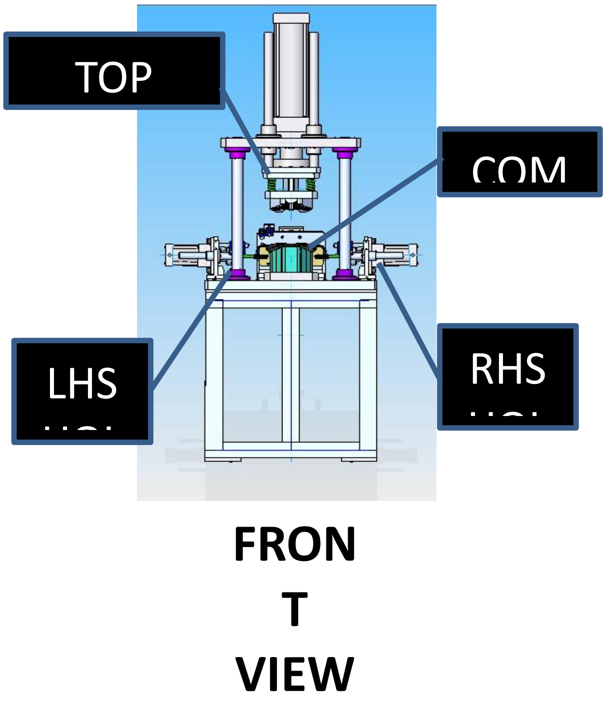

Fig. 6 (a) Station No. 2

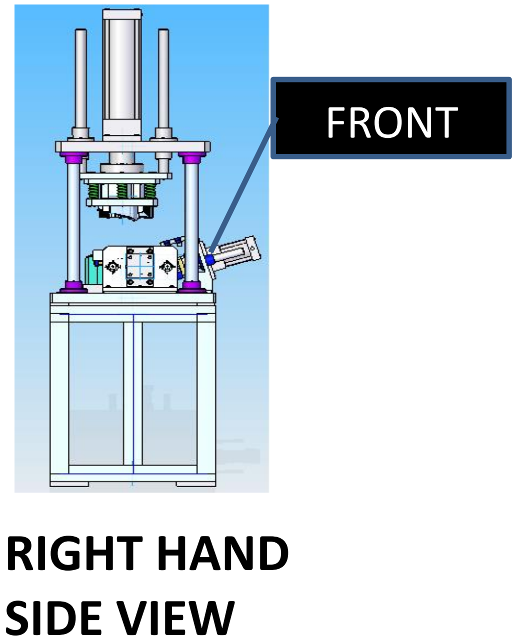

Fig. 6 (b) Station No. 2

V. WORKING OF THE MACHINE

A. Station No. 1-

Operator will manually load the tail lamp bracket casting on fixture then component sensor will sense the component. Top cylinder will not actuate unless and until component presence sensor senses the component. After pressing bi-manual button trimming of all the 4 holes will be done by forward movement of top cylinder, top cylinder will remain in forward position. Then RHS cylinder will get forward stroke to trim out rectangular holes after trimming it will get retract. Drilling cylinder will start its forward stroke along with the rotating spindles. After performing drilling the cylinder will retract to its initial position. And finally top cylinder will retract and operator will unload the component manually.

B. Station No.2-

Operator will manually load the tail lamp bracket casting which is finished on station no. 1 on the locator. Component sensor will sense the existence of component. The top cylinder will not actuate unless and until component presence sensor senses the component. After pressing bi-manual start button trimming operation will be done at profile area. Top cylinder will be in extended position until LHS, RHS, & Front holes will get trimmed by respective cylinders. LHS, RHS and Front cylinders will come forward and trimming of all holes will be done. Then LHS, RHS & Front cylinder will retract at same time. Finally top cylinder will retract and operator will unload the component manually.

VI. RESULTS AND DISCUSSION

After the complete design and manufacturing of the machine, several trials were taken. In these trials it is found that the components are trimmed out smoothly without leaving behind the flashes and trimming marks, an accurate and vibration free drilling operation is achieved. In results a drastic change is found in the parameters like cycle time, number of components trimmed and drilled, number of operators required, finishing of the components. The final results are discussed in table 3-

Table 3.Result Table

Sr No.	Parameters	Before Automation	After Automation
1	Cycle Time (Sec)	180	43 (26+17)
2	No. of Components Finished / month	3640	15288
3	No. of Operators Required	3	1
4	Net Profit / month (Rs)	217374.42	1036441.49
5	Aesthetic Look and Finishing	Poor	Good

Payback period is the period of time required to recoup the funds expended in investment.

$$Payback\ Period = \frac{Total\ Investment\ Cost}{Net\ cash\ in\ flow}$$

From the above mentioned formula payback period comes out to be 9.37 months i.e. 10 months.
The main result achieved after completion of the project is related to aesthetic of the component. Component has about 90% of surface exposed to environment and can be easily seen by naked eyes. Before development of machine the rejection rate was more because of manual operations which results in severe filing, hammering, and deburring tool marks on the component. The final process through which the component goes is anodizing process. After anodizing all the severe marks were clearly seen on the component because of which the component was rejected. After taking several trials on the developed machine all the problems associated with component are completely eliminated with reduced or no rejection of components. Final results are discussed in figs. 7, 8 and 9.

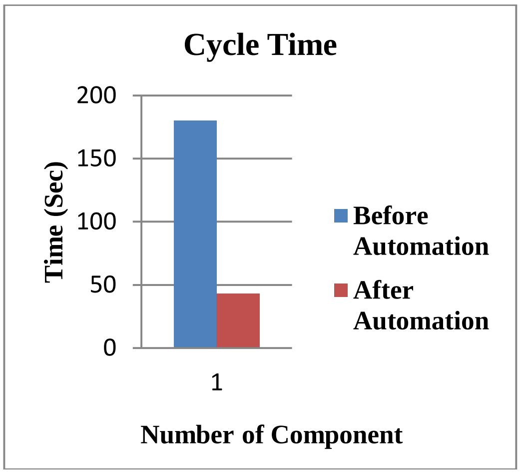

Fig. 7 Bar-Chart Showing Cycle Time Required per Component

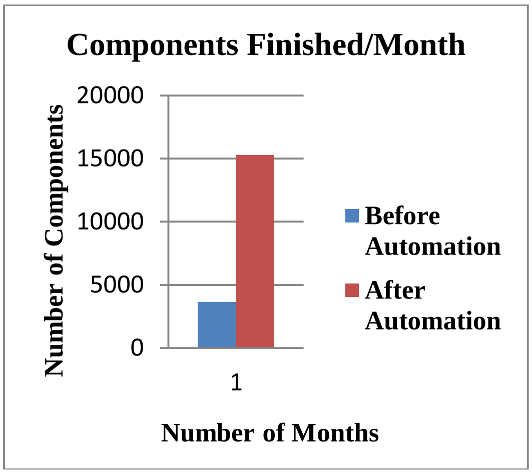

Fig. 8 Bar-Chart Showing Components Finished Per Month

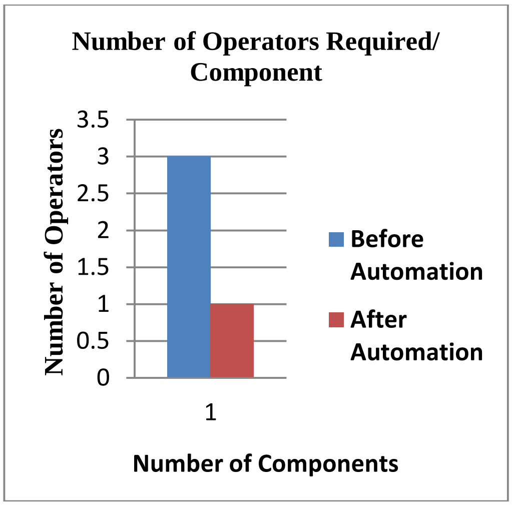

Fig. 9 Bar Chart Showing Number of Operators Required Per Component

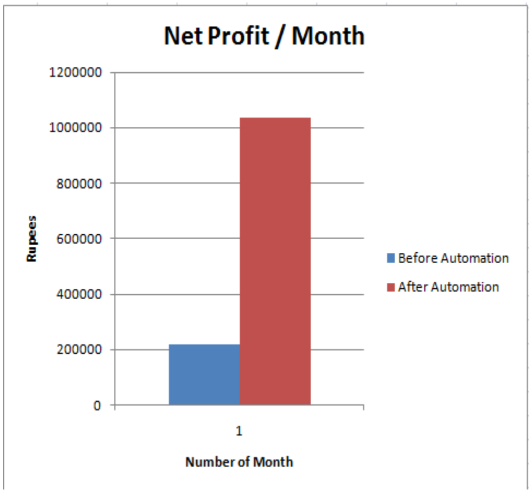

Fig. 10 Bar Chart Showing Net Profit Gained Per Month

VII. CONCLUSION

The paper describes a special purpose machine which is capable of trimming and drilling the respective locations of tail lamp bracket casting of a motor cycle automatically. It includes the design of punches required for trimming the holes, selection of hydraulic cylinders, power pack, PLC, HMI. By implementing the machine for described purpose the productivity of the process will surely increase. The machine is capable of performing the operations sturdily though casting alloy has excellent mechanical, chemical and casting characteristics. The casting has other locations where there is need of trimming; a special care is taken for future development of the machine. Lot of space is kept vacant for trimming top portion of the component and other areas can also be trimmed. The paper can be concluded with major points such as the finished component looks aesthetically pleasant and rejection rates are almost eliminated. Requirement of operators got reduced from 3 operators to a single operator. The great achievement is the drastic reduction in cycle time. The machine requires very less maintenance. We consider the developed machine is an important step towards fulfilling the need for the company.

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AUTHOR PROFILE

Nikhil J. Surwade has received B. E. in Mechanical Engineering from Pune University, Pune, Maharashtra, India in 2013. He is currently a student of M. E. in Advanced Manufacturing and Mechanical System Design from Sant Gadge Baba Amravati University, Amravati, Maharashtra, India.

Vinay K. Thute has received B. E. in Mechanical Engineering from Shivaji University, Kolhapur, Maharashtra, India and M.TECH. from IIT Kharagpur. He has work experience of 18 years and is currently working as Associate Professor at Shri Sant Gajanan Maharaj College of Engineering, Shegaon, Maharashtra, India.