

# Inspection and Testing Methods in Casting.

Vinay Dandge<sup>1</sup>, Omkar Choudhari<sup>2</sup>, Tushar Chavan<sup>3</sup>, S.J. Parihar<sup>4</sup>

<sup>1,2,3</sup> Student, Dept. of Mechanical Engineering, Deogiri College, Maharashtra, India

<sup>4</sup> Professor, Dept. of Mechanical Engineering, Deogiri College, Maharashtra, India

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**Abstract** - Non-damaging checking out is one a part of the characteristic of excellent manage and is complementary to different long-installed techniques. By definition, non-damaging checking out is the checking out of materials, for floor or inner flaws or metallurgical condition, without interfering in any manner with the integrity of the cloth or its suitability for service. The techniques included are Radiography, Magnetic Particle Crack Detection, Dye Penetrate Testing, Ultrasonic Flaw Detection, Eddy Current and Electro-Magnetic Testing. Here on this assignment paintings with the aid of using the usage of the radiography technique of NDT checking out is observed to discover the inner defects of the Al6061 forged specimen that turned into made with the aid of using stir casting technique. The aluminum forged shape worried to mono and multi-warmth dealt with at approximately 450 °C and 600 °C in a muffle furnace and is compressed automatically with the aid of using the usage of hydraulic press preparations earlier than the quick inspection thru NDT checking out. This approach is appropriate for the detection of inner defects in ferrous and nonferrous metals and different materials. Furthermore, the denser the cloth extra could be the absorption. After the number one level of inspection, maximum of the defects had been identified with the aid of using the NDT techniques. In the second one a part of this assignment, SEM photographs may be taken for the compressed casting shape. The structural modifications had been efficiently made at the forged specimen and the bond strength, in addition to hardness had been additionally increased. The assessment turned into made among the NDT inspected values and the SEM microstructure. It suggests the clean illustration of the grain shape and the bond strength.

**Key Words:** Non-destructive testing, Hardness, SEM, Hot forming, Casting.

## 1. INTRODUCTION

Casting technique is one of the earliest steel shaping strategies recognized to human being. It method pouring molten steel right into a refractory mildew hollow space and permits it to solidify. The solidified item is taken out from the mold both via way of means of breaking or taking the mold apart. While casting there can be loads of defects. It is critical to discover all the ones defects and limit them to nearly illness unfastened solid components. In aluminum castings, structural defects, oxide bi-films and pores are not unusual place due to bad soften nice and/or mildew filling machine design. These structural defects have deleterious

results at the tensile electricity and elongation in addition to the fatigue life. Testing and assessment of solid merchandise in a foundry enterprise has one number one objective. It is to ensure that elements being produced virtually meet all required specie-cautions mounted via way of means of the customer. Use of non-unfavorable trying out and assessment as a way of nice manipulate allows the industries to provide higher nice merchandise. Nondestructive trying out is appreciably practical in lots of plants, aerospace, nuclear enterprise, army and defense, garage tank inspection, pipe and tube inspection and composite defects characterization. Discussed on this paper in particular makes a specialty of the scope of NDT software for composite materials. To make certain the nice of the elements produced via way of means of introducing WAAM to assess the ability of the present NDT trying out became targeted via way of means of Lopez et al., they observed that for in-technique inspection Eddy Current, ultrasonic and thermography are the maximum appropriate techniques at the same time as EMAT or Laser UT have much less hindrance and may be an amazing approach. Better techniques which can be appropriate for diverse illness identification techniques and its suitability became explained. The trying out time is virtually decreased via way of means of the usage of EMAT is a right device for fatigue characterization for examining the crack initiation via on-line mode verified via way of means of Dobmann. Adopting the dependable approach for NDT trying out of boiler tubes inspection via way of means of Vakhguelletal. It became concluded that the mixture of wall thinning or overheating became the most important harm mechanism. Two ultrasonic take a look at measures have been advised for early detection of each those harm kinds without eliminating tube from the boiler.

### 1.1 Literature review:

In each manufacturing run, the foundry will select some samples and put up them to unfavourable trying out. The casting is cut, and the houses of the metallic inspected closely. The tester will search for inclusions, porosity, and shrinkage. Although destructively trying out one casting does now no longer assure whatever approximately the alternative castings withinside the run, it does provide a feel of the general pleasant of the procedure. Radiographic and ultrasonic technology have reduced the significance of unfavourable trying out, however it's miles nevertheless used to look into the pleasant and make reviews approximately a run. Non-unfavourable trying out is performed via way of means of foundry workers, clients, and

NDT technicians to affirm the inner and outside soundness of a casting with out unfavorable the casting itself. This technique makes use of the human eye to become aware of floor defects, cracks, fueloline evolution, slag or sand inclusions, misruns, bloodless shuts, and molding flaws. This form of castings inspection is undertaken to make sure a element meets dimensional requirements/tolerances. This may be performed manually or with a coordinate measuring machine (CMM) that makes use of probes to get very unique measurements. Finds tiny cracks, pores, or different floor imperfections in all kinds of metallic castings which could be difficult to peer via way of means of looking. The tester first cleans the casting to put off any debris of grit or dirt that can save you the liquid dye from going into cracks withinside the metallic. MPI is like LPI in that it's miles used to discover small cracks and holes at the floor or shallow subsurface of a casting. However, this procedure can most effective be utilized in castings product of ferromagnetic metallic that may create a magnetic area metals like iron, cobalt, nickel, and a number of their alloys.

The casting is magnetized, typically with electromagnets, to begin the take a look at. This take a look at unearths defects through the usage of excessive frequency acoustic strength transmitted right into a casting, in a generation just like the ultrasounds utilized by scientific technicians. Sound waves tour thru a casting till they hit the other floor or an interface or defect. Any barrier displays the sound waves, which get better and are recorded for an analyst to appearance at. The sample of the strength deflection can imply the area and length of an inner defect. This non-damaging take a look at also can be used to take a look at wall thickness, and the nodule rely of ductile iron. Extremely small flaws may be observed with UT at very massive depths, bearing in mind a exquisite deal of accuracy and confidence. An skilled technician may even make estimates as to the character of an alloy through searching on the acoustic signature of an unknown metal. X-rays create pix like the ones in a health facility that display damaged bones. The ghostly pix produced thru casting X-Ray display darkish spots in which there are shrinkage cavities, the small breaks and crevices of warmth cracking, or the pinhole dots of porosity. These pix assist an skilled metalworker determine if the casting's mechanical houses are compromised through shrinkage, inclusions, or holes and whether or not they may be constant earlier than castings are shipped.

## 1.2 Early history:

Throughout records, metallic casting has been used to make tools, weapons, and spiritual objects. Metal casting records and improvement may be traced lower back to Southern Asia (China, India, Pakistan, etc). Southern Asia traditions and religions relied closely on statue and relic castings. These objects had been regularly crafted from a copper alloy laced with lead. Since the start of metallurgy the bulk of castings had been easy one to 2 piece molds original from both stone or ceramics. However, there may be proof of

misplaced wax castings in severa historic civilizations. The misplaced wax method originated in historic Mesopotamia. The earliest regarded file of misplaced-wax casting is a clay pill written in cuneiform withinside the historic town of Sparta, Babylon, which in particular information how a good deal wax is wanted to forged a key. The earliest-regarded castings withinside the international archaeological file had been made in open stone molds. There are varieties of misplaced wax methods, direct misplaced wax approach and oblique misplaced wax approach. The direct molding approach is to make the wax cloth into the equal wax mildew because the casting with the aid of using hand or different tools; the oblique molding approach is to make the wax mildew via the mildew. The direct molding approach calls for craftsmen to have a excessive technical level, in any other case the first-class of castings can not be guaranteed. However, the dilemma of guide direct molding is that its performance is simply too low to reap mass production. In this regard, oblique moulding has advantages. In oblique moulding, artisans typically make moulds from stone, wood, clay or different plastic materials.

Early civilizations observed lead aided withinside the fluidity of molten copper, permitting them to forged extra elaborate designs. For example, the dancing female of Mohenjodaro is a copper alloy casting that maximum possibly makes use of the misplaced wax method.

## 2. EXPERIMENTAL

### 2.1 Material selection and specimen preparation

In the original stage the material was bought grounded on literature check and experimental plan. originally the aluminum amalgamation was chosen because of light in weight high strength material with further ductile and optimum hardness. The mileage- capability of the accoutrements is more and also the cost becomes low compare with other nonferrous accoutrements . So we named Al6061 amalgamation material which is most considerably used of the 6000 series aluminum blends. It's a protean heat treatable extruded amalgamation with medium to high strength capabilities.

Stir casting is an affordable system of melting and fabricating the needed essence matrix mixes in which a circulated member is mixed with the underpinning complements for the recommended shapes and sizes. The mixing or shifting of molten essence and the addition of mounts with the electric motor coupled with the stirrer placed vertically above the furnace arrangements. The molten sediment was mixed with the mounts and its complements by mechanical stirring action by graphite stirrer rod. It's fully bring effective and qualitative too. It contains magnesium and silicon as major alloying rudiments which is shown in Table 1, also having viscosity of 2700 kg/ cm<sup>3</sup> which is exactly suitable for high strength low weight operations. The needed shapes of the instance are created by the stir casting process. The casting

was done in the high temperature molding furnace which is having the melting temperature range of 900 – 1200 ° C, veritably suitable for making non-ferrous castings. The casting instance shape was turned back in the form of blockish.

**Table 1 – Composition of Al6061 alloy.**

Component	Al	Mg	Si	Fe	Cu	Zn	Ti	Mn	Cr	Others
Weight (%)	Balance	0.8–1.2	0.4–0.8	Max 0.7	0.15–0.40	Max 0.25	Max 0.15	Max 0.15	0.04–0.35	0.05



**Fig. 1 – Preparation of specimen by stir casting of Al 6061.**

**2.2 Innovative heat treatment of casted specimen**

After completing the casting process through machining these samples were prepared and it's involved to primary mono heat treatment at a temperature of 450 ° C sure as shooting time with annealed and quenched mode. then the 600 ° C in multi heat treatment processes was attained over the samples which were annealed and quenched before with mono heat treatment. Completely four samples out of eight were heat treated by mono heat treatment at a temperature of 600 ° C with annealed and quenched manner. In multi heat treated styles, the remaining four samples were treated first with 450 ° C also after the completion of hardening by anneal or quenching those are coming in to the secondary heat treatment with the temperature of 650 ° C. the identical air hardening and quenching has followed after completion of the multi heat treatment process. the warmth treatment was done by using the muffle furnace KSM- 0012 shown in Fig. 2 which has usable chamber size of 100 mm × 100 mm × 225 mm with the operating temperature of 1000 ° C outside up to 1200 °C.

The samples were well hardened and treated by using the annealing and quenching stages the least bit situations of forming temperatures. The secondary heat treated samples were treated with the temperature of 600 °C. It'll motivate the Process by which distorted grains of cold or hot forming essence. Were replaced by the new strain free grains during this fresh heat treatment. It becomes the fabric more ductile, hardness and meliorated grain structure.



**Fig. 2 – Heat treatment of Al6061 cast specimen with the mono and multi heat treatment methods.**



**Fig. 3 – Hot pressing of Al6061 heat treated cast specimen in UTM machine.**



**Fig. 4 – Hardness testing and its impression on heat treated hot pressed Al6061 casted specimen.**



### 2.3. Measurement of hardness and NDT testing on hot pressed specimen

After the completion of warmth treatments, the specimens were suddenly involved for the recent pressing by using the Universal Testing machine FIE-Universal 2001 (UTE). The specimens were involved during this hot pressing by UTM with the gradually applied compressive load of 400 KN before quenching and annealing as shown in Fig. 3.

The displacement and cargo values are noticed from the electronic display within the output response panel of UTM. subsequently the specimens were suggested for hardness measurement as shown in Fig. 4. Defect less casting specimen were prepared successfully by the casting of pure Al6061 alloy material and also the heat treatment highly removed all the inner stresses and defects of the specimen.

Better hardness were identified the flexibility of resisting the hundreds among various samples which is clearly agreed that more hardness is chanced in multi heat treated samples compared with the mono heat treated samples. By using Brinell and Rockwell hardness tester, the BHN and RHN values of every hardened specimens were measured by using steel ball intender with the load of 2000 kg. By measuring the impression of indentation to spot the values of BHN in a straightforward manner.

The defects were also identified by the radiography method of NDT which is clearly assured that the no defects level of outputs after the specimen met these reasonably heat treatments. The scanning microscope (SEM) readings were collected for the highlighted casted piece for finding the grain strength and particle size in a very micro level of observations. Finally, the SEM readings of the sample specimens and NDT results of the identical were analyzed and therefore the readings were tabulated.

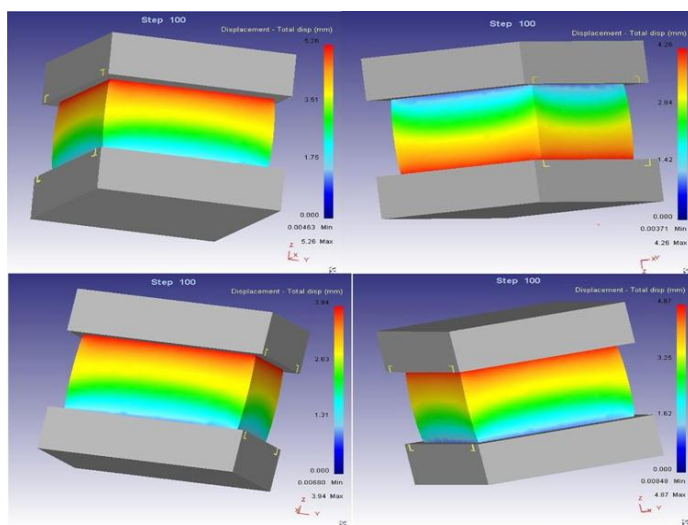


Fig. 5 – Simulation results of displacements on castings for 450 °C and 600 °C (P = 400 KN).

### 3. RESULTS

During the new forming process of Al 6061 amalgamation casting with none mounts the samples were prepared by casting. Two heat treatment processes were followed after the recent pressing through the press action in UTM machine. The instance consistence was reduced from its original shape thanks to moderate amount of applied cargo of 400 KN. The forming temperatures were maintained as 600 ° C and 450 ° C. The forming temperatures grounded on the respectable situations of melting temperatures of aluminum blends and its castings which is precisely near 650 ° C. There are two stages of hot pressing and warmth treatments were initiated similar as mono heat treatment and multi heat treatment for the constant pressing force of 400 KN. within the primary stage of mono treatment, the casted instance hotted at the temperature of 600 ° C within the muffle furnace KSM- MF01 as shown in Fig. 2 which has temperature range of maximum 1000 ° C. After reaching the annealing temperature of 600 ° C which is sort of grasped as liquid result the instance incontinently involved in hot pressing by using FIE Universal testing machine 2001( UTE) as shown in Fig. 3. the recent instance was pressed and also annealed sure holding time for getting further hardness and good mechanical parcels were attained. During the quenching process the new instance were dipped in to the water result.

Then the deportations were calculated from its original thickness of every instance after briskly pressed and it's mentioned in Table 2. The distortion situations were well prognosticated through the dynamic analysis software tool Deform 3D. These prognosticated graphical values of deportations are compared with the measured change in consistence values. We've to calculate the relegation as change in consistence of the new presses specimen under colorful heat treatment processes 3.1. Calculation of displacement variation

Here the displacements were calculated from its initial thickness of each specimen after hot pressed and it is mentioned in Table 2. The deformation levels were well predicted through the dynamic analysis software tool Deform 3D. These predicted graphical values of displacements are compared with the measured change in thickness of the hot presses specimen under various heat treatment processes.

#### 3.1. Simulation results of hot forming

Using Colorful duplications of hot forming by using the dynamic simulator Deform 3D. In this simulation the primary way the input parameters of compressing loads and boundary conditions were added. The accoutrements parcels also mentioned as Al6061 amalgamation from the material library which is automatically included all the data related to the material actions. After the process steps got over the instance model imported and the replication situations are

to be set. After the completion of boundary conditions, the portable and fixed jaws were indicated. multihued loads and forming temperatures are also given as input parameters. The stress values and deportations were linked as affair responses after completion of the iterative simulations. Then the less relegation was recorded as 3.94 for the annealed multi heat treated sample as shown in larger deportations were attained during the mono heat treated samples. The variation among all the trials, these two heat treatments were showed easily the least values of variation 0.61, 0.94 was attained during the multi heat treatment stage at a temperature of 650 °C for the cargo of 400 KN.

### 3.2. Comparison of hardness in hot pressed specimens

It's verified that the prognosticated values of relegation in dynamic simulation tool distort 3D in hot forming, the displacement variation is minimal during the multi heat treated instance examination because of change in consistence varying depends on the heating temperatures at about 600 °C. The grain boundary consistence and flyspeck size were recorded minimum due to the hot compressed multi heat treated Al6061 samples. The strain rate becomes high used to change the flyspeck size minimum. More compliances of flyspeck size reduction, grain boundary strengthening and high hardness were conceded good in multi heat treated hot pressing of Al6061 casting samples. There were no further blights were linked in NDT among the both mono and multi heat treated casting samples. After the heat treatment and hot forming is over, the hardness of each instance were calculated and the compliances are mentioned in Table 3 as shown over. Both Brinell (BHN) and Rockwell hardness (RHN) testing were done on the treated instance in both situations of forming stages. Then we easily linked the hardness of multi heat treated instance has got awful hardness 111.81 BHN and 65.365 RHN, independently. Compared with the mono heat treated instance advanced hardness were achieved in the variation of 2.5125 hardness number with the multi heat treated instance. It's noted that the lower hardness values were recorded in the non-heat treated instance as 99.25 BHN and 58.77 RHN. Advanced hardness was attained on the quenching instance in the multi heat treatable.

### 3.3. Observation of NDT report

Nondestructive testing is used in a selection of settings that securities an expansive choice of an artificial exertion, with new NDT styles and operations, being uninterruptedly established. Nondestructive testing styles are regularly functional in diligence where a failure of a module would beget important hazard or fiscal loss, similar as in transportation and pressure vessels. In both annealing and quenching, the heat treatments were fulfilled at the temperatures of 450 and 600 °C. The heat treated samples observed from the NDT results, there's no internal blights were observed because of added heat with the compressive goods of 400 KN cargo used for the development of refined

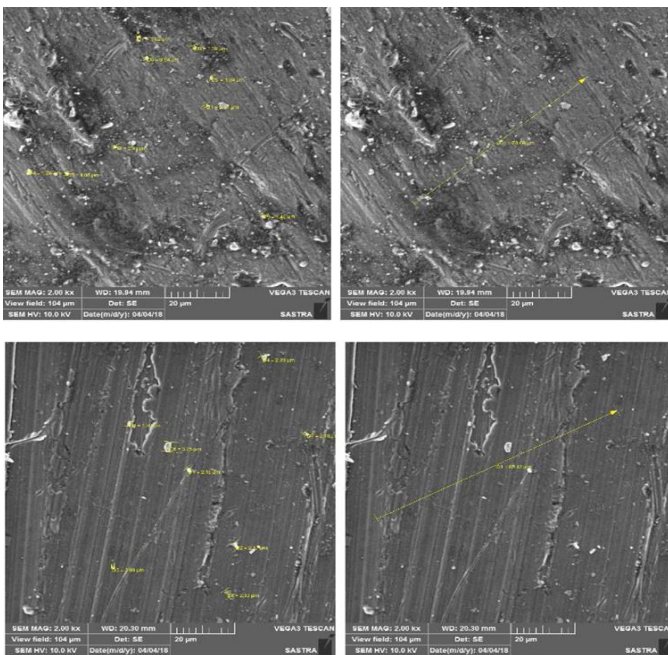
grain structure. Then in this work each instance has involved in to the radiographic examination of NDT testing. Separate flicks were employed in the shape of 6 cm × 3 cm for the readings taken.

The interpretation of test results is showed no blights. It's noted that in Table 4 partial blights were linked in the non-heat treatable aluminum casting instance through the Radiographic test report. else there wasn't indeed single blights not linked during the heat treatable annealed and quenched instance in both stages of compliances. This can be verified with the microstructure representations as mentioned in Table 5. Following by hardness comparison, the good NDT issues will give us clear result and data comparison.

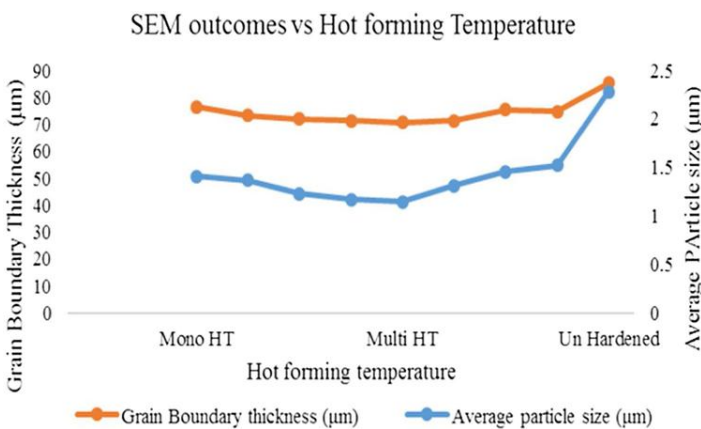
### 3.4. SEM identification of particle size and grain structure

It's vital that the microstructural readings were presented in Table 5. It represents the values of average flyspeck size and grain boundary consistence in micro measures. The observed readings from the micro graphical structure habit to identify the flyspeck size measured through the Scanning ray microscope Vega- 3 TESCAN as shown in Fig. 8. The SEM images showed the detailed structural changes of both discerned casting samples. The stressed samples were involved thorough the SEM examination with the separate exaggeration factor position. for colorful image interpretation colorful readings were captured from the peripherals of the set instance. Its grain boundary also noticed as  $\mu\text{m}$  as recorded from SEM images. also, better flyspeck size 1.1693  $\mu\text{m}$  were set up during the quenching of mono heat treated primary stage of Al6061 casted samples.

The grain boundaries of the numerous compliances also got minimal during the multi heat treatable casted instance. the explanation behind these good bond strength and flyspeck size are the change in consistence by hot compressed instance by UTM



**Fig. 7** – SEM images of particle size and grain boundary at 2k× magnification level image of hot compressed specimen by mono heat treated and multi heat treated compresses specimen.



**Fig. 8** – Relationship of SEM outcomes and hot forming temperature.

**4. CONCLUSION**

- Disfigurement lower casting instance were prepared successfully by the casting of pure Al6061 amalgamation material. Complete survival of material testing was fulfilled by NDT system which explained that the hot forming heat treated samples completely removed all the internal stresses and blights.
- Hardness dimension helps to identify the capability to repel the loads among the colorful samples which is easily agreed that further hardness is chanced in multi heat treated samples compare with the mono heat treated samples.

- Relegation variation is minimal during the multi heat treated instance examination because of change in thickness varying depends on the heating temperatures at about 600 ° C. This was verified with the relegation values of dynamic simulation by Deform 3D forming tool.

- The grain boundary consistence and flyspeck size were recorded minimum due to the hot compressed multi heat treated Al6061 samples. The strain rate becomes high used to change the flyspeck size minimum. This productive material processing applied in the field of aerospace operations and used in light weight high strength factors

- More compliances of flyspeck size reduction, grain boundary strengthening and high hardness were conceded good in multi heat treated hot pressing of Al6061 casting samples. There were no further blights linked among the both mono and multi heat treated casting samples

**5. REFERENCE**

1. Dwivedi SK, Vishwakarma M, Soni A. Advances and researches on non destructive testing: a review <http://dx.doi.org/10.1016/j.matpr.2017.11.620>
2. Lopez A, Bacelar R, Pires I, Santos TG, Sousa JP, Quintino L. Non-destructive testing application of radiography and Ultrasound for wire and arc additive manufacturing. Addit Manuf <http://dx.doi.org/10.1016/j.addma.2018.03.020>
3. Dobmann G. Fatigue monitoring by NDT of austenitic Stainless steel at ambient temperature and 300 °C and new Attempts to monitor a fracture mechanics test. Proc Eng <http://dx.doi.org/10.1016/j.proeng.2014.11.052>.
4. Marashi J, Yakushina E, Xirouchakis P, Zante R, Foster J. An Evaluation of H13 tool steel deformation in hot forging Conditions. J Mater Process Technol <http://dx.doi.org/10.1016/j.jmatprotec.2017.03.026>.
5. Mueller MG, Zagar G, Mortensen A. In-situ strength of Individual silicon particles with in an aluminium casting. Acta Mater <http://dx.doi.org/10.1016/j.actamat.2017.09.058>.
6. Tao P, Shao H, Ji Z, Nan H, Xu Q. Numerical simulation for The investment casting process of a large-size titanium alloy Thin-wall casing. Progr Nat Sci Mater <http://dx.doi.org/10.1016/j.pnsc.2018.06.005>.
7. Milkell P. Groover, “Fundamentals of Modern Manufacturing: Materials, Processes, and Systems”, John Wiley and Sons, New Jersey, 4<sup>th</sup> edition, 2010.
8. Paul DeGarmo, J.T. Black, Ronald A. Kohser, “Materials and Processes in Manufacturing”, Wiley, 10<sup>th</sup> edition, 2007.

9. <https://en.m.wikipedia.org/wiki/Casting#:~:text=Casting%20is%20a%20manufacturing%20process,mold%20to%20complete%20the%20process>

## BIOGRAPHIES



**Vinay Ganesh Dandage.**

*Student, Dept. of Mechanical Engineering, Deogiri College, Aurangabad Maharashtra, India.*



**Omkar Choudhari.**

*Student, Dept. of Mechanical Engineering, Deogiri College, Aurangabad, Maharashtra, India.*



**Tushar Chavan.**

*Student, Dept. of Mechanical Engineering, Deogiri College, Aurangabad, Maharashtra, India.*