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Enhancing The Hardness of Cast Iron Machine Pulley Used In Industrial Application Through Various Techniques Experiment In The Casting Industry

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Abstract – *The authors identified a crucial need to enhance the hardness of cast iron machine pulleys such that their hardness should range from 140 BHN to 180 BHN for Deepshikha Castings Pvt. Ltd., a prominent player in the central Indian casting industry. It was observed that achieving this hardness was feasible in castings with a cross-section thickness below 10mm; however, the hardness decreased as this dimension increased. The company conducted some experiments by varying the contents of some elements like Carbon C, Chromium Cr, Silicon Si etc. after cupola pouring, but the hardness was not achieved uniformly. This issue was discussed with the authors. They conducted a detailed literature review to find the strategies for increasing hardness. Most research papers were discussing on increasing the hardness by varying the contents along with variation in the temperature of casting by cooling after pouring in the mould or removing from the mould. No paper discussed only the effect of variation in temperature by cooling while keeping the composition the same. Hence, the primary focus of the experimentation involved manipulating temperature-related parameters through the heat treatment process, internal chilling, or implementing forced cooling techniques. These experiments aimed to increase the hardness of the cast iron machine pulley while maintaining the existing composition. This research paper emphasizes the significance of improving cast iron hardness through some experiments based on either of the processes like forced cooling, heat treatment, or internal chilling temperature. The outcomes of these experiments, which successfully improved the hardness, are explained in this paper.*

Keywords*- cast press hardness; microstructure of CI; press carbon chart; TTT chart; warm treatment of CI; mechanical properties; cooling rate of CI castings*

INTRODUCTION

Deepshikha Castings Pvt. Ltd., a prominent player in the central Indian casting industry required to enhance the hardness of cast iron machine pulleys to range from 140 BHN to 180 BHN. It was observed that achieving this hardness was feasible in castings with a cross-section thickness below 10mm; however, the hardness decreased as this dimension increased to about 20mm or more. To address this issue, the authors studied various research papers to find strategies for increasing the hardness of cast iron. One more requirement of the industry was to maintain the existing composition as far as possible. So, based on this requirement and the literature review carried out, the authors designed to conduct a series of experiments. These experiments aimed to increase the hardness of the cast iron machine pulley while maintaining the existing composition.

METHODOLOGY FOR APPROACHING THE SOLUTION

The primary focus of the investigation involved manipulating temperature-related parameters through the heat treatment process, internal chilling, or implementing forced cooling techniques.

The authors designed the methodology for addressing this issue.

1. They carried out a detailed literature review of research papers that discussed various ways of increasing the hardness of Cast Iron.

2. Test the hardness of CI Machine pulleys which they achieve by the usual method.

3. Perform the experiments in alliance with the industry (industry suggested keeping the composition the same, so authors focused on performing the experiments bymanipulating temperature-related parameters through separate experiments of the heat treatment process, internal chilling, or implementing forced cooling techniques.)

4. Test the hardness of CI Machine pulleys that is achieved by the heat treatment process, internal chilling, or implementing forced cooling techniques separately.

5. Suggest the industry following the method in which the hardness increased as per the requirement.

REVIEW OF RSERCH PAPER TO IMPROVE THE HARDNESS OF CAST IRON

The authors conducted a detailed literature review of research papers (as mentioned in the reference section) that discussed various ways of increasing the hardness of Cast Iron.

S. P. Sundar Singh Sivam et al (2019) [1] specified the reduction in copper content and increase in the cooling time increased the hardness of CI. The increase in carbon, silicon, and chromium content along with the heat treatment will increase the hardness of CI as in [4][5][6][7][8][9][14][16][18][19].

Ile-Ife et al [11] specified that some variation in C/Cr in the composition of CI along with the forced cooling leads to an increase in the hardness of CI. The internal chilling with some variation of C/Si/Cr/Cu in the composition of CI leads to an increase in hardness [2] [10] [17]. The heat treatment with an increase in chromium content leads to an increase in hardness [3] [4] [12][13][15][19].

The literature review shows that varying the composition along with the temperature-related changes through processes like heat treatment, forced cooling and internal chilling methods can increase the hardness of CI. The research gap found through the literature review was that singly these temperature-controlled cooling methods were not applied without composition variation. Also, the machine pulleys with the same composition but with less thickness than 10mm achieved the required hardness. So, the authors independently applied these temperature-related cooling or heating methods without changing the composition. Then they designed the experiment for applying individually the method of heat treatment / forced cooling /internal chilling to these CI Machine pulleys and tested their hardness.

CAST IRON COMPOSITION AND CASTING PROCESS

To manufacture the castings at Deepshikha Casting Pvt. Ltd., the CI is melted in the cupola and the composition of charge to the cupola is made from CI from various sources like FG PI, Tata, Earth PIG, SG PI Uttam, FR are added to the cupola bucket inside the cupola furnace.

Table 1: Composition of CI (in percentage)

CHEMICAL	%
• Carbon	- 4.79%
• Silicon	-1.465%
• Magnesium	- 0.46%
• Phosphorus	- 0.152%
• Sulphur	- 0.109%
• Chromium	- 0.014%
• Molybdenum	- 0.006%
• Nickel	- 0.015%
• Aluminum	- 0.004%

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- Copper - 0.005%
- Titanium - 0.053%
- Magnesium - 0.002%

After melting, the pouring of molten CI is done to the ladle weighing 40kg. Molten CI from the ladle is poured into the sand mold of the CI Machine Pulley. The pouring time is 16.9 seconds for this machine pulley.

It is allowed to be set in the mold for around 3 Hours as a normal procedure. The mold is then broken and the castings are allowed to cool at room temperature with normal air in a room for 2-3 days. Figure 1 shows the pouring of the molten cast iron into the mould for producing the cast iron machine pulley.

EXPERIMENT BASED ON TEMPERATURE RELATED PROCESS

HEAT TREATMENT

Annealing and Quenching was used in this method. Annealing is the process where the specimen is being heated to a particular temperature above the re-crystallization temperature and held there for some time. This changes the physical and the chemical properties of a material to make it more workable. Annealing is followed by quenching. Quenching is soaking a material into a fluid—water, oil, or even air to cool it down from a high temperature quickly. Typically, quenching is done to preserve the mechanical properties of a phase distribution or crystalline structure that would otherwise be lost during slow cooling.

Fig 1: Pouring the molten Cast iron into the mould at Deepshikha Castings Pvt. Ltd., Nagpur, India

Fig 2: Cast iron Machine Pulley Speciment By Normal Process At Deepshikha Castings Pvt. Ltd., Nagpur, India

The CI Machine pulley specimen was annealed i.e. heated at the rate of 5°C per min to the temperature 870°C . It was held at this temperature for one hour and then quenched i.e. force cooled using a blower.

Specifications of heat treatment are as below:

Annealing Temperature: 870°C (at the rate of 5 °C/min)

Holding time at annealing temperature: 1.5 hour

Quenching Duration by blower: 30 min

Blower speed - 2800 RPM, 3900 CMH

The result of hardness test after the heat treatment is shown in Table 2. It shows significant increase in hardness.

Table 2: The result of the hardness of the CI Machine pulley after the heat treatment.

Sr No	Hardness before heat treatment (HBW)	Hardness after heat treatment (HBW)
1	130	200

FORCED COOLING

The resulting mechanical properties of Cast Iron are largely dependent on the pace of cooling. It establishes the size and rate of grain growth. Cast Iron's mechanical characteristics can be altered throughout its length by sectioning the material to check varying cooling rates.

By utilizing forced cooling by air at higher flow rates, this study aims to examine the effect on its hardness.

In the normal procedure, as explained earlier, the castings are allowed to set in the mould for 3 Hours. The mould is then broken and the castings are allowed to cool at room temperature in normal air for 2-3 days. In forced cooling, after the casting is removed from the mould, it is cooled by forcing the air using the blower. The specimen was force cooled for 4 hours and then further allowed to cool at room temperature 24°C for 2-3 days. The apparatus for forced cooling is shown in

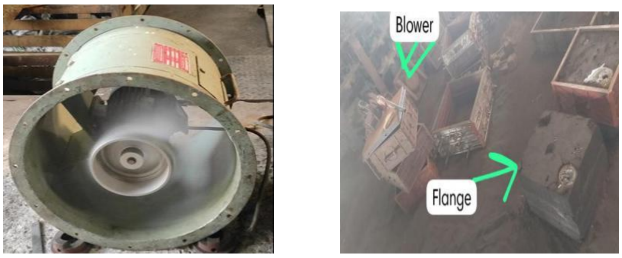

Figure 3.

Fig 3: Forced cooling on Cast iron machine pulley after it is removed from the mould after it is set and Blower used for forced cooling; at Deepshikha Castings Pvt. Ltd., Nagpur, India

The specifications of forced cooling are as below:

Temperature of air when force cooled: 24°C

Blower duration: 4 hours.

Blower speed: 400RPM, 3900 CMH

The result of the hardness of the CI Machine pulley after the forced cooling is mentioned in Table 3 which shows increase in the hardness of CI Machine pulley compared to the normal manufacturing process.

Table 3: The result of the hardness of the CI Machine pulley after the forced cooling

Sr No	Hardness before forced cooling (HBW)	Hardness after forced cooling (HBW)
1	130	200

INTERNAL CHILLING

Chilling is adopted to promote solidification in a specific portion of a metal casting mold. It is done by providing the chills i.e. metal pieces in the sand mould, so that they conduct more heat from mould to the outside atmosphere while cooling and hence promote solidification. In this process, the chills melt and mix with the casting and hence the material should be the same as that of the casting. If we used Cast iron pieces along with the sand in mould preparation in this industry, then it would harm the labourer’s hand while breaking the mould. So, the authors thought of providing simply some holes in the sand mould instead of the chills and this would increase the cooling rate to some more extent compared to the normal process.

For implementing internal chilling, the mould was provided with additional holes to release the heat of molten metal, so that directional solidification is achieved and the casting cools earlier. For the given machine pulley mould 30 holes of 1.5mm diameter were created on the face of the mould after pouring the molten CI. The molten metal was poured at 1450 °C.

Fig 4: Molten Cast Iron poured and holes made for internal chilling at Deepshikha Castings Pvt. Ltd. Nagpur, India

The pouring time and the temperature are very important in the internal chilling method. The casting was cooled within 2 hours and it was removed from the mould. The image of process of internal chilling is shown in figure 3. Later, it was allowed to cool at room temperature for 3 days in normal air whose temperature was 24 °C. The machine pulley was tested for hardness after this process. The result of the CI Machine pulley hardness after the internal chilling is mentioned in Table 4.

Parameters noted during internal chilling:

Ambient temperature: 24 °C

Temperature of Molten metal while pouring: 1450 °C

No. of holes in a mold: 30 number x 1.5mm diameter

Duration for casting to set in the mold: 3 hours

Table 4: The result of the hardness of the CI Machine pulley after the internal chilling

Sr No	Hardness before internal chilling (HBW)	Hardness after internal chilling (HBW)
1	130	165

The result shows that the hardness increased after internal chilling process.

CONCLUSION

The authors identified a gap in the existing literature concerning temperature-related parameters in the cooling process of castings, particularly in heat treatment, internal chilling, and forced cooling techniques.

They conducted experiments to manipulate temperature-related parameters during the cooling phase of castings. These experiments aimed to enhance the hardness of cast iron (CI) machine pulleys while preserving their original composition.

Our findings revealed that manipulating temperature-related parameters in heat treatment, internal chilling, and forced cooling processes led to a significant increase in the hardness of CI machine pulleys without altering their composition. Based on our results, we recommend implementing forced cooling and internal chilling techniques in the industry to enhance the hardness of CI machine pulleys. These methods offer effective solutions for increasing hardness while maintaining the original composition of CI components.

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