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Analysis of Cast Iron Machine Parts

Abu Bakr Azam[1], Akshay Narasimhan S.[1], B. Hariprasath[1], Dr. Pratibha Nalini R[2*]

[1]B.Tech. Mechanical Engineering, Vellore Institute of Technology, Chennai Campus, Vandalur - Kelambakkam Road Chennai, Tamil Nadu - 600 127, India
[2]Assistant Professor, Vellore Institute of Technology, Chennai Campus, Vandalur - Kelambakkam Road Chennai, Tamil Nadu - 600 127, India

Corresponding author: *pratibha.nalini[at]vit.ac.in

Abstract: ***Different forms of cast iron are used to make various machine parts like pistons and gears, due to it is castability. It also shows resistance to deformation at high temperatures, even being restorable after damage caused by fire. It is thus important to systematically analyze the various properties of such materials. In this paper an attempt is made to study different machine parts like gears, pistons and ball bearings and their relationship between Rockwell hardness values before and after annealing and their microstructure is analyzed.***

Keywords: Cast iron, Rockwell hardness, Microstructure, Annealing, Gears

1. Introduction

Throughout the centuries, cast iron has found its place in many areas, from cookware to automobiles [1-2] with productions in tons for machine products with low performance necessities. Crankshafts and gears can be regarded as major examples. In terms of its properties, it is an iron-carbon based alloy, which has at least more than 2% of Carbon content in it. It's usually brittle but they have a reasonably low melting point [3] and can be machined with ease. Cast iron is produced by re-melting pig iron, usually with considerable amounts of iron, steel, limestone, coke and taking various steps to remove undesirable impurities.

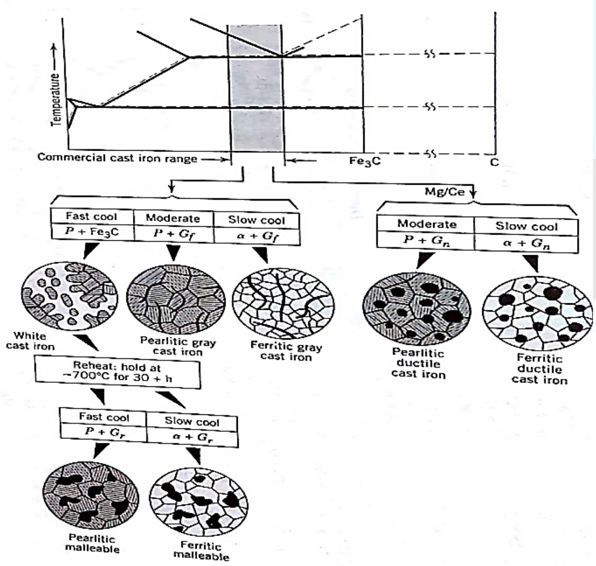

Figure 1: From the iron-carbon diagram, composition ranges of various commercial cast irons. Image courtesy: Callister [7]

There are many forms of cast iron, like white, grey, ductile, and malleable cast iron, which are used for specific purposes, like the use of ductile cast iron to reduce noise in a mechanical material. Figure. 1 shows an overview of different types of cast iron. Manufacturing machine parts consists of several processes like heat-treating, casting machining etc., each of which determines the material's property for their specific purpose.

Pistons are used for high-speed machine applications, mainly in IC engines. Bearings are used to restrict relative motion, for example, hydrodynamic bearings in gas turbine based engines, [3-5] while gears are used mainly for power transfer, like in printing machines, automated machines etc. [6]

This paper presents a comparative analysis of commonly used cast iron machine parts such as piston, ball bearing and gears. The result of Rockwell hardness tests and microstructures before and after annealing is studied.

2. Testing Arrangements

2.1Test specimens

Figure 2: Mounted specimens (gear and piston)

For the hardness test and annealing, the specimens were the gears, pistons, ball bearings, where the test was conducted on various parts of the specimen. For annealing, a muffle furnace was used.

For observing the microstructure, small portions of the machine parts were cutusing an angular metal cutter and a mounted specimen was prepared using a hot mounting press. The mounted specimen is shown in figure 2.

2.2 Testing devices

The Rockwell hardness testing was performed using model RH150 (Chennai Metco) coupled with diamond indenter. The Rockwell Scale C was used and the major load applied was

150 Kgf. An inverted microscope M1001, coupled with a pixel-fox camera, having a resolution of 200x was used to get the microstructure of the samples.

2.3 Testing Procedure

The 150Kgf load is applied, then removed to get the value of Rockwell hardness.

The muffle furnace is used to heat the specimen (gear) up to the austenizing temperature (950^0), [7] after which it is left in the furnace for 10-12 hours to anneal.

The specimens prepared from the molding press are polished, grinded and etched with Nital solution check its microstructure.

3. Experimental Results and Discussion

3.1 Rockwell hardness test

Table 1 consolidates the actual values obtained from different positions of the specimen from the Rockwell hardness tester for all the specimens. Three trials were taken at three different positions for each sample. Figure 3 shows the trend of average hardness values obtained for different machine parts before and after annealing.

Annealing is used to finely distribute the ferrite and cementite present in the material. Reduce metallurgical nonuniformity which could be formed due to previous machinery, making it easier to machine, relieve internal stresses caused by previous treatments [6].

It is noted that the gear and bearings show similar hardness and the piston has the least hardness among the specimens tested. This could be attributed to the carbon content in the machine parts which may be lower in piston materials. Gear is typically made of grey cast iron and the piston is made of ductile cast iron or aluminum alloy. The higher carbon content due to the grey cast iron in gears render the material to possess higher hardness.

As it is known, annealing reduces a material's hardness. In this case, the observed hardness change was between 50-60%.

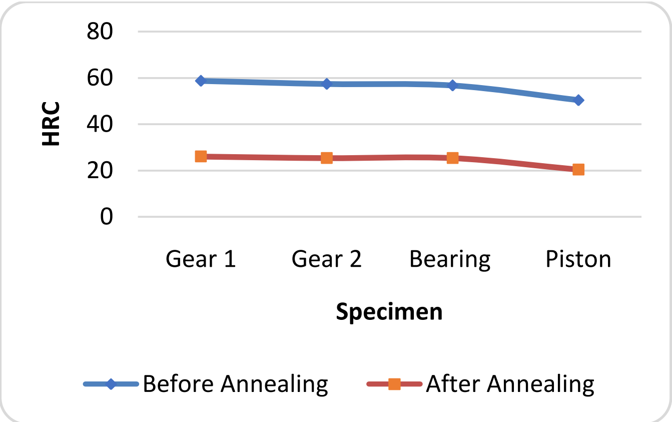

Figure 3: Rockwell hardness test graph before and after annealing

Table 1: Rockwell hardness values before and after annealing

Part/Heat treatment	Before Annealing	After Annealing	Percent change
Gear 1	58	26	55
Gear 2	57	25	55
Bearing	56	25	55
Piston	50	20	59

3.2 Microstructures

The white regions are ferrite and the dark regions in figure 4 are pearlite.

Figure 4 is the microstructure of a piece cut from a gear box, which has the highest hardness as shown above. The presence of graphite flakes is well noted, marked as 1 in the figure, and confirms the earlier assumption and reasons out the cause for higher hardness.

Due to this, it is used for applications requiring excellent wear resistance, corrosion resistance and increased fluidity during casting. [9]

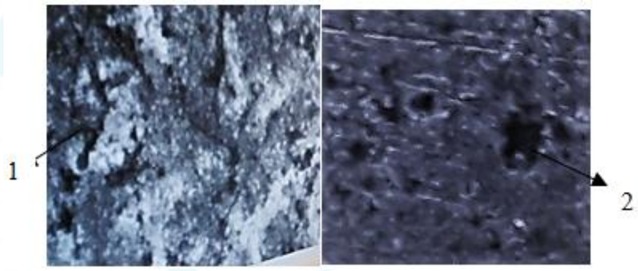

Figure 4: Microstructure of gear and piston

In the microstructure of a piece of a piston, which has the lowest hardness, the presence of nodules was observed, marked as 2 in figure 4, thus indicating the machine part to be made up of ductile/nodular cast iron.

Nodular cast iron is an excellent competitor with polymers like PVC and polypropylene. It is also used for huge and multifaceted structures with large loads.

4. Conclusions

Components like gears and ball bearings display greater hardness values as they experience frictional force throughout their life cycle. Since pistons work under very high temperatures conditions, along with friction, the hardness values thus obtained are justified.

However, high hardness value also contributes to their brittleness which leads to their instantaneous failure upon reaching their fatigue point. This requires cast iron to be tougher. The reduced value of the hardness, due to annealing does not affect the main purpose the product. It enhances its performance by increasing the toughness.

It was also found that cast iron component's hardness is in par with the aluminum's hardness which has been replacing cast iron for numerous and various applications.

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