International Journal of Scientific Modern Research and Technology
(Volume: 7, Issue: 3, Number: 8)
ISSN: 2582-8150

Improving the Mechanical Properties of AISI 4140 Alloy Steel Made by Investment Casting

B. Sreevani[1], A. Lalu Prasad[1], C. Sekhar[1], K. Akhil Kumar[1], M. V. S. Bhanu Charan[1]
G. Sudharsana Reddy[2]
[1]UG Scholars, [2]Associate Professor
Department of Mechanical Engineering, Vemu Institute of Technology, Andhra pradesh

Abstract: Now-a-days Alloy steel materials have become more important for its wide range of application in design flexibility, aerospace, space craft, most of the industries are conducting various experiments and researches to develop Mechanical properties. In this we are using AISI 4140 alloy steels made by investment casting and to find out Micro structure, Mechanical properties like Hardness, Impact strength, Tensile strength, Compressive strength etc.,

Keywords: Alloy Steel, Tensile Strength, Compression, Aerospace, Investment Casting, Hardness;

I. INTRODUCTION

AISI 4140 alloy steels are widely used in the machinery manufacturing industry. For example, AISI 4140 alloy machine-building steel is used at a rate of 10% in the machining industry and is a steel with high hardenability due to the alloying elements it contains (MKE, 1993).The most important feature of AISI 4140 alloy steel is that it can form a hard martensitic structure after quenching due to the Cr and Mo alloying elements it contains, allowing mechanical properties such as strength, ductility, and toughness to be provided together. For all these reasons, AISI 4140 alloy steel is always common steel. (Avner, 1986; Choo et al., 2000).The brittleness that may occur during tempering at specific temperature values in most machine elements is one of its biggest disadvantages (Oliveira et al., 2000). In order to prevent this negative effect, it is very important to choose the appropriate temper temperature (Charre, 2004; Buytoz, 2004).

Problem Statement

Now-a-days, manufacturing companies needs good quality and strong metals to withstand against the competition in the markets. So it is challenging to the manufacturers, to selecting the best manufacturing method and following steps to produce great quality metal. So we researched for best manufacturing methods and we found Investment Casting as best because it can produce complicated shapes and gives good finish. We designed a new Heat treatment process which involves Hardening and tempering processes with different temperatures to increase the Hardness and gives more Strength. This project gets evolved during our thoughts to with stand against the current competition.

Objectives

- To Manufacturing of IC 4140 Alloy Steel by Investment Casting and improve the mechanical properties such as Tensile strength, Hardness, Impact strength and Compressive strength.
- The alloying elements are added to steels in order to improve specific mechanical properties, and to find out the microstructure of alloy steel mainly made by investment casting.

II. LITERATURE SURVEY

Investigation of the Effect of Normalization on Mechanical Properties and Microstructure of the AISI 4140 Alloy Steel, In this study observed that mechanical properties of the material increased with the Normalization process and increased the Tensile and Yield strengths and decreased the Impact Strength [1]. Investigation of the tempering process of martensitic AISI 4140 steel at high heating rates, With increasing heating rate, it appears that an incomplete precipitation of carbide occurs due to an overlap of the precipitation regimes. An investigation of the developing microstructure after tempering has shown a refinement of the precipitated cementite with increasing heating rate which is consistent with literature reports [2]. Effect of Heat treatment and Mechanical characterisation of AISI 4140 steel, the

annealed specimen shows lower hardness and strength compared to as bought, hardened, normalized and tempered specimen. Hardness and strength indicate that pre-treatment specimen is similar to the normalized specimen. Tempering improves the ultimate tensile strength of the hardened material [3]. Effect of austempering temperatures on surface hardness of AISI 4140 steel, the effect of austempering on the hardness value of AISI 4140 steel were obtained that the greatest hardness value was 264.4 BHN, which was achieved at the austempering temperature of 350°C. Hardness and microstructure values were affected by the austempering temperature. When the austempering temperature was decreased, the hardness value increased [4]. Investigation of the Effect of Heat Treatment Parameters on Mechanical Properties of AISI 4140 Alloy Steel by Quenching in Water, a rapid increase in impact strength was observed at tempering above 300°C.Percentage Elongation and percentage reduction in area increased in directly proportion to the increase in tempering temperature. The hardness decreased with the increase in temperature. The highest elongation at break and reduction in cross section values were achieved as a result of the tempering process at 600°C [5]. Feasibility Exploration of Super alloys for AISI 4140 Steel Repairing Using Laser Engineered Net Shaping, It should be noted that the tensile strength and hardness value of the specimen is less than that of industrial requirement (UTS: 1080 MPa and hardness: 550 HV1), however, it is reported that both of the two properties can be improved with proper heat treatment method. Due to the limitations of equipment, currently, these treatments are not performed as an optional method to improve the two properties. Also, some properties that are required for the AISI 4140 steel, such as bending strength, corrosion resistance as well as high-temperature wear resistance, are not covered in this study [6]. Assessment of Mechanical Properties of AISI 4140 and AISI 316 Dissimilar Weldments, Successful welds of AISI 4140 and AISI 316 could be obtained by GTA welding process employing with and without filler wire. Martensite formation is observed at the HAZ of AISI 4140 in both the cases. Tensile failure occurred at the parent metal of AISI 316 in all the trials for both the weldments. The strength of the welds are found to be higher and comparable with AISI 4140 candidate metals [7]. Fatigue Crack Growth Behaviour of Austempered AISI 4140 Steel with Dissolved Hydrogen, In presence of dissolved hydrogen, above the transition stress intensity factor value, the crack growth rate was increasingly greater in the annealed specimens as compared to the austempered specimens. When compared to the as-received (annealed) condition, austempering of 4140 steel appears to provide a processing route by which the strength, hardness, and fracture toughness of the material can be increased with little or no degradation in the ductility and fatigue crack growth behaviour [8].

III. EXPERIMENTAL SETUP

3.1 Specimen Material

Rolled low alloy AISI 4140 alloy steel was used in this experiment. Chemical analyzes were carried out in the laboratory of Karunya Institute of Technology, Chennai, using the ARL ADVANT'X XFR spectrometer device. Its chemical analysis is given in Table 1.

Table 1: Chemical Composition of AISI-4140 Alloy Steel.

Elements	Fe	C	Mn	Si	P	S	Cr	Mo
%	BAL	0.35-0.45	0.70-1.00	0.20-0.80	0.04Max	0.04Max	0.80-1.10	0.15-0.25

3.2 Methodology

We used Investment casting to manufacture the specimen, this method helps to get complicated shapes and we will get good surface finish. Investment casting contains the following steps:-

1. Pattern Making,

2. Assembly,

3. Shell Building,

4. Dewax,

5. Metal Casting,

6. Knocked out and Cut off.

Investment casting, also known as precision casting or lost-wax casting, is a manufacturing process in which a wax pattern is used to shape a disposable ceramic mold. A wax pattern is made in the exact shape of the item to be cast. This pattern is coated with a refractory ceramic material. Once the ceramic material is hardened, it is turned upside-down and heated until the wax melts and drains out. The hardened ceramic shell becomes an expendable investment mold. Molten

metal is poured into the mold and is left to cool. The metal casting is then broken from of the spent mold. The term investment casting is derived from the process of "investing" (surrounding) a pattern with refractory materials. Investment casting is often selected over other molding methods because the resulting castings present fine detail and excellent as-cast surface finishes. They can also be cast with thin walls and complex internal passageways. Unlike sand casting, investment casting does not require a draft.

Table 2: Heat treatment cycle used to this Specimen

SL.NO	OPERATION	PROCESS DETAILS
1	HARDENING	Heat to 980 °C and Soak for 60 minutes and Quench using N2 gas at minimum 3 bar over pressure to room temperature.
2	TEMPERING-1	Heat to 720 °C and Soak for 130 minutes and cool at air to room temperature.
3	TEMPERING-2	Heat to 620 °C and Soak for 240 minutes and cool at air to room temperature

After the specimen manufactured with Investment Casting, we applied the above heat treatment cycle for increasing the hardness to the specimen. In this expiring we used three rounds of heat treatment processes for more hardness. At first, we did hardening to the specimen, it means heat the specimen to 980oC and soaked for 60 min and quenched using N2 gas at the pressure of 3 bar to room temperature. Then Tempering followed by hardening which involves heating of specimen to 720oC and soak for 130 minutes and have to cool at air to room temperature to get hardened. The third process involved in this heat treatment process is also tempering but with different values, in this process we heated the specimen upto 620 oC and soak for 240 minutes and cooled at air to room temperature. Actually, by using multi heat treatment processes gives the more hardness as compared to the specimens which faced only individual heat treatment processes.

IV. RESULTS AND DISCUSSIONS

The following are the values of mechanical properties for AISI-4140 specimen which is made by Investment casting and applied for above Heat treatment cycle:

Table 3: Mechanical Properties of resulting Specimen

SL.NO	PROPERTIES	VALUE
1	Tensile Strength (N/mm^2)	1282
2	Compression Strength (N/mm^2)	2045
3	Shear Strength (N/mm^2)	404
4	Impact Strength (Joules)	36.7
5	Hardness (HRc)	30
6	Elongation (%)	0.689
7	Yield Strength (N/mm^2)	867

As compared to other manufacturing processes, Investment Casting gives good surface finish and helps to get complicated shapes and geometry. a rapid increase in impact strength was observed at tempering above 300°C. Percentage Elongation and percentage reduction in area increased in directly proportion to the increase in tempering temperature. The hardness increased with the increase in temperature. The highest elongation at break and reduction in cross section values were achieved as a result of the tempering process at 600°C. Because of multi heat treatment processes Tensile and compression strengths increases with great values and has better yield strength. Brittleness increases and ductility decreases.

V. CONCLUSIONS

By using the Investment casting helps to complicated shapes and we will get close tolerances, and by the heat treatment cycle which we used helps to increases the Hardness and it creates more impact on the mechanical properties like Tensile, Compression, Shear, Impact strengths etc., The results are clearly showing the impact of hardening and tempering processes which shows more Tensile and Impact strength and here clearly knew that ductility decreases and increases the brittleness.

REFERENCES

[1] Yusuf YILMAZ, Ethem KESTİ, 2020. Investigation of the Effect of Normalization Process on Mechanical Properties and Microstructure of the AISI 4140 Alloy Steel, International Journal of Science and Research (IJSR) ISSN: 2319-7064

[2] Daniel Kaiser, Bernhard de Graaff, Stefan Dietrich, Volker Schulze, 2017. Investigation of the tempering process of martensitic AISI 4140 steel at high heating rates, Conference: IFHTSE Congress 2017.

[3] BHAGYALAXMI, SATHYASHANKARA SHARMA & VIJAYA KINI, 2018. Effect of Heat

 ISSN: 2582-8150

treatment and Mechanical characterization of AISI 4140 steel, International Journal of Mechanical and Production Engineering Research and Development (IJMPERD).

[4] M Badaruddin, B Bakti, B Prasetyo, Sugiyanto, 2020. Effect of austempering temperatures on surface hardness of AISI 4140 steel.

[5] Yusuf YILMAZ1, Ethem KESTİ2, 2020. Investigation of the Effect of Heat Treatment Parameters on Mechanical Properties of AISI 4140 Alloy Steel by Quenching in Water, International Journal of Science and Research (IJSR) ISSN: 2319-7064.

[6] Zhichao Liua, Weilong Cong , Hoyeol Kima, Fuda Ninga, Qiuhong Jiang, Tao Lib, Hong-chao Zhanga, 2017. Feasibility Exploration of Superalloys for AISI 4140 Steel Repairing Using Laser Engineered Net Shaping, 45th SME North American Manufacturing Research Conference, NAMRC 45, LA, USA.

[7] Madduru Phanindra Reddy, A. Aldrin Sam William, M. Mohan Prashanth, 2013. Assessment of Mechanical Properties of AISI 4140 and AISI 316 Dissimilar Weldments, MRS Singapore - ICMAT Symposia Proceedings 7th International Conference on Materials for Advanced Technologies.

[8] Varun Ramasagara Nagarajan, Susil K. Putatunda , James Boileau, 2017. Fatigue Crack Growth Behavior of Austempered AISI 4140 Steel with Dissolved Hydrogen