Impact of Carburizing temperature on the mechanical behaviour of mild steel

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Abstract

Carburization of steel involves heat treatment of soft metallic surface using a source of carbon. Carburization is used to increase the surface hardness of low carbon steel, thus making outer surface hard and more resistant to wear and tear. In past carburization was done by application of charcoal around the sample to be treated (then referred to as case hardening), but modern techniques use carbon-containing gases or plasmas (such as carbon dioxide , carbon monoxide or methane). The process depends primarily upon surrounding gas composition and temperature of the furnace, which must be carefully controlled, as the heat may also impact the microstructure of the remainder of the material. The objective of the study is to analyze the effect of cutting speed, feed rate and depth of cut on the surface roughness and the cutting forces generated during the turning operation. The main objective involves finding the minimum value of surface roughness for the combination of the machining parameters (feed rate, depth of cut and cutting speed) so that the machined element itself after the process of heat treatment can directly as the die or punch which is required in the industry. The analysis of the entire experiment is done using Box Behnken method of response surface methodology (RSM).

Keywords:- Carburization, surface hardness, cutting speed, feed rate, RSM.,

1. Introduction

Carburizing is one of the most commonly used surface hardening process. The process involves diffusing carbon into a low carbon steel alloy to form a high carbon steel surface. Carburization provides a gradual change in the carbon content and carbide volume from the surface to bulk, resulting in a gradual alteration of mechanical properties. Carburisation is a heat treatment process in which steel or iron absorbs carbon when the metal is heated in the presence of a carbon containing material, such as charcoal or carbon monoxide.

The heat treatment and carburization increase the mechanical and wear resistance. This process involves addition of carbon to the surface of low-carbon steels at temperatures generally between 850 and 950°C, at which austenite, with its high solubility for carbon, is in its stable crystal structure. Hardening is accomplished when the high-carbon surface layer is quenched to form martensite, thus a high-carbon martensitic case with a good wear and fatigue resistance is superimposed on a low strength carbon steel core. Carburizing steels for case hardening usually have base-carbon contents of about 0.2%, with the carbon content of the carburized layer generally being controlled at 0.8 to 1% of carbon. However, surface carbon is often limited to 0.9% because too high a carbon content can result in retained austenite and brittle martensite. It is applied to low carbon work-pieces, which are made in contact with high carbon gas, liquid or solid, it produces hard work-piece surface layer, and the cores of specimen remain soft. In this way, a good wear and fatigue resistance is superimposed on a tough low carbon steel core.

Carburizing steel is widely used as a material of automobiles, form implements, machines, gears, springs and high strength wires etc. which are required to have the excellent strength, toughness, hardness and wear resistance, etc. because these parts are generally subjected to high load and impact. Such mechanical properties and wear resistance can be obtained from the carburization and quenching processes. When the carburized iron or steel is quenched, the higher carbon content on the outer surface becomes hard due to the transformation from austenite to martensite, while the core remains soft and tough as a ferritic or pearlite microstructure.

2. Need of the Study

Agriculture is the backbone of economy for most of the developing nations including India and a source of income for more than 60% of their population. In spite of the fact that the mechanization of agriculture helps in reducing human drudgery and raising grain productivity, the level of mechanization in these countries is still at very low level. The main reason for this is non-availability of high-quality implements and lack of demonstrated services for their populization. Mechanization does not mean only the agro-machines operated by power, but also the implements run by animals and men. Most commonly used farm implements are ploughs, harrows, cultivators, peddlers, furro opener, khurpy, kudali, etc. Indian agro industries and village artisans usually use cheaply and abundantly available low carbon and mild steels for the manufacture of these farm implements to suit every farmer, either rich or poor.

During agricultural operations (either dry or wet) the farm implements undergo abrasion by the scratching actions of sand and stone particles present in the soil and it is the most common cause of their quick failure and damage. It is therefore necessary to minimize wear. Due to limited resources and unavailability of economically feasible technology, agro-industries have not been able to substantially improve the mechanical properties and wear resistance of these steels. The attempt has been made by researchers to improve the wear resistance of steel materials, but very little attention has been paid in reducing the wear of farm implements materials. Thus, there is an urgent need to substantially upgrade the mechanical properties and wear resistance of low carbon and mild steels in actual soil conditions. The present work aims to improve the wear resistance and mechanical properties of mild steel by developing an economically feasible carburization technique. Also, the present work is applicable not only for the farm implements but also for the applications like material of automobiles, machines, gears, springs and high strength wires etc.

3. Objectives and Methodology of the Study

The objective of the present study includes the following understandings:

- Investigating the impact of carburizing temperature on the mild steel for different temperatures.
- Behavioural understanding of mild steel post carburizing under different loads while wear testing.

Literature survey and the gaps generated from it helps us to generate the experimental methods required to find out the practical output of the conclusions drawn from the literature and find out the real time challenges faced during the process. The analysis of the entire experiment is done using Box Behnken method of response surface methodology (RSM).

4. Results and Discussion

The different mild steel samples were carburized and tempered under different conditions and then tested for various kinds of test like abrasive wear test, tensile strength test and hardness test.

4.1. Results of abrasive wear test

The results of abrasive wear test of carburized mild steels, carburized at different temperature of 850, 900 and 950°C is shown in table 4.1 to table 4.3.

Carburization condition	**Wear Volume, $cm^3 x10^{-2}$**	**Wear rate, $cm^2 x10^{-7}$**	**Wear resistance, $cm^{-2} x10^7$**
Simple mild steel	2.69	3.98	0.245
850°C	1.71	2.53	0.413
900°C	1.48	2.26	0.455
950°C	1.38	2.05	0.475

Table 4.1 Result of abrasive wear test for carburized mild steel, at load 14.7 N

Carburization condition	**Wear Volume, $cm^3 x10^{-2}$**	**Wear rate, $cm^2 x10^{-7}$**	**Wear resistance, $cm^{-2} x10^7$**
Simple mild steel	3.31	4.51	0.222
850°C	2.10	2.97	0.324
900°C	1.76	2.67	0.384
950°C	1.56	2.73	0.439

Table 4.2 Result of abrasive wear test for carburized mild steel, at load 29.4 N

Carburization condition	**Wear Volume, $cm^3 x10^{-2}$**	**Wear rate, $cm^2 x10^{-7}$**	**Wear resistance, $cm^{-2} x10^7$**
Simple mild steel	3.95	5.81	0.164
850°C	2.47	3.60	0.286
900°C	2.33	3.18	0.331
950°C	1.98	2.88	0.395

Table 4.3 Result of abrasive wear test for carburized mild steel, at load 49 N

The abrasion test is conducted under three different loads of 14.7 N, 29.4 N and 49 N and it is obtained from the test that the weight loss during the abrasion is highest for the load of 49 N and is lowest for the load of 14.7 N. so it is concluded from the test that, as the load increases the weight loss during abrasion is also increases. The wear rate is highest for uncarburized simple mild steel and is lowest for the mild steel carburized at temperature of 950°C and wear rate gradually decreases with increase in carburization temperature. This is due to the fact that the weight loss during abrasion is directly proportional to the wear rate, so as the carburization temperature increases the weight loss during abrasion decreases and simultaneously there is the decrease in the wear rate.

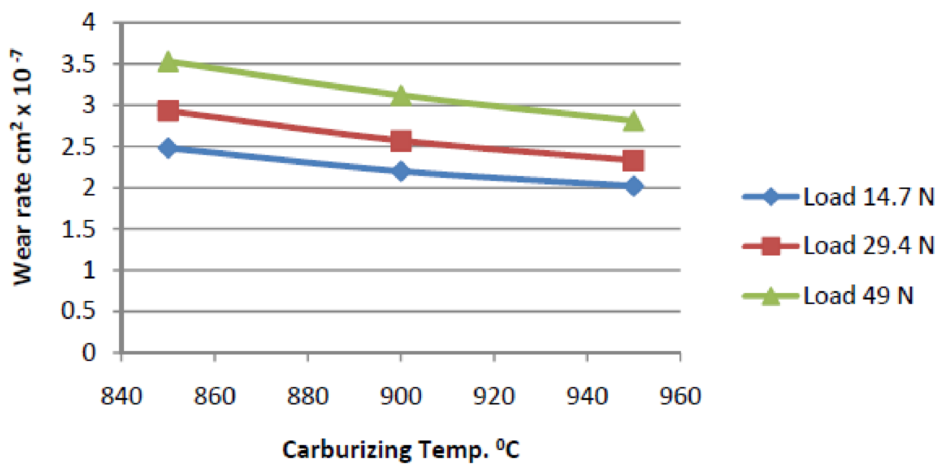

Figure 4.1 Comparison of wear rate with different carburization temperature for three loads of 14.7 N, 29.4 N and 49 N.

The wear rate is also load dependent and the abrasion test results shown that the wear rate increases gradually while increasing the applied load, so the wear rate is highest for the load of 49 N and it is lowest for the load of 14.7 N. This comparison is shown graphically in the figure 4.1.

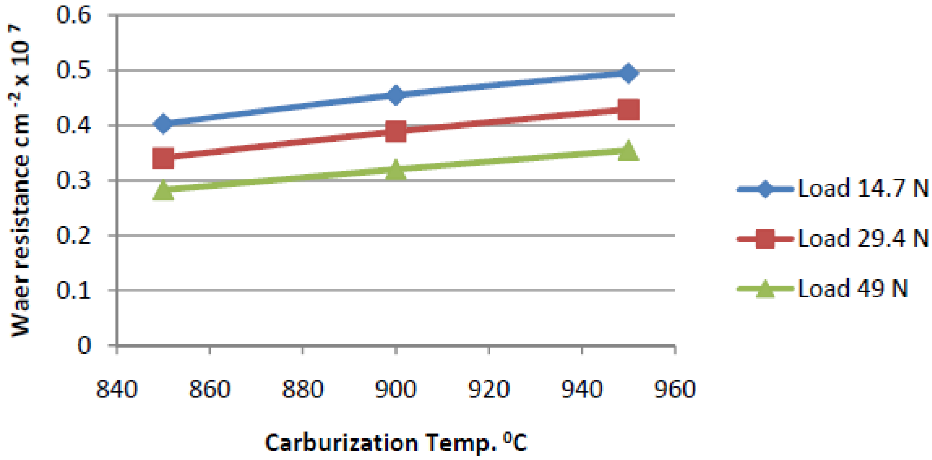

Figure 4.2 Comparison of wear resistances with different carburization temperature for three loads of 14.7 N, 29.4 N and 49 N.

The wear resistance is highest for the mild steel carburized at the temperature of 950°C and it is lowest for the uncarburized mild steel. For taking the case of only carburized mild steels also the wear resistance is highest for the mild steel carburized at the temperature of 950°C and is lowest for mild steels carburized at temperature of 850°C. Hence the abrasion results explain that the wear resistance is directly proportional to the carburization temperature, as the carburization temperature increases the wear resistance increases. These results are shown graphically in the figure 4.2. The net results is that the mild steel carburized at temperature of 950°C giving the best results, as it has having the highest wear resistance, lowest weight loss due to abrasion and lowest wear rate.

4.2. Results of tensile strength and hardness test

In general heat treatment and carburization of mild steel resulted in an increase in hardness, tensile strength and wear resistance and decreases the weight loss during abrasion. The test results of different mechanical characteristics like tensile strength and hardness under the different carburization temperature of 850, 900 and 950°C is shown in table 4.4.

Carburization condition	**Tensile Strength, (Mpa)**	**Hardness, HRC**
Simple mild steel	445	-

850°C	1923	57
900°C	1945	52
950°C	1955	55

Table 4.4 Tensile strength and hardness of carburized mild steel

The tensile strength is varied between the ranges of 441MPa – 1960 MPa (Table – 8) and is highest for the mild steel carburized at temperature of 950°C and lowest for the uncarburized simple mild steel. These results show that the carburization greatly improved the tensile strength of mild steels. For taking the case of carburized mild steels only, the tensile strength is highest for the mild steels carburized at the temperature of 950°C and is lowest for the mild steels carburized at temperature of 850°C, that's leads to the conclusion that with the increase in the carburization temperature, the tensile strength of carburized mild steels increases. This result is also shown graphically in the figure 4.3.

The hardness values varied between range of 51 HRC to 57 HRC and it is highest for the mild steel carburized at temperature of 950°C and is lowest for the mild steels carburized at 850°C, so with increase of carburization temperature the hardness values increase. This is also shown graphically in the figure 4.4. From the hardness test experiment, it is also noted that the hardness values of uncarburized simple mild steel is unable to calculate in HRC scale because of its very less hardness values. The net results are that the mild steels carburized at 950°C is giving the best results for the mechanical and wear properties like tensile strength, hardness and wear resistance except the case of toughness test.

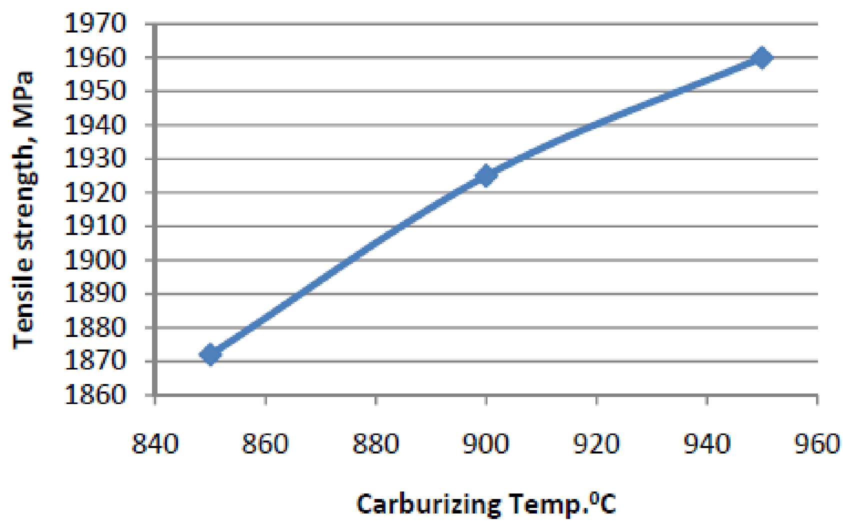

Figure 4.3 Variation of tensile strength with carburization temperature.

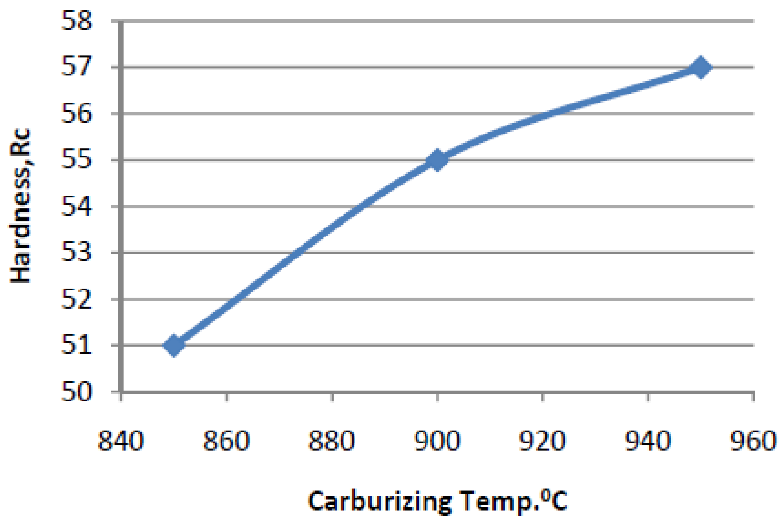

Figure 4.4 Variation of hardness with carburization temperature.

5. Conclusion

From the present studies on mechanical and wear properties of carburized mild steels samples the following conclusion have been drawn.

- The mechanical and wear properties of mild steels were found to be strongly influenced by the process of carburization and carburizing temperature.
- The carburization treatment followed by the water quenching appreciably improved the hardness, wear resistance and tensile strength of mild steels.
- Hardness, wear resistance and tensile strength increases with increase in the carburization temperature.
- The mild steel carburized under the different temperature range of 850, 900, and 950°C with in which the mild steel carburized at the temperature of 950°C is giving the best results for the mechanical and wear properties like tensile strength, hardness and wear resistance.

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