Analysis and Optimization of Machining Parameters for FSW Joint of aluminium alloy using Taguchi approach

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Abstract- The aim of this research paper is to investigate the machinability of CSN 12050 carbon steel bars using carbide insert tool in order to utilize the optimum cutting parameters by employing Taguchi approach. Experiments have been performed under dry cutting condition using an optimization approach according to Taguchi's orthogonal arrays; signal-to-noise ratio tests are designed. Analysis of variance (ANOVA) was performed to determine the importance of machining parameters on the material removal rate (MRR). The results were analysed using signal-to-noise ratios (S/N); 3D surface graphs, main effect graphs of mean, and predictive equations are employed to study the performance characteristics. The optimal parameters resulted as (i.e., cutting speed 275 (m/min), depth of cut 0.35 (mm), and feed rate 0.25 (mm/rev), respectively). In the present study, there is an improvement of 5.22 dB at optimal cutting conditions for each significant MRR response parameters such as cutting speed, depth of cut, and feed rate. With these proposed optimal parameters, it is possible to optimize machinability for product sustainability.

Keywords: Carburization, abrasive wear, weight loss, wear-resistance, and hardness.

1.Introduction- Engineers usually require a material with a blend of high yield strength and good elongation, but these properties are often mutually exclusive. It has been shown that the yield strength of normalized low carbon mild steel can be increased by inducing strain aging effects in the steel until the yield stress attains values up to and beyond the ultimate tensile strength, but unfortunately, the elongation is correspondingly reduced [1]. Steels are alloys of iron and carbon together with any other alloying elements. The steel is being separated as low carbon steel, high carbon steel and medium carbon steel. The controlled heating and cooling processes are used to change the structure of a material and alter its physical and mechanical properties [2, 3]. Heat treatment is generally employed for the purpose such as to improve mechanical properties like tensile strength, hardness, ductility, yield strength, and so on. The heat treatment and carburization increase mechanical and wear resistance. The heating of a metal at a constant temperature for a suitable duration of time is called soaking time. Mechanical properties of mild steels were found to be strongly influenced by the carburizing temperature and soaking time at carburizing temperature. The mechanical properties of mild steel were found to be strongly influenced by the process of carburization, carburizing temperature, and soaking time at carburizing temperature [4-7].

Carburizing is a metal treatment process that adds carbon to the surface of the metal that has a low carbon content to increase the hardness of the metal. The metal is heated at an elevated temperature in an atmosphere rich with carbon. The heat will cause carbon atoms to diffuse into the metal surface. The process is done below the melting point of the metal being carburized. There are five carburizing methods pack, gas, liquid bath, vacuum, and plasma. Pack carburizing uses a furnace to heat the metal parts to be carburized that are packed inside a container with a sufficient amount of carbon powder. The heating process will last for 12 to 72 hours at a high temperature. This method is noted to be slow compared to the other methods and has heating inefficiencies because of the difficulty in maintaining an even temperature. Gas carburizing follows the same procedure applied in pack carburizing. It, however, feeds carbon monoxide (CO) to the furnace to improve Diffusion, which is not done in the pack method. The process has safety issues because CO is a poisoning gas that is odourless and colourless and could be inhaled by persons working inside the plant. The gas method is preferred in carburizing large volumes of metal [8–14].

Hardening is accomplished when the high-carbon surface layer is quenched to form martensite so that a high-carbon martensitic case with good wear and fatigue resistance is superimposed on a tough, low-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 between 0.8 and 1% C. However, surface carbon is often limited to 0.9% because too high a carbon content can result in retained austenite and brittle martensite. 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. This manufacturing process can be characterized by the key points such as it is applied to low carbon work pieces, work pieces are in contact with high carbon gas, liquid or solid, it produces hard work piece surface, work piece cores retain soft [15].

Hardness is the property of a material to resist permanent indentation. Because there are several methods of measuring hardness, the hardness of a material is always specified in terms of the particular test that was used to measure this property. Although hardness testing doesn't give a direct measurement of any performance properties, hardness correlates with strength, wear resistance, and other properties. Hardness testing is widely used for material evaluation due to its simplicity and low cost relative to the direct measurement of many properties. Wear is commonly defined as the undesirable deterioration of a component by the removal of material from its surface. In laboratory tests, wear is usually determined by weight loss in material, and wear resistance is characterized by the loss in weight per unit area per unit time.

1.1 Principle of Friction Stir Welding

Generally, friction welding is carried out by way of transferring one element with respect to the following along a normal interface, even as making use of a compressive pressure over the joint. The contact warming produced on the interface softens the two parts, and when they progress closer to becoming plasticised the interface fabric is expelled out of the edge of the joint with the purpose that spotless material from each segment is left alongside the first interface. The relative motion is then stopped, and a final compressive pressure might be related before the joint is accredited to chill. In friction welding no molten fabric is created and the specified weld being shaped inside the solid state.

The standard of this manner is the converting of mechanical power into warmth power. One issue is gripped and circled about its axis at the same time as the opposite element to be welded to it is held and does no longer turn however as an alternative can be moved axially to reach the rotating element. At a factor fusion temperature is achieved, at that factor rotation is stopped and forging pressure is applied. When warmness is produced because of friction and is concentrated and localized at the interface, grain structure is subtle by way of hot paintings. At that point welding is finished, however there might not happen the melting of figure metal.

Friction welding process comprise in bringing into touch component to be welded whilst one of the two is static and the opposite is turned quickly on its axis. As the soon as the heat generated by way of weakening at the interface is adequate for solid state welding without dissolving, the rotation is stopped and the components are constrained together under strain turning in nearby production which finishes up the close becoming a member of and moreover ousts on the joint all surface infection and a part of the upset material known as flash.

In friction welding one component is rotated and one segment is held stationery. The component that is rotated is carried into contact with the stationary component and whilst sufficient warmness has been produced to deliver the part to a plastic state and the desired burn off has been accomplished, revolution is stopped. More axial pressure is then applied among the two parts bringing approximately a strong state bond at the interface shaping a friction welded joint

2. Material & Methods

2.1Materials Selection

Mild steels test specimens of the required dimensions were prepared. The chemical composition of mild steel is C-0.16%, Si-0.03%, Mn-0.32%, S-0.05%, P-0.2%, Ni- 0.01%, Cu-0.01%, Cr-0.01% and Fe-balance.

Preparation of test specimen

Carburization of mild steel samples

The prepared test samples were embedded in the activated carbon inside a steel pot which was then tightly sealed with clay cover to prevent the CO from escaping and prevent unwanted furnace gas from entering the steel pot during heating. The furnace temperature was adjusted to the required temperature range and the loaded steel pot was charged into the furnace. When the furnace temperature reaches the required carburizing temperature, it was then held/soaked for thirty minutes. After that, the steel pot was removed from the furnace and the material was quenched in industrial engine oil (which was initially at the ambient atmospheric temperature).

The hardness of all the samples has been done using a Vickers hardness testing machine. The applied load during the testing was 100 N, with a dwell time of 10 s. It has a square-base diamond pyramid indenter. Ten hardness readings are taken at a different location to circumvent the possible effects of particle segregation.

A computerized pin on disc wear test machine was used for the wear and friction tests of alloy samples under different loads from 10 N to 100 N and a linear speed of 0.65 m s^{-1} for one hour. The rotating disc was made of carbon steel of diameter

50 mm and hardness of 64 HRC. The alloys samples were held stationary and a required normal load was applied through a lever mechanism. Wear resistances are measured by a weight loss using four digital microbalances. Each wear sample is ultrasonically cleaned and weighed before the wear test using a balance with an accuracy of 0.01 mg. Three samples for each condition are tested and the average of the weight loss measurements is used for calculation of the wear property. The test specimen for abrasive wear and hardness test is prepared to have the dimensions (4cm x 2.5cm x 0.5cm).

3 Results and Discussion

3.1 Abrasive Wear Test

The results of the abrasive wear test of the samples are shown in figures (1–3). The wear resistance is higher for the carburized mild steel and it is lowest for the carburized mild steel. The weight loss during abrasion is higher for carburized simple mild steel and is lower for the carburized mild steel at a temperature of 950 ^{o}C because of comparatively low carbon content at lower carburization temperature. So it is concluded that, as the carburization temperature increases the weight loss during abrasion is decreases. The weight loss is higher for the load of 49 N and it is lower for the load of 14.7

N, this is because of the increase in the force, the friction increases which causes weight loss, as shown in the figure (1)

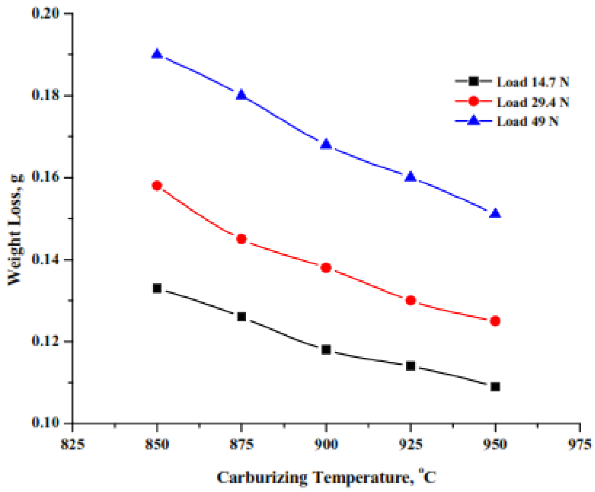

Fig. (1): A comparison of weight loss vs. carburization temperature at different loads.

For taking only the case of carburized mild steels, the wear resistance is higher for the mild steel carburized at the temperature of 950 ^{o}C and is lower for mild steels carburized at a temperature of 850 ^{o}C as shown in figure (2). 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. I.e. The mild steel carburized at a temperature of 950 °C is giving the best results, as it has to have the highest wear resistance, lowest weight loss due to abrasion, and the lowest wear rate

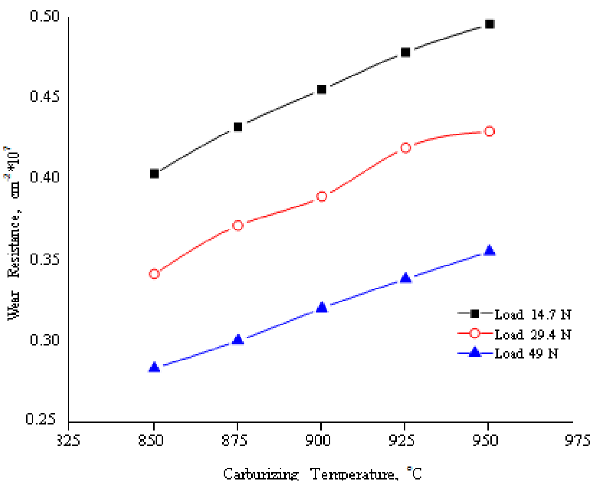

Fig. (2): A comparison of wear resistance vs. carburization temperature at different loads

3.2 Hardness

The hardness values varied in the range of 551 Hv–694 Hv as shown in figure (3). With an increase of carburization temperature the hardness values increase. The hardness value is higher for the mild steel carburized at a temperature of 950 °C and is lower for the mild steel carburized at 850 °C, so with an increase of carburization temperature the hardness values increases as shown in figure (4). I.e., the carburized mild steel at 950 °C is giving the best results for the mechanical properties like tensile strength and hardness except for the case of toughness test.

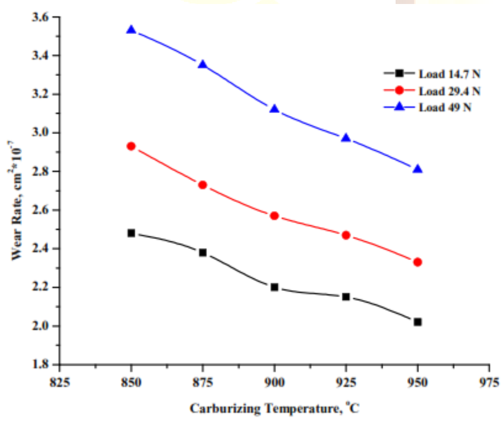

Fig.(3): A comparison of wear rate vs. carburization temperature at different loads.

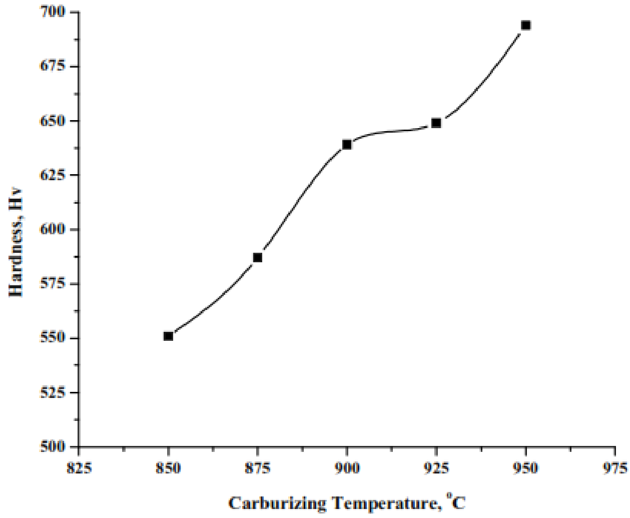

Fig. (4): Variation of hardness with the carburization temperature. temperature at different loads

3.3 Effect of Hardness on the Weight Loss and Wear Resistance of Carburized Mild Steels:

The variation between hardness and weight loss due to abrasion is represented in figure (5). The weight loss due to abrasion is highly affected by the hardness and it varies inversely with the hardness. That is because of the hard material having the greater abrasive wear resistance, so the less wear occurs in the carburized mild steels, and the weight loss decreases.

The wear resistance is affected by the hardness as represented in figures (6). The wear resistance increases as the hardness increases

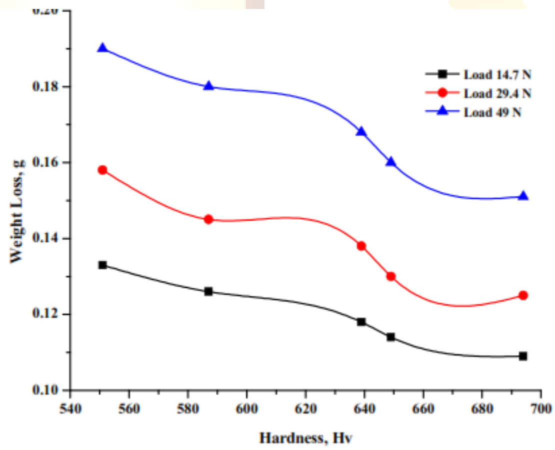

Fig. (5): A comparison of weight loss due to abrasion vs. hardness at different loads

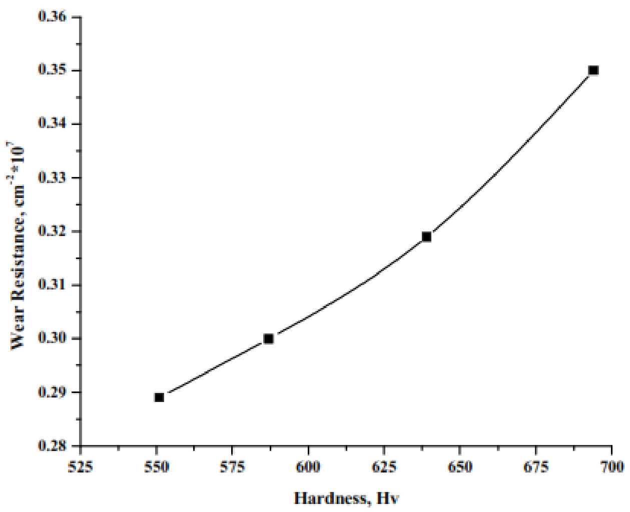

Fig. (6): Variation of wear resistance with hardness for the carburization temperature

Conclusions

From the above discussions so far it can be concluded that:

1. The mechanical and wear properties of SAE 1020 steels were found to be strongly influenced by the process of carburization and carburizing temperature.
2. Hardness and wear resistance increase with an increase in the carburization temperature, while the wear rate decreases.
3. The weight loss due to abrasion, wear volume, and wears rate increases with the increase in the applied load..
4. With an increase in the hardness the wear resistance increases, but there is a decrease in weight loss due to abrasion and wear rate.
5. As comparing for different carburization temperature, the SAE1020 steels carburized at the temperature of 950 °C shows the best combination of higher hardness and less wear rate.
6. Finally, the net conclusion is that the mild steel carburized under the different temperature range of 850 to 950 °C in which the SAE1020 steel carburized at the temperature of 950°C is giving the best results for
7. carburization and hydrogenation on the impact toughness of AISI 4118 steel", surface and coating

REFERENCES

[1] R. G. Luther and T. R. G. Williams, "The tensile properties of carburized and uncarburized low carbon mild steel"; Journal of Materials Science, January 1974, Volume 9, Issue 1, pp 136-144

[2] Krauss G., "Principles of Heat Treatment of Steel", American Society for Metals, Ohio, 1980, pp. 209-219.

[3] Totten G. E., Howes M. A. H., "Steel Heat Treatment Handbook", 2nd Edition, Marcell Dekker, Inc., New York, Chapter 7, 1997.

[4] Denis S., "Coupled temperature stress, phase transformation calculation model numerical illustration of the internal stresses evolution during cooling of a eutectoid carbon steel cylinder", Metallurgical Transaction A, 1987, 18A, p. 1203-1287.

[5] Leblond J. B., "Mathematical modeling of transformation plasticity in steels I: Case of iplastic phases II: Coupling with strain hardening phenomena", International Journal of Plasticity, 1989, 5, p. 551-591.

[6] Wang K. F., Chandrasekar S., Yang H. T. Y., "Experimental and computational study of the quenching of carbon steel", International Journal of Manufacturing Science and Engineering, 1997, 119, p. 257-265.

[7] Liu C. C., Xu X. J., Liu Z., "A FEM modeling of quenching and tempering and its application in industrial engineering", International Journal of Finite Elements in Analysis and Design, 2003, 39, p. 1053-1070.

[8] Gulyaev A., "Physical Metallurgy", 5th Edition, Mir Publishers, Moscow, 1980, p–173.

[9] Rao P. N., "Manufacturing Technology", 2nd Edition, Tata McGraw Hill Publisher, New Delhi, 2003, p–28, 13–20.

[10] Dieter G. E., "Mechanical Metallurgy", 3rd Edition, McGraw Hills, Singapore, 1988, P–277, 333, 334.

[11] Wieser P. F., "Steel casting Handbook", 5th Edition, Steel Founders Society of America, Ohio, 1980, P–4.

[12] Singh V., "Physical Metallurgy", Standard Publisher, Delhi, 2007, p–482.