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Machinability of Alloy Steels- A Review

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Abstract— This paper deals with literature review on the machinability characteristics of alloy steels. Mach inability of materials depends on surface roughness, MRR and work material hardness etc. Different optimizing techniques like Taguchi's design approach, Analysis of variance (ANOVA) are reviewed to investigate their effectiveness in optimization and finding significant factors in the machining of Alloy Steels.

Key words: Alloy Steels, MRR, Surface Roughness, ANOVA, Work Material Hardness

I. INTRODUCTION

Alloy steel is the steel that is alloyed with variety of elements in total amounts between 1.0% and 50% by weight to improve its properties. Alloy steels are broken down into two categories: low-alloy steels and high-alloy steels. The difference between the two is somewhat arbitrary [1-2]: Most commonly, the phrase "alloy steel" refers to low-alloy steels. Nickel is an important alloying addition to low-alloy steels where it improves strength and toughness whilst retaining good ductility in engineering components such as gears and transmission shafts. Nickel improves the low temperature toughness of ferritic steels, enabling them to be used for cryogenic applications. For example, 9% nickel steel is used for LNG handling and storage. It also contributes to high strength steels and the "maraging" steels can be produced with particularly high tensile strengths. Nickel is also important in some carburising, nitriding and tools steels.

Every steel is an alloy, but not all steels are called "alloy steels". The simplest steels are iron (Fe) alloyed with carbon (C) (about 0.1% to 1%, depending on type). However, the term "alloy steel" is the standard term referring to steels with other alloying elements added deliberately in addition to the carbon. Common alloyants include manganese (the most common one), nickel, chromium, molybdenum, vanadium, silicon, and boron. Less common alloyants include aluminum, cobalt, copper, cerium, niobium, titanium, tungsten, tin, zinc, lead, and zirconium. The following is a range of improved properties in alloy steels (as compared to carbon steels): strength, hardness, toughness, wear resistance, corrosion resistance, harden ability, and hot hardness. To achieve some of these improved properties the metal may require heat treating. Some of these find uses in exotic and highly-demanding applications, such as in the turbine blades of jet engines, in spacecraft, and in nuclear reactors. Because of the ferromagnetic properties of iron, some steel alloys find important applications where their responses to magnetism are very important, including in electric motors and in transformers. High-strength low-alloy steel (HSLA) is a type of alloy steel that provides better mechanical properties or greater resistance to corrosion than carbon steel. HSLA steels vary from other steels in that they are not made to meet a specific chemical composition but rather to specific mechanical properties. They have carbon content between 0.05–0.25% to retain formability and weldability. Other alloying elements include up to 2.0% manganese and small quantities of copper, nickel, niobium, nitrogen, vanadium, chromium, molybdenum, titanium, calcium, rare earth elements, or zirconium. Copper, titanium, vanadium, and niobium are added for strengthening purposes. These elements are intended to alter the microstructure of carbon steels, which is usually aferrite-pearlite aggregate, to produce a very fine dispersion of alloy carbides in an almost pure ferrite matrix. This eliminates the toughness-reducing effect of a pearlitic volume fraction yet maintains and increases the material's strength by refining the grain size, which in the case of ferrite increases yield strength by 50% for every halving of the mean grain diameter. Precipitation strengthening plays a minor role, too. Their yield strengths can be anywhere between 250–590 megapascals (36,000–86,000 psi). Because of their higher strength and toughness HSLA steels usually require 25 to 30% more power to form, as compared to carbon steels [3-4].

Copper, silicon, nickel, chromium, and phosphorus are added to increase corrosion resistance. Zirconium, calcium, and rare earth elements are added for sulfide-inclusion shape control which increases formability. These are needed because most HSLA steels have directionally sensitive properties. Formability and impact strength can vary significantly when tested longitudinally and transversely to the grain. Bends that are parallel to the longitudinal grain are more likely to crack around the outer edge because it experiences tensile loads. This directional characteristic is substantially reduced in HSLA steels that have been treated for sulfide shape control. They are used in cars, trucks, cranes, bridges, roller coasters and other structures that are designed to handle large amounts of stress or need a good strength-to-weight ratio. HSLA steel cross-sections and structures are usually 20 to 30% lighter than carbon steel with the same strength. HSLA steels are also more resistant to rust than most carbon steels because of their lack of pearlite – the fine layers of ferrite (almost pure iron) and cementite in pearlite. HSLA steels usually have densities of around 7800 kg/m³ [3-4].

II. LITERATURE REVIEW

A.Venkata Vishnu .et.al. [7]outlines an experimental study to optimize the effects of selected cutting parameters i.e. Cutting Speed, Feed rate, Depth of cut and type of tool, for Surface Roughness of EN-36 steel alloy by employing Taguchi robust design methodology. Taguchi orthogonal array is designed with three levels of turning parameters and experiments are carried out using L_9 (3^4) orthogonal array. Taguchi method stresses the importance of studying the response variation using the Analysis of Variance (ANOVA), resulting the minimization of quality characteristic variation due to uncontrollable parameter. The surface roughness is considered as the quality characteristic parameter in the concept of "the smaller the better". The surface roughness values measured from experiment and their optimum value for surface roughness are calculated. Analysis of Variance suggests that the selected cutting parameters are significant and Feed rate has the most significant factor for the surface roughness.

By using Taguchi Robust Design methodology the End milling of EN-31 steel alloy is carried out in order to optimize the milling process parameters and to minimize the surface roughness. The selected milling process parameters are Cutting Speed, Feed rate, Depth of cut and coolant flow. Taguchi orthogonal array is designed with three levels, four factors and nine experiments using L_9 (3^4) orthogonal array. The nine experiments are performed and surface roughness is calculated. Results obtained by Taguchi Method, shows that the factors affecting the surface roughness are Significant and Cutting Speed is the most influence significant parameter. Multiple Regression equation is formulated for estimating the predicted values for surface roughness [8].

Taguchi approach, the Turning of EN-36 steel alloy is carried out in order to optimize the turning process parameters. The present paper deals with the optimization of selected process parameters, i.e. Speed, Feed rate, Depth of cut and type of tool. Taguchi orthogonal array is designed with three levels of machining parameters and different experiments are done using L9 (34) orthogonal array. Taguchi method stresses the importance of studying the response variation using the signal to noise (S/N) ratio, resulting the minimization of quality characteristic variation due to uncontrollable parameter. The material removal rate is considered as the quality characteristic in the concept of "the larger the better". The material removal values measured from experiment and their optimum value for material removal rate are calculated. The S/N ratio of predicted value and verification test values are valid when compared with the optimum value. It is found that S/N ratio value of verification test is within the limits of predicted value and the objective of the work is full filled [9].

Shashikant.et.al. used to investigate the relationships and parametric interactions between the measurable and controllable variables on the material removal rate (MRR) in die sinking EDM of EN19 material. The material is extensively being used for the application in High speed components e.g. gears. For conducting the experiments, four process variables viz. pulse on time, pulse off time, discharge current and gap voltage were considered and electrolytic copper was used as the electrode material. Total 31 experiments were carried out for different combinations of process parameters. The experimental results were analyzed using Response Surface Model (RSM). The significant coefficients were obtained by performing analysis of variance (ANOVA). From the analysis, it was found that pulse off time, discharge current, gap voltage and the interaction terms were significant where as the pulse on time had almost negligible effect towards MRR. This methodology was found to be very effective and the model sufficiency was very satisfactory. Moreover, an attempt has been made to optimize the material removal rate in the studied region. The error between the predicted and experimental MRR value was found to be 1.45% [10].

Mahendra Korat et.al. outlines an experimental study to optimize the effects of cutting parameters on surface finish and MRR of EN24 work material by employing Taguchi techniques. The orthogonal array, signal to noise ratio and analysis of variance were employed to study the performance characteristics in turning operation. Five parameters were chosen as process variables: Speed, Feed, Depth of cut, Nose radius, Cutting environment (wet and dry). The experimentation plan is designed using Taguchi's L18 Orthogonal Array (OA) and Minitab 16 statistical software is used. Optimal cutting parameters for, minimum surface roughness (SR) and maximum material removal rate were obtained. Thus, it is possible to increase machine utilization and decrease production cost in an automated manufacturing environment [11].

Abhang, L. B.et.al. objective is to select a right lubricant from amongst a number of lubricants during the machining of En-31 steel work piece with tungsten carbide inserts by using combined multiple attribute decision–making method. The procedure is based on a combined TOPSIS and AHP method. The selection of an optimal material for an engineering design from a list of available alternative materials on the basis of two or more attributes in multiple attribute decision making problem. The analytic hierarchy process, being a simple, but powerful decision making tool, is being applied to solve different manufacturing problems. TOPSIS method is based on the concept that the chosen alternative should have the shortest Euclidean distance from the ideal solution and the farthest from the negative ideal solution. TOPSIS thus gives a solution that is not only closest to the hypothetical best, which is also the farthest from the hypothetically worst. Lubricant selection factors are identified and these are chip-tool interface temperature, cutting force, tool wear and surface roughness. Combined multi-attribute decision-making is aimed at integrating different measures into a single global lubricant index helps to select right lubricant and rank the given lubricant for a steel turning operation. The framework that is used in steel turning operation could serve as one of the tools for making a strategic decision. The effectiveness of our model is demonstrated through an actual experimental work [12].

Keerthiprasad.Ket.al. have been discussed widely used in aerospace and automotive industries. Machining of these materials requires better understanding of cutting processes regarding accuracy and efficiency. This study addresses the modelling of the machinability of EN353 and 20mncr5 materials. In this study, multiple regression analysis (MRA) is used to investigate the influence of some parameters on the thrust force and torque in the drilling processes of alloy steel materials. The model were identified by using cutting speed, feed rate, and depth as input data and the thrust force and torque as the output data. The statistical analysis accompanied with results showed that cutting feed (f) were the most significant parameters on the drilling process, while spindle speed seemed insignificant. Since the spindle speed was insignificant, it directed us to set it either at the highest spindle speed to obtain high material removal rate or at the lowest spindle speed to prolong the tool life depending on the need for the application. The mathematical model is based on a power regression modelling, dependent on the three above mentioned parameters [13].

Alloy Steel EN-24 (Medium Carbon Steel) used in manufacturing of Automotive & aircraft components, Axles & Axles components, Shafts, Heavy duty Gears, Spindles, Studs, Pins, collets, bolts, couplings, sprockets, pinions & pinion arbors. Turning is the most common process used in manufacturing sector to produce smooth finish on cylindrical surfaces. Surface roughness is the important performance characteristics to be considered in the turning process is affected by several factors such as cutting tool material, spindle speed, feed rate, depth of cut and material properties. In this research Response surface methodology (RSM) was applied to determine the optimum machining parameters leading to minimum surface roughness in turning process. Puneet Saini et.al has studied the effect of carbide inserts on EN-24 Alloy Steel surface by using three parameters (spindle speed, feed rate and depth of cut). This research was conducted by using 100 HS Stallion CNC Lathe machine. Seventeen sets of experiments were performed. In this work empirical models were developed for surface roughness by considering spindle speed, feed rate and depth of cut as main controlling factors using response surface methodology. The optimum value of the surface roughness (Ra) comes out to be 0.48 μm. It is also concluded that feed rate is the most significant factor affecting surface roughness followed by depth of cut. As Cutting speed is the less significant factor affecting surface roughness. Optimum results are finally verified with the help of confirmation experiments [14].\

Joseph Emmanuel et. al. objective is to develop a taguchi optimization method for low surface roughness in terms of process parameters when turning the EN-353 steel on conventional lathe machine. Considering the process parameters as Depth of cut, Feed, Spindle Speed, Rake Angle & Pressurized Coolant Jet, a series of turning experiments were performed to measure surface roughness data. Taguchi orthogonal arrays, signal-to-noise(S/N) ratio, and analysis of variance (ANOVA) are used to find the optimal levels and the effect of the process parameters on surface roughness. Confirmation experiment with the optimal levels of process parameters was carried out in order to demonstrate the effectiveness of the taguchi method. It can be concluded that Taguchi method is very suitable in solving the surface quality problem of turned work pieces [15].

T.Rajaprabu et.al. Investigation focuses on the influence of machining parameters on the surface finish obtained in turning of EN19 steel. The experiments are conducted based on Taguchi‘s experimental design technique in this work; the effect of machining parameters on the surface roughness is evaluated and optimum machining conditions for maximizing the metal removal rate and minimizing the surface roughness are determined using Taguchi technique. Signal to Noise ratio, Analysis of means and ANOVA are employed for determining optimum level combination and percentage contribution. Finally an attempt has been made to develop a model for the turning process. The developed model can be effectively used to predict the surface roughness on the machining [16].

Turning is one of the common machining methods in manufacturing industry. Hardness of the material is the most significant property in the field of design to satisfy the safety and reliability. AL. Arumugam et.al investigation is to analyse the changes in the hardness of material on the machined surface due to machining operation (turning) by considering the spindle speed, feed and depth of cut. EN353 forged steel was selected for the analysis to measure the hardness. The hardness was estimated using Rockwell hardness tester by varying the cutting parameters using Taguchi method [17].

III. Conclusions

A thorough study of literature suggests that the machining of Alloy Steel is very difficult, compared to other alloy materials.

Very few works have been done in the Optimization of process parameters in Machining of steel alloy with different controlled parameters. Review of various latest optimizing techniques such as Taguchi’s approach, shows significant effect of process parameters i.e. depth of cut, feed rate, cutting speed etc. on performance characteristics like surface roughness, tool flank wear, MRR. We also found that for surface roughness the most significant parameters are speed and feed for most of the Alloy Steels and for MRR the most significant parameters are DOC, feed and speed. Form the Literature, the best Suited Lubricant for Most of the Alloy Steels for which optimum results drawn are SAE10, 20 and 40 along with Boric acid. Carbide cutting tools is the best suited tool for Alloy steels compared to HSS.

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