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OPTIMIZATION OF DRILLING PROCESS PARAMETERS OF AISI 321 STEEL

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Abstract - *The objective of the present work is to optimize the process parameters, based on Taguchi method for minimizing surface roughness. Taguchi methods are widely used for design of experiments & analysis of experimental data for optimization of processing condition. The research contributions are classified into methodology for investigation & analysis. The experiments were conducted on CNC drilling machine using solid carbide cutting tool on material AISI 321 austenitic stainless steel. Four cutting parameters such as cutting fluid, speed, feed and hole-depth, each at three levels except the cutting fluid at two levels were considered. Taguchi L_{18} orthogonal array was used as design of experiment. The signal-to-noise (S/N) ratio was carried out to determine which machining parameter significantly affects the surface roughness and also the percentage contribution of individual parameters. Confirmation test was conducted to ensure validity of the test result. The results revealed that the combination of factors and their levels $A_2B_3C_2D_1$ i.e. the machining done in the presence of cutting fluid, at a speed of 500 r.p.m. with a feed of 0.04 mm/s and hole-depth of 25 mm yielded the optimum i.e. minimum surface roughness. Further, the results are indicated that all four cutting parameters significantly affected the surface roughness with maximum contribution from speed (27.02%), followed by cutting fluid (25.10%), feed (22.99%), and hole-depth (14.29%). It is also observed that the surface finish for drilling process can be improved effectively through this approach.*

***Key Words*: Taguchi L_{18} orthogonal array, signal-to-noise (S/N) ratio, surface roughness, cutting fluid, drilling process, signal-to-noise (S/N) ratio**

1. INTRODUCTION

In the 1960s and 70s, manufacturers competed the basis of cost efficiency. In 1980s, quality was the rage and Zero Defects and Six Sigma came into vogue. Cost and quality are still crucial to world-class operations, but today the focus is squarely on speed. Nearly all manufacturers today are under pressure from customers to cut lead times.

1.1 Quality Optimization and its improvement

The challenge of modern machining industries is particularly focused on achieving high quality in terms of work piece dimensional accuracy, surface finish, high production rate, less wear on the cutting tool, economy of machining in terms of cost saving and increase the performance of the product with reduced environmental impact. Surface roughness plays an important role in many areas and is factor of evaluation of machining accuracy. The quality of drilling is too important in order to retain industrial advantage. The surface quality is an important parameter to evaluate the productivity of machine tools as well as machined components. Hence, achieving the desired surface quality is of great importance for the functional behaviour of the mechanical parts. A reasonably good surface finish is desired for improving the tribological properties, fatigue strength, corrosion resistance and aesthetic appeal of the product. Optimization of process parameter is the key step in the Taguchi method to achieve high quality without increase in cost. This is because optimization of process parameters can improve quality and the optimal process parameters obtained from the Taguchi method are insensitive to the variation of environmental conditions and other noise factors. A large number of experiments have to be carried out when the number of the process parameters increases. To solve this task, the Taguchi method uses a special design of orthogonal array to study the entire process parameter space with only a small number of experiments. Using an orthogonal array to design the experiment could help the designers to study the influence of multiple controllable factors on the average of quality characteristics and the variations in a fast and economic way. Also use of signal-to-noise ratio helps to analyze the experimental data that give the ideas to the designers to easily find out the optimal parametric combinations. The surface roughness and production time are affected by several factors including drill diameter, cutting speed, feed rate and depth of hole.

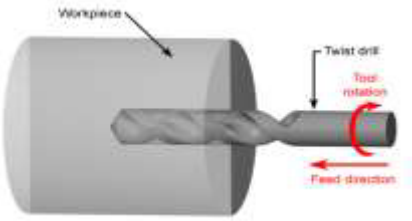
1.2 Heat Exchangers

Shell and tube heat exchangers are most commonly used in the process refinery industries due to a large ratio of heat transfer area to volume and weight. The tubes are basic component of the heat exchanger, providing the heat transfer surface between one fluid flowing inside the tube and the other fluid flowing across the outside of the tubes. The tubes are held in place by being inserted into holes in the tube sheet and there either expanded into grooves cut into the holes or welded to the tube sheet were the tube protrudes from the surface. The integrity of tube-tube sheet joints play critical rule in heat exchanger durability and life cycle cost. The tube-tube sheet joint strength is dependent on tube sheet hole surface finish.

Cut section of Shell and Tube Heat Exchanger

Improper preparation of tube sheet holes and drum seats is a major cause in tube leakage. If the tube sheet or drum is gouged, it is extremely hard to expand the tube to full these gouges or tears without over-rolling. The smoother the tube sheet hole or drum seat, the easier it is to roll an optimum tube joint. The ligaments and the light tube walls make it more important that the finish of the tube sheet hole be in the low micro range. Many manufacturers drilling, reaming and sizing or burnishing to get the micro finish desired for tube sheet holes. Drilling operation is the most commonly used machining operation that uses multipoint cutting tool called drill or drill bit to remove unwanted material for producing or enlarging desire hole. The main focused of modern machining industries on achievement of high quality, in term of work piece drilled accuracy and surface finish. Surface finish is concerned with the geometrical irregularities on the surface of material. Surface roughness is the one of the crucial performance parameter that has an appreciable effect on mechanical properties of finished parts such as creep life, fatigue behaviour and corrosion resistance, etc. The geometry of cutting tool, work materials, and parameters like cutting speed and feed directly affects drill performance. These parameters should be selected to optimize the drilling operation. So it can be achieved by function of drilling conditions using design of experiments (DOE).Industries and applications that require large production, the drilling time and finishing of holes rivals the cost of process. So an intensive study of machining process is required to make the production economical. Machining of AISI 304 austenitic stainless steel is critical due to its supreme properties like high wear resistance, high toughness, low thermal conductivity and high tensile strength. In traditional approach the selection of cutting condition for machining is left to the machine operator. In this condition the experience of the machine operator plays a vital role, but even for a highly skilled operator it is difficult to attain the desired quality output values every time by considering the parameters values on the basis of his knowledge. Nowadays, many industries are interested in optimizing machining process in order to improve quality reduce cost, & for obtaining high efficiency. To achieve this conditions, analysis of data during manufacturing is needed to be carried out by using suitable optimization techniques.

1.3 BASIC DRILLING PROCESS



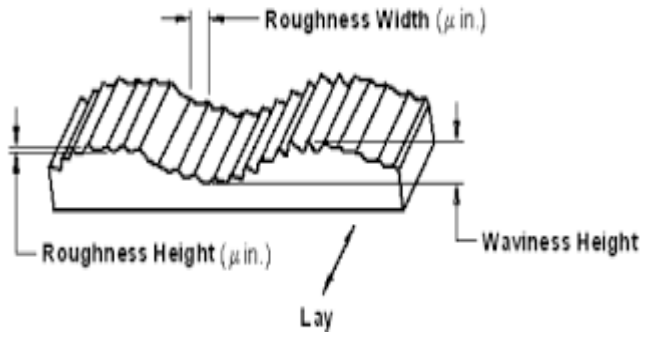
Basic Drilling Process

Drilling is a cutting process that uses a drill bit to cut a hole of circular cross-section in solid materials. The drill bit is usually a rotary cutting tool, often multi-point. The bit is pressed against the work-piece and rotated at rates from hundreds to thousands of revolutions per minute. This forces the cutting edge against the work-piece, cutting off chips from the hole as it is drilled. Drilled holes are characterized by their sharp edge on the entrance side and the presence of burrs on the exit. The inside of the hole usually has helical feed marks. The drill's mechanism is actually quite simple: A trigger switch activates an electric motor, which in turn drives a rotating chuck. Numerous accessories can fit into in the chuck, allowing the drill to bore holes, drive screws, and sand, polish, and grind a wide variety of materials. Drilling parameters play a large role in helping drillers achieve a good rate of penetration, superior drilling performance and long bit life. They are basic recommendations that help guide a driller avoid burning bits or damaging other drilling equipment.

2. Taguchi method

Taguchi method is a effective tool for the design of high quality systems. It provides simple, effective and systematic approach to optimize designs for performance, quality and cost. Taguchi method is efficient tool for designing process that operates consistently and optimally over a variety of conditions. To determine the optimum design it requires the use of a strategically designed experiment. Taguchi approach to design of experiments in easy to analyze and apply for users with limited knowledge of statistics, hence gained wide popularity in the engineering and scientific community. The desired cutting variables are determined based on experience or by hand book. Cutting parameters are reflected.

2.1 SURFACE ROUGHNESS PROCESS



Surface roughness often shortened to roughness, is a component of surface texture. It is quantified by the deviations in the direction of the normal vector of a real surface from its ideal form. If these deviations are large, the surface is rough; if they are small, the surface is smooth. In surface metrology, roughness is typically considered to be the high-frequency, short-wavelength component of a measured surface. However, in practice it is often necessary to know both the amplitude and frequency to ensure that a surface is fit for a purpose.

2.2 Effect of Process Parameters on Surface Roughness

The effects of cutting parameters according to the experiments conducted can be summarized as follows. The feed rate has the greatest effect on surface roughness followed by spindle speed. It can be observed that a increase in spindle speed decreases surface roughness from its lower level to middle level and then slightly increases from middle level to higher level. But the better surface roughness is noticed at higher level of feed rate irrespective of spindle speed and depth of hole. It can be observed that at higher level of feed value the minimum value of surface roughness occurs at a feed rate of 50 mm/min. At higher level of speed, the increases the value of surface roughness which occurs at medium and/or higher levels of feed. When the depth of drill hole is at its lower and higher level there is no change in surface roughness value.

2.3 EXPERIMENTAL OBJECTIVES

After detail investigation that has been carried out in literature review, it can be concluded that, it is a necessity to make more research on optimizing drilling process parameters for AISI 321 Stainless Steel material. Hence the aim of this work is to study and find the optimum drilling process parameters for AISI 321 material using High Speed Steel (HSS) drill bit by analyzing surface roughness and cut time using Taguchi technique. Also the significant effect of each controlling factor on other will be find out. Therefore following objectives are coin for the optimization of drilling parameters

1. To optimize the parameters of drilling process such as surface roughness and cut time.

2. To find thrust force and its effects on work piece for optimum reading from L_9 array.

The cutting parameters that considered are drill diameter, spindle speed, feed rate and depth of hole for AISI 321 steel.

3. CONCLUSIONS

This journal presents the optimization of cutting parameters namely, drill diameter, spindle speed, feed rate and depth of hole in drilling of AISI 321 steel using the application of Taguchi method. The conclusions drawn from this work are as follows;

1) An optimum parameter combination for the minimum surface roughness and drilling time was obtained by using the analysis of signal-to-noise (S/N) ratio.

2) The combination of parameters and their levels for optimum surface roughness and drilling time is $A_2B_2C_3D_1$ (i.e. Drill diameter- 20mm, Spindle Speed- 560 rpm, feed rate- 0.07mm/rev, depth of cut- 20mm) and $A_1B_3C_3D_1$ ((i.e. Drill diameter- 20mm, Spindle Speed- 560 rpm, feed rate- 0.07mm/rev, depth of cut- 20mm). As the feed rate increases, the time taken to finish the drill operation is faster and machine time is reduced and productivity is increased.

3) The experimental results confirmed the validity of the used Taguchi method for enhancing the surface roughness, cutting time and optimizing the process parameters in drilling operations.

4) The optimized machining parameters were used for the confirmation of experiments for validation; the measured value for the surface roughness and cut time is 1.952 and 1.41m respectively.

5) The Taguchi approach to quality engineering places a great deal of emphasis on minimizing variation as the main means of improving quality. The idea is to design products and processes whose performance is not affected by outside conditions and to build this in during the development and design stage through the use of experimental design. The method included a set of tables that enable main variables and interactions to be investigated in a minimum number of trials.

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