A Review of Analysis and Optimization of Performance Parameters for Drilling of Inconel625

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Abstract— Nickel based Super alloys are high-temperature, precipitate-hardening alloy, due to its excellent mechanical properties at low and intermediate temperatures, it has been widely applied, in recent years, in aerospace, petroleum and nuclear energy industries. With regard to the quality characteristics of drilled parts, some of the problems encountered include Thrust force, circularity and Surface roughness, among these characteristics, surface roughness and circularity play the most important roles in the performance of a drilled part as super alloys find its application in aerospace where fatigue life is a crucial consideration. Cutting speed, feed rate, point angle, drill work piece material, drill tool type and coolant conditions are the drilling parameters which highly affect the performance measures. Thrust force has significant effect on surface roughness and circularity. Among the various parameters, cutting speed, feed and tool material have significant contribution in accuracy and quality hole.

Key words: Circularity, Cutting Speed, Feed, Super Alloy, Surface Roughness, Thrust Force, Tool material

I. INTRODUCTION

Nickel base super alloys are extensively used in high temperature applications such as gas turbines, electric power generation equipment, nuclear reactors and high temperature chemical vessels. Alloy 625 is produced by vacuum induction melting or by Argon Oxygen Decarburization (AOD) refining. Alloy 625 (UNS designation N06625) is a nickel-chromium-molybdenum alloy possessing excellent resistance to oxidation and corrosion over a broad range of corrosive conditions. Alloy 625 also has exceptional fatigue resistance. The presence of highly abrasive carbide particles and high tendency to welding to the tool results in forming of built–up edge, make them extremely difficult-to-machine.

Drilling is a process of producing round holes in a solid material or enlarging existing holes with the use of multi tooth cutting tools called drills or drill bits. The twist drill is a cutting tool with two symmetrical opposite cutting edges, each removing part of the material in the form of chip from the work piece and produce a hole in the material.

With regard to the quality characteristics of drilled parts, some of the problems encountered include temperature, Thrust force, Torque, Surface roughness, Burr height, Power, Material removal rate, Among these characteristics, surface roughness and burr height play the most important roles in the performance of a drilled part. Cutting speed, feed rate, work piece material, drill tool type and coolant conditions are the drilling parameters which highly affect the performance measures. In order to improve machining efficiency, reduce the machining cost, and improve the quality of machined parts, it is necessary to select the most appropriate machining conditions.

Drilling problems can account to expensive production waste because many drilling operation are usually among the final stages in manufacturing a part. There are number of problem occurred in drilling process and also facing by various industries in drilling include: unwanted thrust force which leads to reduced drill life; drill fracture; burr formation in metals, temperature effect; lower material removal rate, and vibration that affect surface finish and dimensional accuracy. Thus, the hole quality becomes a serious concerned and surface roughness have significant effect on fatigue life. Conventional machining of super alloys is difficult due to lower material removal rate, higher thrust force. Due to higher thrust force it will lead to vibration and temperature which leads to lower surface finish.

II. LITERATURE REVIEW

A. Turgay KIVAK, Kasim HABALI, Ulvi SEKER , The Effect of Cutting Parameters on The Hole Quality and Tool Wear During The Drilling of Inconel 718, GU J Sci 25(2):533-540 (2012):

In this Study researcher had carried out experiment on Inconel718 for measuring hole quality and tool wear during machining of drilling. They measure hole quality in terms of circularity and hole diameter and tool wear of coated and uncoated carbide drill. They took speed and feed as a input parameter and depth of 8 mm of thick plate. They found that there was a decrease of tool performance and hole quality at high cutting speed (10,12.5,15,17.5) and feed rate(0.05,0.75.0.1) combinations. A serious increase in tool wear was observed when increasing cutting speed. They revealed that the Utmost wear type was seen in the form of flank wear and chisel edge wear. They suggested that the hole quality under dry cutting conditions, in the drilling of Inconel 718 uncoated cementite carbide tools are recommended. Furthermore, the hole quality can be increased by using lower feed rates.

B. J. Prasanna, L. Karunamoorthy, M. Venkat Raman, Sai Prashanth, D. Raj Chordia, Optimization of process parameters of small hole dry drilling in Ti–6Al–4V using Taguchi and grey relational analysis, Measurement 48 (2014) 346–354:

In this Study researcher had carried out experiment on drilling on measuring geometric accuracy (circularity and over size) and thrust force. In this study, they investigated through holes machined in a Ti–6Al–4V plate of 0.4 mm thickness using twisted carbide drill bits of 0.4 mm diameter by conventional dry drilling. The Taguchi's experimental design and Analysis of Variance (ANOVA) techniques have been implemented to understand the effects, contribution, significance and optimal machine settings of process parameters, namely, spindle speed, feed rate and air

pressure. The performance characteristics of the small hole drilling were evaluated through thrust force, overcut, circularity and taper. They used grey relational analysis and mathematical modeling for Multi-performance optimization of the process parameters. They revealed that spindle speed and air pressure have the most significant impact on the dimensional accuracy of the hole; spindle speed and feed rate controls the thrust force.

C. Arshad Noor Siddiquee, Zahid A. Khan, Gaurav Agarwal, Pankul Goel, Noor Zaman Khan, Mukesh Kumar, Optimization of Deep Drilling Process Parameters of AISI 321 Steel using Taguchi Method, Procedia Materials Science 6 (2014) 1217 – 1225:

In this Study researcher had conducted experiment on optimizing deep drilling parameters based on Taguchi L_{18} orthogonal array was used for minimizing surface roughness. The deep drilling experiments were conducted on CNC lathe machine using 10mm diameter solid carbide cutting tool on AISI 321 austenitic stainless steel. Cutting parameters such as cutting fluid, speed, feed and hole-depth, each at three levels and cutting fluid at two levels were considered. The signal-to-noise (S/N) ratio and the analysis of variance (ANOVA) was carried out to determine which machining parameter significantly affects the surface roughness and also the percentage contribution of individual parameters. The results revealed that 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 minimum surface roughness. Further, the results of ANOVA 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%).

D. V. Baghlani, P. Mehbudi, J. Akbari, M. Sohrabi, Ultrasonic assisted deep drilling of Inconel 738LC super alloy, Procedia CIRP 6 (2013) 571 – 576:

In this Study researcher had conducted experiments on super alloys Inconel 738LC through ultrasonic EDM. They have been examined the effect of ultrasonic vibration amplitude, spindle speed and number of steps to drill each hole on machining force and surface roughness. They found that the optimum conditions predicted by Taguchi method is achieved in 10µm amplitude of vibration, 5 steps and 355RPM spindle speed. They showed that the holes were drilled in this optimum condition and an average thrust force of 417N and surface roughness of 1.610µm was obtained. i.e. 1.551µm surface roughness and 408N thrust force which show 2 and 4 per cent difference with Taguchi prediction of surface roughness and thrust force respectively.

E. M.C. Hardy, C.R.J. Herbert, J. Kwong, W. Li, D.A. Axinte A.R.C. Sharman, A. Encinas-Oropesa and P.J. Withers, Characterizing the Integrity of Machined Surfaces in a Powder Nickel Alloy used in Aircraft Engines, Procedia CIRP 13 (2014) 411 – 416:

In this Study researcher had carried out and characterized the integrity of machined surfaces in a powder nickel alloy that is being used for disc applications in aircraft engines. They have inspected the effects of process parameters on surface integrity for hole making and finish turning and then presents the findings of work that has been conducted to understand the influence of machining anomalies on fatigue life. For characterizing surface integrity, they include surface inspection, surface roughness measurement, metallographic assessment of etched surfaces using light microscopy and micro hardness measurement. Also they discussed more novel techniques, exploiting advanced electron microscopy, nano-indentation and x-ray diffraction methods. They have been suggested that all mention methods are capable of understanding the effects of machining processes on microstructure and quantifying the depth to which machining processes can change the material microstructure.

F. J.Pradeep Kumar, P.Packiaraj, Effect of drilling parameters on surface roughness, tool wear, material removal rate And hole diameter error in drilling of OHNS, IJAERS/Vol. I/ Issue III/April-June, 2012/150-154

In this Study researcher had conducted experiment on OHNS steel by L18 orthogonal array of Taghuchi's method to analyze the effect of drilling parameters such as cutting speed, feed and drill tool diameter on surface roughness, tool wear by weight, material removal rate and hole diameter error using HSS spiral drill. Orthogonal arrays of Taguchi, the Signal–to- Noise (S/N) ratio, the analysis of variance (ANOVA), and regression analysis are employed to analyze the effect of drilling parameters on the quality of drilled holes. Linear regression equations are developed with an objective to establish a correlation between the selected drilling parameters with the quality characteristics of the drilled holes. Linear regression equations are developed to predict the values of surface roughness, tool wear, material removal rate and hole diameter error and the predicted values are compared with measured values. Through ANOVA, it is found that the feed and speed are important process parameters to control surface roughness, tool wear, material removal rate and hole diameter error.

G. R.Hood, S.L. Soo, D.K. Aspinwall, P. Andrews, C. Sage, Twist drilling of Haynes 282 super alloy, Procedia Engineering 19 (2011) 150 – 155:

In this Study researcher had carried out experiment on Haynes 282 aero engine casing material using coated carbide tooling with high pressure (50 bar) cutting fluid. They took cutting speed and feed rate as an input parameter. They observed that the increase in hardness (up to 50 HK0.05 above the bulk) within the first 50 µm and Surface/subsurface microstructural damage consisted of deformed grain boundaries up to a depth of ~15 µm with a discontinuous white layer of up to ~6 µm from the surface. They showed that the Tool flank wear at lower operating parameters was generally uniform however extensive wear/fracture of the tool corner chamfer was evident on more than half the tests. They found that the Burrs were up to 250 µm in height generated on both hole entry and exit in the majority of specimens during analysis.

H. Turgay Kivak, Gürcan Samtas, Adem Çiçek Taguchi method based optimization of drilling parameters in drilling of AISI 316 steel with PVD monolayer and multilayer coated HSS drills Measurement 45 (2012) 1547–1557:

In this Study researcher had conducted experiment on a CNC vertical machining centre on AISI 316 stainless steel blocks using uncoated and coated M35 HSS twist drills

under dry cutting conditions. They used L16 orthogonal array of Taguchi method to find the optimum drilling parameters like cutting tool, cutting speed and feed rate and analysis of variance (ANOVA) was performed to investigate the influence of parameters on surface roughness and thrust force during drilling. They found that the cutting tool was the most significant factor on the surface roughness and that the feed rate was the most significant factor on the thrust force. They concluded to the final results by the confirmation experiments showed that the Taguchi method was notably successful in the optimization of drilling parameters for better surface roughness and thrust force.

I. Du Jin & Zhanqiang Liu, Damage of the machined surface and subsurface in orthogonal milling of FGH95 super alloy, Int J Adv Manuf Technol (2013) 68:1573–1581:

In this Study researcher had conducted experiment on FGH95 is one kind of powder metallurgy (PM) super alloy developed for turbine disc applications to improve aero engine efficiency under higher operating temperatures. The machining process can lead to damage of the machined surface and subsurface. In order to investigate damage of the machined surface and subsurface, Orthogonal milling experiments using coated carbide inserts were carried out on a CNC machining center. The machined surface was observed and recorded using an optical microscope, white light interferometer, and scanning electron microscope. Machined surface defects were recorded and analyzed. The effects of cutting speed on machined surface roughness, white layer thickness, plastic deformation, and microhardness were investigated. The results show that better surface roughness can be generated at higher cutting speeds. The surface roughness of FGH95 decreased by 39.18 % as the cutting speed increased from 40 to 200 m/min., while several defects appeared on the FGH95 machined surface. White layer thickness which taken as carbide compound, machined surface microhardness and plastic shear strain in the machined surface layer increase with the cutting speed. The depth of plastic deformation decreases with the increase of cutting speed. These investigation results are essential for the prediction of PM super alloy service life

J. Juan Carlos Campos Rubio, Leandro José da Silva, Wanderson de Oliveira Leite Tulio Hallak Panzera, Sergio Luiz Moni Ribeiro Filho, João Paulo Davim, Investigations on the drilling process of unreinforced and reinforced polyamides using Taguchi method, Composites: Part B 55 (2013) 338–344:

In this Study researcher had conducted experiment on drilling process of unreinforced and reinforced polyamides using Taguchi method. They investigated Experimental on PA6 and a PA66GF30 composite was conducted using three carbide drills (K20) with different geometries. They took tool geometry, spindle speed and feed rate factors as an input parameter to influence the effect on the thrust force, hole mean diameter and circularity error. They revealed that the quality of the holes can be improved by proper selection of cutting parameters. They showed that the drilling of PA66GF30 the best setup condition for diameter was achieved when the tool point geometry was set at 115^0, in addition the other factors were not statistically significant.

K. V.N. Gaitonde, S.R. Karnik, J. Campos Rubio, A. Estevez Correia J. Paulo Davim, A.M. Abrao, Analysis of parametric influence on delamination in high-speed drilling of carbon fiber reinforced plastic composites, Journal of material processes and technology, 203 (2008) 431–438:

In this Study researcher had**]** carried out experiment on carbon fiber reinforced plastic composites using cemented carbide (K20) twist drills, were performed based on full factorial design of experiments with three levels defined for each of the process parameters like cutting speed, feed rate and point angle to investigate the effect the delamination of performance characteristics. They developed computed values of delamination factor are empirically related to process parameters by developing a second order non-linear regression model based on response surface methodology (RSM). They suggested that the delamination tendency decreases with increase in cutting speed and combination of low values of feed rate and point angle reducing the damage.

III. CONCLUSION

I found that most of all researches carried out on various super alloy material with use of various tools, methods, parameters and observed the effect on various responses during drilling. I found research gap that very few researchers had worked on nickel based alloy for conventional drilling. Due to application of super alloy in aerospace, fatigue life is serious concern effect of machining on surface and sub-surface is of good importance to avail good defect free surface.

It is observed from above mentioned research papers that wear increases with increase in cutting speed but the Tool wear at lower operating parameters was generally uniform. Spindle speed has significant impact on the dimensional accuracy of the hole. The hole quality can be increased by using lower feed rate.It is found that the feed and speed are important process parameters to control surface roughness, tool wear, material removal rate and hole diameter error. The cutting tool was the most significant factor on the surface roughness and that the feed rate was the most significant factor on the thrust force.

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