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MACHINING OPTIMIZATION AT ELEVATED TEMPERATURE (HOT MACHINING): A LITERATURE REVIEW

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Abstract-The ultimate aim of the manufacturing company is to reduce the cost of products by optimizing the productivity. Hot machining methods can aids to counter the difficulties of cutting speeds, feeds, depth of cut and also overcome in reducing the forces withstands by the machine system. As we know that due continuous development in new materials which are difficult to cut possesses a challenge in machining. So the principle behind the hot machining is that the workpiece surface on which machining is to be done is preheated which is lower than the re-crystallization temperature in order to avoid the transformation of phase .so this resulting in reduction of shear force to a great extent and make easy to machine thereby also enhances the tool life. Thus aids in boost up the machining performance parameters. In hot machining various conventional and non- conventional methods can be used.

Keywords- Hot machining, Surface roughness, Re-crystallization, Hardness, Material removal rate, Tool wear, Tool life, Cutting forces, Surface roughness.

I INTRODUCTION

Hot machining is applied for optimized machining and to eradicate the problems of cutting at lower speed, feed and critical loads onto the machine components. When the machining is done on the hard or difficult to cut materials in this method, first the materials are exposed to heat before the machining or at the time of machining keeping in mind the temperature must not exceed the recrystallization point. On doing so the machining force gets down to a great amount. It also overcomes the problems that occur at the time of cold working operation. The crystal structure, chemical properties and chemical compositions must not alter at the time of machining. It boosts the tool life and the machining forces also reduced in hot machining.

Titanium alloys having high strength to weight ratio and resistance to corrosion at room and elevated temperature which makes it in demand for various applications. It is having applications in Jet engines, petro chemicals and marine components, biomaterials such as orthopaedic implants because of its ultimate mechanical, chemical and high temperature resistance properties. Titanium alloys having its contribution at an about 30% of the total engine mass in commercial and 40% in armoury products .So machining of it alloys because of high strength it is difficult to machine by simple cutting tools. Tool wear also occurs when machining the titanium alloys and also time taking to complete the operations. Hence by the application of hot machining method machining can be performed with ease. Technological advantages of hot machining of metals mainly cover the reduction of the mechanical load of cutting tools due to softening of the workpiece materials at elevated temperatures as well as stabilisation of austenitic phase in austenitic steels. This process is very helpful in reducing total cost of machining by decreasing the tool wear rate and minimizing the time of processing while machining the difficult to cut materials.

FACTORS AFFECTING HEATING TECHNIQUES SELECTION

- Temperature at which hot machining to be done.
- Temperature control and its regulation with ease.
- shear zone where the deformation occurs.
- Optimized Material Removal rate.
- Cost effectiveness of operation.
- Optimized production cost.
- Limit to heating capacity.
- Machine tool adaptation.
- Safe operation.

HOT MACHINING TECHNIQUES

The heating techniques can be classified as follow:
1. Complete heating of workpiece:
- Resistance heating.
- Oven.

- Heating workpiece by previous operation.

2. Localized heating:
- Flame heating.
- Induction.
- Electric arc.
- Electric contact.
- Radiation.
- Friction.
- Electron beam.
- Plasma arc.
- Laser-assisted.

II LITERATURE REVIEW

Nikunj R Modh et. al. has performed measure, tool wear (VB) are deduced by applying an orthogonal array and the analysis of Variance (ANOVA) at 200 ^{0}C, 400 ^{0}C and 600 ^{0}C in hot turning operation. For each performance measure Optimal cutting parameters was found. By Using multiple linear regression equation the relation between the parameters and the Performance measure is determined. These relations can be used to make an estimation of the expected values of the performance level for any factor levels. [1]

Venkatesh Ganta et. al. has made an investigation for optimizing the performance characteristics of 15-5PH stainless steel by machining with K313 carbide tool based on Taguchi L27 orthogonal array design. The sample was heated using oxy-acetylene gas flame which is the economic method compared to other heating methods applied during hot machining process. Variance analysis has been done to obtained the significance of input on the performance characteristics and has been found that the cutting speed significantly affect the performance characteristics in comparison to feed, depth of cut and temperature. The optimized set of parameters obtained to be cutting speed (31 m/min), feed(0.4mm/rev), depth of cut (0.4 mm) and work piece temperature(400°C) to enhance the material removal rate and reduce the surface roughness. [2]

K.A.Patel et. al. has investigated to boost the inputs contribution used during process are speed, feed and depth of cut. The outcomes are surface quality which is obtained by hot machining process that resulting in good surface finish at high cutting speed, high temperature and low feed rate. It is also advantageous in terms of surface roughness and the Optimum results are achieved when Cutting speed is 300 rev/min, Depth of Cut is 0.8 mm, Feed is 0.111 mm/rev and Temperature is 500°C .During hot machining, the change of the work piece surface colour was also found at temperature of 500°C. [3]

Nirav M. Kamdar et. al. the study were made under machining inputs parameter at 200 °C, 300 °C, 400 °C, 500 °C and 600 °C at fixed depth of cut 0.8 mm. The optimized result got during the experimentation by Taguchi methods. Significant parameters and its percentage contribution change as per the Behaviour of the parameter with objective response. [4]

MUHAMMAD, R. ... et al. whenever the heat is applied on to the work materials the effective force of cutting decreases because in the shear plane the shear strength of the workpiece decreases. Hence, at higher temperatures workpiece gets soft and becomes easy for cutting tool to perform the operation. In CT (conventional turning) and HCT (Hot conventional turning), the tool is in touch with the work materials throughout the operation because of which single magnitude of force is required, But for the case of HUAT(Hot ultrasonically assisted turning) the cutting tool detached from the work material at the time when there is no machining occurring at the interval in periodic vibration cycle of which leads to the changes in the value of forces from maximum to minimum. Due to Softening of the material in HCT because of thermal effect, force needed to perform the operation was lesser with respect to CT .same phenomenon was found effect for the case of HUAT in which the maximum value of force gets down due to heating effect. Machining at 500°C and the 300°C are compared. So, from the experimental observation it has been observed and has been recommended to perform operation on Ti-15333 at 300°C.The magnitude of force of cutting reduced in hot machining because of reduction in yield strength of Ti-15333 at elevated temperatures. For the case of HUAT, when the softening of work materials is assisted by separating the tool in each vibration cycle leads to decrease in force to a great extent with respect to any turning operation. Thermal assisted turning also increase the surface finish. [5]

Fedor Egorov et. al. Machining of soft ferrite-pearlite and heat treated bainite materials carried out in temperature ranges 20 °C and 500 °C. it has been obtained that there is decrease in forces for both heat treated conditions. So, small power needed with respect to previous conventional operation. Loads on the tool reduced because of decrease in forces of cutting. Hence the life of the tool increased by 2.5 times. Also machining at elevated temperature provide stability to the operation. At 400°C optimum cutting condition was obtained for the tool life when turning the bainite steel. [6]

M.I. Hossain, A.K.M. Nurul Amin, A.U. Patwari, A .Karim et. al. In order to machine Ti-6Al-4V, preheat is done by induction method.To preheat the workpiece, heating by induction is done at higher frequency to softening the surface layer of workpiece to reduce the tensile strength and strain hardening. While doing experiment on Ti-6Al-4V operation was performed at room condition and at preheat condition (420°C).Preheat affects the tool life to a great extent. To take benefits of preheat machining a speed, feed and depth of cut parameters play a vital role in increasing the tool life and optimising the operation. While performing end milling operation on Ti-6Al-4V with the inserts made up of PVD TiAlN coated carbide, the tool life increase to a large extent due to preheating effect Life of the tool enhanced by 80.13% under preheat condition (at 420°C) with respect to machining at normal room temperature. [7]

III TABLE OF LITERATURE SURVEY ON OPTIMIZATION OF HOT MACHINING METHODS

IV

Sr. No.	Name of author	Title	Year	Methodology used/Parameter analysed	Result and Discussion
1	Nikunj R Modh, G. D. Mistry, K. B. Rathod	An experimental investigation on hot machining process by design of experiments using taguchi method.	2017	The analysis is done by taguchi method. Taguchi technique advocates the usage of orthogonal array like L8, L9, L16, L18etc. Ivarious parameters like depth of cut, speed, velocity, temperature to get surface roughness and material removal rate as a response parameter.	widely used and efficient method for manufacturing. this method machining can be done easily by using less power using design.
2	Venktesh Ganta,D chakradhar	Multi objective optimization of hot machining of 15-5PH stainless steel using grey relation analysis.	2014	Grey relation analysis/parametersused are cutting speed,feed and depth of cut.	The optimal set of process parameters are found to be cutting speed at 31 m/min, feed rate 0.4mm and depth of cut 0.4 mm at a temperature 400 ^{0}C.
3	K.A.Patel, S.B.Patel, K.A.Patel	Performance evaluation and parametric optimization of hot machining process on EN-8 material.	2014	Taguchi orthogonal array is used for statistical method. The work piece tested is EN-8 steel material. The input parameters during process are speed, feed and depth of cut. The output parameters are surface quality.	Hot machining process gives good surface finish at high cutting speed, high temperature and low feed rate. And it is also beneficial in terms of surface roughness. Optimum results are achieved when Cutting speed is 300 rev/min, Depth of Cut is 0.8 mm, Feed is 0.111 mm/rev and temperature is 500 ^{0}C. During hot machining, the change of the work piece surface colour was also observed at temperature of 500 ^{0}C.
4	Nirav M. Kamdar, Prof. Vipul K. Patel	An experimental investigation to optimize the process parameters of ALSI 52100 Steel in hot machining.	2012	DoE method used to investigate the individual and interaction affects of process parameter./ Parameters analysed by using Analysis of variance(ANOVA).	Optimized output obtained when the cutting speed is 965rev/min, feed is 0.265 mm/rev and the temperature is 600 ^{0}C.
5	Riaz Muhammada, Agostino Maurottob, Murat Demiralc, Anish Royd, Vadim V. Silberschmidte	Thermally enhanced Ultrasonically assisted machining of Ti alloy.	2014	Cutting speed, depth of cut, feed rate, temperature, frequency and amplitude used as a parameter.	Due to application of heat, force responsible for cutting reduced to a great extent and also improvement in surface finish of a machined surface obtained.

6	Fedor Egorov	Hot machining: utilisation of the forging heat for efficient turning at elevated temperatures.	2013	Cutting forces were measured using a piezoelectric 3-component dynamometer. Cutting parameter are speed , Feed, Cutting temperature.	The results show the potential of utilisation of the heat energy from the hot forming integrated heat treatment for hot turning of forge steels with bainite structure.
7	M.I. Hossain, A.K.M. Nurul Amin, A.U. Patwari, A. Karim	Enhancement of machinability by workpiece preheating in end milling of Ti-6Al-4V	2008	End milling tests were conducted on Vertical Machining Centre (VMC ZPS, Model: MCFV 1060. Tool life, cutting force and vibration.	The tool life increase to a large extent due to preheating effect. Life of the tool enhanced by 80.13% under preheat condition (at 420 ^{0}C) with respect to machining at normal room temperature .workpiece preheating using induction heating system to enhance the machinability of Ti-6Al-4V.

V CONCLUSIONS

Hot machining can be applied in machining operation, finishing operation, bulk deformation operation. By the application of hot machining methods the discontinuous chips produced in machining may be changed to continuous form. This process is very helpful in reducing total cost of machining by decreasing the tool wear rate and minimizing the time of processing while machining the difficult to cut materials. Heating the job prior to the machining or during operation have positive impact by enhancing life of the tools, minimizing machining force and others parameters such as dynamic forces and amplitude of vibration.

FUTURE SCOPE

The cutting speed, feed, depth of cut and temperature significantly imparts in performance characteristics. Hot machining operation has positively affected the requirements of the cutting forces and also enhances the tool life. So there is a lot of scope in these fields to have further research on the machining parameter on varied composition of materials for the optimization of machining operation. For different composition of workpiece materials more researches can be done to obtain the optimised cutting parameters by using different heating techniques in hot machining.

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