CHAPTER 1

Cutting Parameters using RSM for High Speed Precision Machining of Titanium Alloys

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ABSTRACT

The aerospace, automotive and biomedical parts manufacturers use Titanium Metal matrix composites extensively because of their high specific strength and exceptional corrosion resistance. Machinability of Titanium Metal matrix composites poses biggest threat as their low thermal conductivity and elastic modulus are bigger challenges to be addressed; it also gets high hardness at elevated temperature with high chemical reactivity.

This research is to analyst Machinability parameters of machining of Titanium Metal matrix composites, and focuses on optimization of machining process. The possible parameters to be improved are cutting and machining forces, chip formation using alloying and reducing cutting temperature. The CNC milling process of Ti- 6Al-4V alloy parameters were identified and being studied in detail for optimization.

Keywords*— *Titanium Metal matrix, high hardness, high chemical reactivity etc.

INTRODUCTION

The Machinability of Titanium metal matrix composites is reportedly the biggest challenge to be resolved and the researchers of industry and academia reported many times in the journals of repute. The selection

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of correct cutting speed, feed and depth of cut defines many of the parameters in dynamics of cutting out of all machining parameters.

The main objective of the paper is to understand the effect of change in machining environment on various aspects of machining of titanium alloys. Some other parameters like angle of cutting, tool wear ratio type of cutting tool, type of coating on the cutting edge, thermal conductivity of cutting material, lubricant fluid and flow rate of lubricants, type of chip formation, effect of alloying elements and its crystalline structure unlike other materials of ferrous and non-ferrous class the material hardness is not being the indicative parameter for the optimal planning of cutting parameters. Extensive study on the experimental results of diamond milling of metals such as aluminum, stainless steel etc are considered for defining the parameters on Titanium Metal matrix composites.

A homogeneous crystalline material forms single crystals, which indicates fluctuation in cutting forces depends on the frictional condition during cutting. Hence, such polycrystalline material in which there is a strong crystallographic texture also requires special attention for Machinability studies. It is understood that the dynamic behavior of different forces and signals is affected by type, location and configuration of the wear mode. Simulation of high speed dry machining of Ti-6Al-4V alloy showed that the cutting force fluctuation can be caused by chip segmentation.

Reducing the mass of a vehicle and thereby fuel consumption is one of the most important objective of research on automotive materials. Titanium alloys are the promising automotive materials due to their excellent ‘strength-to-weight’ ratio, high corrosion resistance and ability to maintain the strength at high temperature.

However, titanium alloys have limited applications in the consumer automotive segments due to their higher processing cost. Properties of titanium alloys like poor thermal conductivity, low modulus of elasticity, ability to maintain strength at high temperature and reactivity with the tool material increases the processing cost of titanium alloys. A significant research has been carried out to reduce the processing cost of titanium alloys through advancement in tool material and geometry, formulation of new lubricants and techniques of lubricant application, coating, and varying machining environments

LITERATURE REVIEW

The literature review indicates that the machinability studies of titanium material, Taguchi‘s technique in machining optimization, response surface methodology in machining optimization, surface roughness and cutting temperature measurement are extensively discussed.

MACHINABILITY STUDIES OF TITANIUM MATERIAL

The demand for machining of titanium alloy has been increased in recent years. In order to understand and access the current status of research in machining of titanium alloys, an extensive literature review has been carried out. The present study is focused on the machining characteristics of titanium. In general, a finish machining of a titanium component will be necessary, because of the requirement of exact dimensional accuracy, surface quality and material homogeneity. Machining of titanium alloy poses considerable problem due to its poor machinability (Klaus Gebauer 2006, Komanduri& Reed 1983 and Awopetu et al 2005). The poor machinability of titanium has led many large companies to invest large amount of money in developing techniques to minimize machining costs. Machao & Wallbank (1990) and Ramesh et al (2008) deliberated that the tool makers are looking for new tool materials which can extend tool life in the presence of such a challenge.

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It has been noticed that the first literature on machining of titanium alloy was presented by Siekmann (1955). It has been pointed out that machining of titanium and its alloys will always be a problem, no matter what technique is employed to transform this metal into chips. Komanduri & Von (1981) have commented that the machining difficulty of titanium alloy is still true as far as cutting tool materials are concerned. While improving the machining rates will go a long way towards increasing the usage of the material, it must be noted that this is only one of the number of factors affecting the use of the material. Others, which include material cost, must also be considered in any specific application.

The detailed information about the alpha-beta alloy, Ti-64 which accounts for about 45% of the total titanium production, unalloyed grades comprise about 30% is presented by several researchers. Komanduri et al (2005) presented some new observations on the mechanism of chip formation to increase productivity when machining titanium and reported interesting findings towards the goal. Hartung et al (1982) have investigated turning test on Ti-64 with conventional Carboloy 820 and Kennametal K68 grade cemented carbides. They analysed and suggested that tool wear rate of tool materials, which maintain a stable reaction layer, is limited by the diffusion rate of tool constituents from the tool-chip interface. The diffusion flux correlates well with the observed wear rate. Bhaumik et al (1995) has developed a boron nitride- cubic boron nitride (wBN-cBN) composite tool by high pressure/high temperature sintering for machining Ti-64 alloys. In their investigation they indicated that this composite tool can be used economically to machine titanium alloys.

Tool failures mode and wear mechanisms for the two tools have been examined at various cutting conditions. The performance of the uncoated and the multi- layer CVD- coated alloyed carbide tools is analysed in terms of tool life and surface finish. It has been observed that most of the studies are concentrated on either tool temperature or surface roughness. There is no comprehensive analysis being carried out to assess the performance of machining titanium.

Nurul Amin et al (2007) listed the several application of Titanium in many areas such as petroleum refinery, surgical implications, chemical industries, food industries, automotive and marine applications. Titanium serves as the best material in these industries because of its superior mechanical properties, heat resistant and corrosion properties. Titanium having a density only about 60% of steel, has a far greater strength than many steel alloys. However, titanium has many difficulties in machining. It has a low conductivity and therefore heat due to cutting does not dissipate quickly. This results in concentration of heat on the cutting edge and hence greatly limits the machinability of this material.

METHODOLOGY

Milling is one of the mostly used machining operations in manufacturing industry. The situation becomes very difficult to handle when hard materials are required to go through milling process. The probability of tool wearing and damaging of surface roughness increases when high cutting forces and high temperatures are involved at interface of cutting tool and work material.

Experimental data shows that cryogenic cooling is more sustainable than dry and conventional cooling process, and it gives the best results for tool life, surface finish of machined part, productivity with least impact on the environment, least energy cost and machining cost.

PROBLEM STATEMENT

Literature survey on recent papers reveals that the following are the possible parameters identified using the case study method, Cutting speed, Feed rate, Depth of cut, Friction Tool wear, Chip Microstructure, Machine Influence, Increasing of cutting speed caused a linear increase of dynamic force frequency, but

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the respective amplitude changed inversely during dry milling of Ti-6Al-4V alloy, vibration during machining. These parameters needs to be studied for high speed machining operation and machinability of Titanium Metal matrix composites are generally governed by the listed parameters. An objective case study is conducted to identify the parameters in a standard machine tool. The machinability of Titanium Metal matrix composites is considerably low in comparison to other materials. The material behavior during high-speed milling operation is being studied; the structure of material needs to be checked after machining. Surface roughness is a measure of the technological quality of a product and has influence on manufacturing cost and the quality of the product. Therefore, industries always choose to maintain the good quality of the machined components.

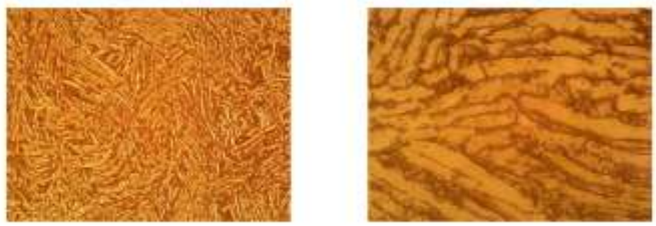

Fig.1. Tested SEM Images

EXPECTED RESULT

This research would use statistical analysis methods in the area of high speed machining, considered different sets of input parameters, output parameters and tried various analysis techniques based on statistics, including structured equation modeling (SEM) analysis, robust design, and Taguchi design approaches have reported high-speed milling for testing the suitability of high- speed milling for different kinds of materials. So far the researchers addressed issues with better machinability materials like steels, aluminium alloys, graphites and polymer matrix composites.

EXPERMINTATION

ORTHOGONAL ARRAY SELECTION

An orthogonal array has been selected using Taguchi orthogonal array selection technique. The orthogonal array selected should have greater degree of freedom as compare to degree of freedom required. In this analysis an interaction analysis was also done to get the significance of interaction of two variables on output. So L27 was selected as design of experiment.

Material removal rate is the volume of material removed per unit time from the work piece surface. We can calculate material removal rate as the volume of material removed divided by the time taken to cut. The volume removed is the initial volume of the work piece minus the final volume. The cutting time is the time needed for the tool to move through the length of the work piece this parameter strongly influences the finishing grade of the work piece. Material removal rate basically depend upon the feed rate, spindle speed, tool diameter and depth of cut. It is important output characteristic in milling or every machining process because MRR has direct relation with the production. And quick and high production is the need of modern production system. Thus every company focuses on the optimization of the technical parameters for high material removal rate. In end milling, the cutter generally rotates on an axis vertical to the work piece. It can be tilted to machine tapered surfaces. Cutting teeth are located on both the end face of the cutter the naming of sample was done according to design of experiments. The prepared samples were machined using CNC machine. The machining time in each sample milling case

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was noted carefully. After completion of machining the surface roughness was measured using Mitutoyo SJ-301 surface tester. An analysis of S/N Ratio and ANOVA was performed.

RESPONSE PARAMETERS

The MRR of the work piece was measured by compared the weight of work piece before and after machining (found by weighing method using balance) against the machining time that was achieved. After completion of each machining process, the work piece was blown by compressed air using air gun to ensure for blowing out the debris. A precise balance was used to measure the weight of the work piece required. The following equation is used to determine the MRR.

Surface Roughness: Roughness is a measure of the texture of a surface. It is quantified by the vertical deviations 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. Roughness is typically considered to be the high frequency, short wavelength component of a measured surface. Surface roughness is an important measure of product quality since it greatly influences the performance of mechanical parts as well as production cost. Surface roughness has an impact on the mechanical properties like fatigue behavior, corrosion resistance, creep life, etc. surface roughness tester to measure surface roughness of work piece.

There are various methods available for measuring the surface roughness of the work piece. The arithmetic surface roughness value (Ra) was adopted and measurements were carried out at the left and at the right side and at the middle of the surface using a Surftest SJ301. Before conducting the measurement, all the samples were cleaned with acetone. The Ra values of the surface were obtained by averaging the surface roughness.

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MACHINING OF TITANIUM ALLOY

Fig.2. Ti-6AL-4V Workpiece

RESULT AND CONCLUSION

Despite recent developments and extensive usage of titanium alloys, machining of titanium alloys still remains as a major industrial concern: short tool life, low metal removal rates, higher cutting force and temperature, and poor surface quality. To improve the machinability of titanium alloys, special attentions must be paid to machining strategies and cutting tools. There are many types of cutting tools employed for machining of titanium alloys. Amongst, carbide tools are still the most commonly used materials. The cutting temperature and high pressure at the tool-chip interface, built up edge (BUE) formation and the chemical interaction between the titanium and the tool are the main reasons of the tool wear. In fact, the tendency of titanium alloys to react with the most of cutting tool materials is the main factor of tool wear which hinders the machinability of titanium alloys. Tool wear mostly occur in the tool flank side in both coated and uncoated tools in machining titanium alloys.

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Machining titanium alloys is generally associated with high cutting forces. Increased cutting forces are also attributed to strain rate hardening. Substantial improvements in decreasing the cutting forces are observable when using hybrid machining approaches, such as laser-assisted machining (LAM). The behavior of the Ti-6A1-4V titanium alloy during machining operations strongly affects the mechanisms of particle emission and the chip formation. The disintegration of coarse particles produced during the machining of titanium alloys under certain conditions produces fine and ultrafine particles.

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