THERMAL ANALYSIS & OPTIMIZATION OF COATED TURNING INSERT ON AISI 304 AUSTENITIC STAINLESS STEEL MATERIALS-A REVIEW

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Abstract

Austenitic stainless steels are a mostly used group among stainless steels. The austenitic stainless steel is consumed in large volumes (72%) among the other grades of stainless steels. Many of research works contributed their efforts to overcome poor mach inability of austenitic stainless steels. Many problems have been faced by users during machining due to its low thermal conductivity, high work hardening, high strength, and high ductility. These made it complicated to machine the materials. The aim of our present experimental investigation is to study the temperature analysis and to determine the optimal levels of process parameters for optimizing the surface quality of AISI 304 austenitic stainless steel work piece by employing Taguchi's orthogonal array design and Analysis of Variance (ANOVA) using PVD coated turning insert tool on CNC lathe. Taguchi's Design of Experiments approach (DOE) is used to analyze the effect of process parameters on surface roughness to obtain their optimal setting. The ANOVA is used to identify the significant process parameters more accurately by investigating the relative importance of process parameters. This paper deals with the study of the performance of coated turning insert in turning AISI 304 austenitic stainless steel material.

Key words: PVD coated insert, Surface roughness, AISI 304 austenitic stainless steel, Taguchi approach, ANOVA

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INTRODUCTION

The AISI 300 series of austenitic stainless steels represent the largest group of steels in use of total. However these steels have very high corrosion resistance, Ozek C (2006) says that it is more difficult to machine these materials because of their low heat conductivity, built – up edge tendency and high work hardening properties than carbon and low alloy steels .Poor surface finish and high tool wear are the common problems.

Since turning is the primary operation in most of the production processes in the industry, surface finish of turned components has greater influence on the quality of the product. Dr.S.S.Mahapatra, Amar Patnaik, Prabina Ku. Patnaik (2006),has been found to be influenced in varying amounts by a number of factors such as feed rate, work material characteristics, work hardness, unstable built-up edge, cutting speed, depth of cut, cutting time, tool nose radius and tool cutting edge angles, stability of machine tool and work piece setup, chatter, and use of cutting fluids.

A large amount of heat is generated in machining processes as well as in other processes in which deformation of the material occurs. Heat is a parameter that strongly influences the tool performance during these processes. One way to increase the tool life consists of coating its cutting surface with materials that provide minor wear with thermal isolation features. An important investigation is the study of the influence of cutting tool coatings on heat transfer and friction wear, resulting in a distribution of the cutting temperature both on the chip and on the tool. Rogério Fernandes Brito, Solidônio Rodrigues de Carvalho, Sandro Metrevelle Marcondes de Lima e Silva, João Roberto Ferreira (2009) observed that most orthogonal metal cutting simulations were designed for uncoated cemented carbide tools and that now an opposite trend has considered the use of single and multiple coatings.

HEAT IN CUTTING

In metal cutting operations, temperature develops at the chip – tool interface due to the plastic deformation developed at the primary shear plane and friction at the tool – chip interface. This temperature rise affects the tool wear and its life, and surface integrity of material.Ozek.C (2006) studies that parameters such as cutting speed, feed rate and depth of cut were changed to explore their effects on the temperature rise at the tool – chip interface, surface roughness and tool flank wear. A large amount of heat is generated in machining processes as well as in other processes in which deformation of the material occurs. Heat is a parameter that strongly influences the tool performance during these processes Rogério Fernandes Brito, Solidônio Rodrigues de Carvalho (2009). There are various attempts by researchers all over the world to understand the mechanism and theory behind the temperature built-up during machining in order to achieve optimized machining procedure and best work piece results. Theories are developed, experiments conducted (W.S.Lin 2006) as well as models and simulations proposed (Dr.S.S.Mahapatra, Amar Patnaik, Prabina Ku. Patnaik, 2006).

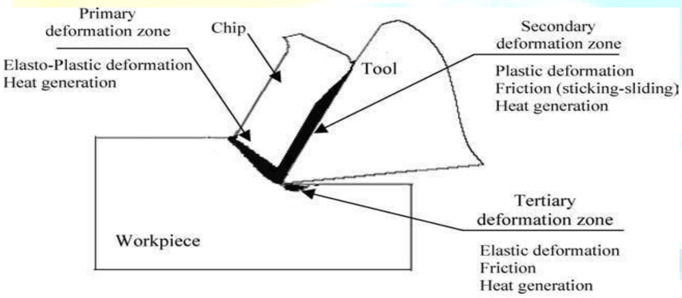

Figure 1.Heat affected zone.

FINDINGS FROM EXPERIMENTS

Cebeli ÖZEK, Ahmet HASÇALIK, and Ulaş ÇAYDAŞ*, Faruk KARACA, Engin ÜNAL (2006) found that with increasing cutting speed, tool – chip interface temperature and tool flank wear were decreased. Surface roughness got better with decreasing feed rate and depth of cut. Dr.S.S.Mahapatra (2006) makes an attempt to generate a surface roughness prediction model and optimize the process parameters Genetic algorithms (GA) W.S.Lin (2008) is focused on the surface roughness variation in high speed fine turning of the austenitic stainless steel. When the feed rate smaller than the critical feed rate, the chatter will occurs and the surface roughness of the work piece would be deteriorated. The higher the cutting speed is, the higher the cutting temperature of cutting tool is.Tian-Syung Lan (2009) measures the surface roughness, tool wear and Material Removal Rate (IVERR) which are major intentions in modern Computer Numerical Controlled (CNC) machining in dusty; therefore, the $L_9(3^4)$ orthogonal array of Rogério Fernandes Brito, Solidônio Rodrigues de Carvalho, Sandro Metrevelle Marcondes de Lima e Silva, João Roberto Ferreira (2009) examines the heat influence in cutting tools considering the variation of the coating thickness and the heat flux..The numerical methodology utilizes the ANSYS® CFX software.

MODELLING AND SIMULATIONS PERFORMED

Dr.S.S.Mahapatra, Amar Patnaik, Prabina Ku. Patnaik (2006) used several statistical models to generate models including regression and Taguchi methods, an attempt has been made to generate a surface roughness prediction model and optimize the process parameters Genetic algorithms (GA). Tian-Syung Lan (2009) used technique for order preference by similarity to ideal solution (TOPSIS), the multiple objectives can additionally be integrated and introduced as the S/N (signal to noise) ratio into the Taguchi experiment. The S/N ratio is moreover analyzed by MINITAB. Rogério Fernandes Brito (2009) uses the numerical methodology utilizes the ANSYS® CFX software. Boundary conditions and constant thermo physical

Properties of the solids involved in the numerical analysis are known. To validate the proposed methodology an experiment is used.

HEAT DISSIPATION

Heat generated during machining is dissipated away

Through four systems within the machining system that is through the cutting tool, the work piece, the chip and the use of cooling agents. In metal cutting operations, temperature develops at the chip – tool interface due to the plastic deformation developed at the primary shear plane and friction at the tool – chip interface. This temperature rise affects the tool wear and its life, and surface integrity of material. The heat generated and temperature are also connected the use of process parameters and thermo physical Properties of work piece and tool materials (Ozek C.2006).

A large amount of heat is generated in machining processes as well as in other processes in which deformation of the material occurs. Heat is a parameter that strongly influences the tool performance during these processes. One way to increase the tool life consists of coating its cutting surface with materials that provide minor wear with thermal isolation features. (Rogério Fernandes Brito 2009) study of the influence of cutting tool coatings on heat transfer and friction wear, resulting in a distribution of the cutting temperature both on the chip and on the tool.

COATING APPROACHES USED BY METAL CUTTING RESEARCHERS

As indicated by Ozek C. (2006) while turning of AISI 304 austenitic stainless steel material parameters such as cutting speed, feed rate and depth of cut were changed to explore their effects on the temperature rise at the tool – chip interface, surface roughness and tool flank wear. WC ISO P10 cemented carbide tool was used. K10 and diamond tools substrate with TiN and Al2O3 coatings were used by Rogério Fernandes Brito (2009) In this work, ten cases with single layer coated cutting tools are analyzed, presenting varying thickness of 1 (μm) and 10 (μm) and two types of heat fluxes used on the tool-chip interface.

EFFECTS ON SURFACE ROUGHNESS

The challenge of modern machining industries is mainly focused on the achievement of high quality in terms of work piece dimension accuracy, surface integrity, and high production rate. Surface roughness plays an important role in the evaluation of machining accuracy and mach inability W.s.Lin (2008)

Since turning is the primary operation in most of the production processes in the industry, surface finish of turned components has greater influence on the quality of the product. Surface finish in turning has been found to be influenced in varying amounts by a number of factors such as feed rate, work material characteristics, work hardness, unstable built-up edge, cutting speed, depth of cut, cutting time, tool nose radius and tool cutting edge angles, stability of machine tool and work piece setup, chatter, and use of cutting fluids. Dr.S.S.Mahapatra (2006).

Temperature rise affects the tool wear and its life, and surface integrity of material. Ozek C.(2006)

EFFECTS ON MACHINING PARAMETERS

Most of the stainless steel machining proceeds at low cutting speeds because the austenitic stainless steel is a hard machining material. The research result of this paper indicated that high speed fine turning of austenitic stainless steel is possible.W.S.Lin (2006)

The chatter phenomenon occurs as feed rate being smaller than critical feed rate. In order to get the best surface roughness, unlimited minimizing the feed rate doesn't worked. Therefore, we can said that the ideal cutting condition of high speed fine turning of stainless steel of SUS303 is cutting speed V = 250 to 350 m/ min and the feed rate f = 0.04 to 0.06 mm/rev. cutting velocity (V_c), feed rate (f) and depth of cut (d) on the total variance of the results is performed. The experiments were conducted for each combination of factors (columns) as per selected orthogonal array. The number of observations under each combination of factors is one, i.e. the number of replications is one. Dr.S.S.Mahapatra (2006) parameters such as cutting speed, feed rate and depth of cut were changed to explore their effects on the temperature rise at the tool – chip interface, surface roughness and tool flank wear. Ozek C.(2006) The machining process on CNC lathe is programmed by speed, feed rate and cutting depth, which are frequently determined based on the job shop experiences. However the machine performance and the product characteristics are not guaranteed accepatable, therefore the optimum turning conditions have to be complished.tool nose run off will affect the performance of the machining process

EFFECT ON TOOL WEAR AND LIFE

Rogério Fernandes Brito (2009)'s work showed that

Coating treatment on cutting tools increases their hardness. Tool wear period is extended, lengthening tool life.

EFFECT ON TOOL / WORK PIECE

Works by Rogério Fernandes Brito (2009)'s has shown that the coating also offered some cushion during cutting hence lowering the friction between the cutters and the work pieces.

CONCLUSION

The aim of our present experimental investigation is to study the temperature analysis by using CFX software and to determine the optimal levels of process parameters for optimizing the surface quality of AISI 304 austenitic stainless steel work piece by employing Taguchi's orthogonal array design and Analysis of Variance (ANOVA) using latest technology of PVD coated turning insert tool on CNC lathe.

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