TO DETERMINE WEAR AND LIFE OF CERAMIC TOOL WHILE MILLING SUPER ALLOY METAL

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ABSTRACT

A cutting tool or cutter is any tool that is used to remove material from the workpiece by means of shear deformation. Cutting may be accomplished by single-point or multipoint tools. Single-point tools are used in turning, shaping, plaining and similar operations, and remove material by means of one cutting edge. Milling and drilling tools are often multipoint tools. Cutting tools must be made of a material harder than the material which is to be cut, and the tool must be able to withstand the heat generated in the metal-cutting process.

In this thesis different experiments are conducted to optimize the process parameters to improve the tool life and reduce the tool wear of an alumina based ceramic cutting tool while machining super alloy (Nickel alloy). A series of experiments are done by varying the milling parameters spindle speed, feed rate and depth of cut considering L9 orthogonal array by Taguchi Method. The optimization is done using Response Surface Methodology for less tool wear and more tool life..

Keywords: Super alloy ,ceramic tool , analysis, Catia.

INTRODUCTION

Milling is the machining process of using rotary cutters to remove material from a workpiece by advancing (or feeding) in a direction at an angle with the axis of the tool It covers a wide variety of different operations and machines, on scales from small individual parts to large, heavy-duty gang milling operations. It is one of the most commonly used processes in industry and machine shops today for machining parts to precise sizes and shapes.

Milling can be done with a wide range of machine tools. The original class of machine tools for milling was the milling machine (often called a mill). After the advent of computer numerical control (CNC), milling machines evolved into machining centers (milling machines with automatic tool changers, tool magazines or carousels, CNC control, coolant systems, and enclosures), generally classified as vertical machining centers (VMCs) and horizontal machining centers (HMCs).

The integration of milling into turning environments and of turning into milling environments, begun with live tooling for lathes and the occasional use of mills for turning operations, led to a new class of machine tools, multitasking machines (MTMs), which are purpose-built to provide for a default machining strategy of using any combination of milling and turning within the same work envelope.

CERAMIC AND CERMETS CUTTING TOOLS

Materials

Alumina ceramic is sintered from high pure alumina oxide which is cold pressed, hot pressed or hot isostatic pressed (H.I.P.). Silicon nitride ceramic consists of silicon nitride and special nitride. TiC ceramic contains mostly titanium carbide. Cermet is composed mainly of TiC + TiN cermet and titanium nitride. Tough

TiN cermet made from special alloy is also available. There are multicoated carbide inserts with alumina nitride and alumina.

Milling Cutters designed for Ceramic / Cermet Insert Features

Fig: Cermet Insert Features

Ceramic / cermet is a cutting tool material composed mainly of TiC (Titanium Carbide) and TiN (Titanium Nitride).The name, cermet, is derived from the words CERAMIC and METAL(representing carbide).

As the name suggests, cutting performance is also in the mid-range of ceramic's and carbide's. The advantages of this material grade are high-quality and excellent surface finishes can be achieved with elevated cutting speeds. Cermets provide extended tool life.

Tool Wear and Tool Life

One or more of the following wear modes may occur:
i) flank ii) notch iii) crater iv) edge rounding v) edge chipping vi) edge cracking vii) catastrophic failure

There is no single universally accepted definition of tool life. The life needs to be specified with regard to the process aims. A common way of quantifying the end of a tool life is to put a limit on the maximum acceptable flank wear, VB or VBmax. Typical figures are:

HSS tools, roughing	1.5 mm
HSS tools, finishing	0.75 mm
Carbide tools	0.7 mm
Ceramic tools	0.6 mm

Table – Acceptable flank wear values for different tools

EXPERIMENTAL SETUP AND PROCEDURE

Experiments have been performed by machining super alloy material in order to investigate the effects of one or more factors of the process parameters (spindle speed, feed rate and depth of cut) on the tool life and tool wear.
The main aim of the project is to determine the influence of Alumina Based Ceramic tool in metal working. The investigation is based on tool life and tool wear during milling of super alloy with ceramic tool. The cutting parameters considered are feed rate, spindle speed and depth of cut.

EXPERIMENTAL PROCEDURE

This experiment employed a CNC vertical milling machine. Ceramic cutting tool is used. The experiment has been done under conditions of feed rate 1000mm/min, 1500mm/min, 2000 mm/min, spindle speeds are 1500rpm, 2500rpm, 3000rpm, and depth of cut 0.3mm, 0.4 and 0.5mm.

MACHINE SPECIFICATIONS

Machine Model – Feeler
Control – Siemens 840d
Travel Size X – 1000mm, Y – 500mm, Z – 500mm

SELECTION OF PROCESS PARAMETERS AS PER TAGUCHI TECHNIQUE

PROCESS PARAMETERS	**LEVEL 1**	**LEVEL 2**	**LEVEL 3**
CUTTING SPEED(rpm)	1500	2500	3000
FEED RATE (mm/min)	1000	1500	2000
DEPTH OF CUT(mm)	0.3	0.4	0.5

Table – Process Parameters as per Taguchi Technique

JOB NO.	**SPINDLE SPEED (rpm)**	**FEED RATE (mm/min)**	**DEPTH OF CUT (mm)**
1	1500	1000	0.3
2	1500	1500	0.4
3	1500	2000	0.5
4	2500	1000	0.4

5	2500	1500	0.5
6	2500	2000	0.3
7	3000	1000	0.5
8	3000	1500	0.3
9	3000	2000	0.4

Table – L9 Orthogonal Array

OBSERVATION

While machining, tool wear is measured and tool life is measured for every experiment at given spindle speed, feed rate and depth of cut. Tool wear is measured for the removal of material from the edge of the tool. Tool Life is the time taken for the cutting tool to wear out in min's.

The following are the observations measured by running the experiments

THEORETICAL TOOL LIFE CALCULATIONS

The Taylor tool life equation can be written as: **$vT^n = C$, where**

v is the cutting speed, m/min

T is the tool life, in minutes

C is the cutting speed for a tool life of 1 minute = 3000m/min

n is the Taylor exponent = 0.7 (Ceramic Tool)

1. Cutting Speed – 1500rpm = 471.23m/min

$vT^n = C$

$471.23\ T^{0.7} = 3000$

$T^{0.7} = 4.774$

T = 14.05min

2. Cutting Speed – 2500rpm = 785.38m/min

$785.38\ T^{0.7} = 3000$

$T^{0.7} = 3.819$

T = 6.776min

3. Cutting Speed – 3000rpm = 942.46m/min

$942.46\ T^{0.7} = 3000$

$T^{0.7} = 3.183$

T = 5.224min

OPTIMIZATION OF MILLING PARAMETERS FOR INCREASED TOOL LIFE AND REDUCED TOOL WEAR

In order to identify the process parameters affecting the tool life and tool wear, the following process parameters are selected for the present work: Spindle speed (A), Cut Feed (B) and Depth of Cut (C). The selection of parameters of interest and their ranges is based on literature review and some preliminary experiments conducted.

Selection of Orthogonal Array

The process parameters and their values are given in table. It was also decided to study the three – factor interaction effects of process parameters on the selected characteristics while milling. These interactions were considered between spindle speed, cut feed and step over.

PROCESS PARAMETERS	LEVEL1	LEVEL2	LEVEL3
CUTTING SPEED(rpm)	1000	1500	2000
FEED RATE (mm/min)	2000	2500	3000
DEPTH OF CUT(mm)	0.3	0.4	0.5

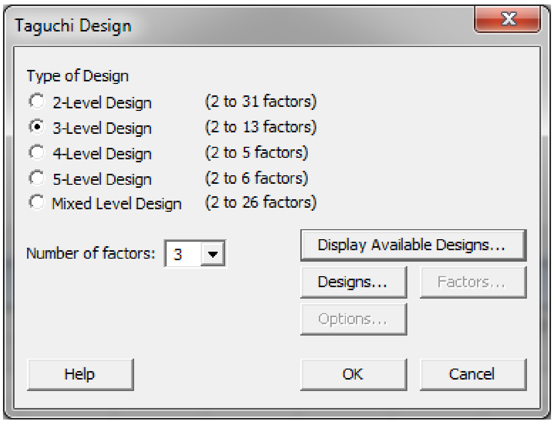

Fig – Type of Design and Number of Factors

SELECTION OF PROCESS PARAMETERS AS PER TAGUCHI TECHNIQUE

Table – Process Parameters as per Taguchi Technique

JOB NO.	SPINDLE SPEED (rpm)	FEED RATE (mm/min)	DEPTH OF CUT (mm)
1	1000	2000	0.3
2	1000	2500	0.4
3	1000	3000	0.5
4	1500	2000	0.4
5	1500	2500	0.5
6	1500	3000	0.3
7	2000	2000	0.5
8	2000	2500	0.3
9	2000	3000	0.4

Fig – Type of Design and Number of Factors

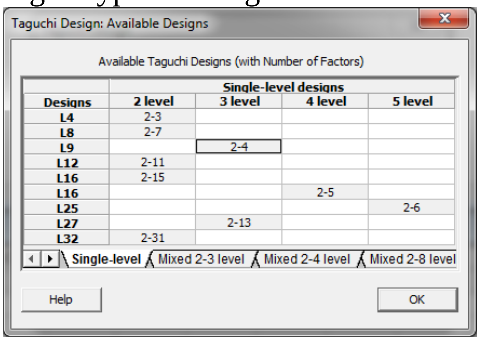

Fig – Select L9 Design

Linear in Factor A and Factor B:

$$E(\text{Response}) = \beta_0 + \beta_A \text{FactorA} + \beta_B \text{FactorB}$$

β_0 =the expected level of the response when Factor A and Factor B are set to zero

β_A =the expected change in the response when Factor A is increased one unit (i.e. from the center to the edge of the cube).

Note: Often, $2\beta_A$ is used in this interpretation because this is the expected change when moving from the low to high level of Factor A (i.e., the effect).

β_B = the expected change in the response when Factor B is increased one unit

Fig – Response Tool Life

Select Results

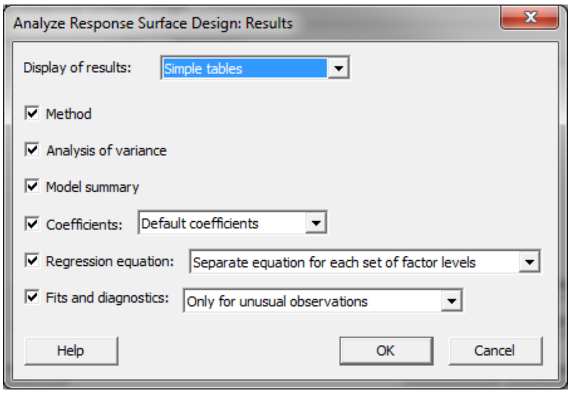

Fig – Results required

Regression Equation in Uncoded Units

TOOL LIFE (min) = 150.0 - 0.02400 SPINDLE SPEED (rpm) - 0.01267 FEED RATE (mm/min) + 15.0 DEPTH OF CUT (mm)

Response Surface Regression: TOOL LIFE (m versus SPINDLE SPEE, FEED RATE (m, DEPTH OF CUT

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Model	3	2270.17	756.72	42.12	0.001
Linear	3	2270.17	756.72	42.12	0.001
SPINDLE SPEED (rpm)	1	2016.00	2016.00	112.21	0.000
FEED RATE (mm/min)	1	240.67	240.67	13.40	0.015
DEPTH OF CUT (mm)	1	13.50	13.50	0.75	0.426
Error	5	89.83	17.97		
Total	8	2360.00			

The residual plots indicate that the deterministic portion (predictor variables) of the model Spindle Speed, Feed Rate and Depth of Cut are not capturing some explanatory information that is “leaking” into the residuals. The graph could represent several ways in which the model is not explaining all that is possible. Possibilities include:

A missing variable

A missing higher-order term of a variable in the model to explain the curvature

A missing interaction between terms already in the model

CONCLUSION:

different experiments are conducted to optimize the process parameters to improve the tool life and reduce the tool wear of an alumina based ceramic cutting tool while machining super alloy (Nickel alloy). A series of experiments are done by varying the milling parameters spindle speed, feed rate and depth of cut considering L9 orthogonal array by Taguchi Method. The optimization is done using Response Surface Methodology for less tool wear and more tool life.

The experiment has been done with process parameters feed rate 1000mm/min, 1500mm/min, 2000 mm/min, spindle speeds are 1500rpm, 2500rpm, 3000rpm, and depth of cut 0.3mm, 0.4 and 0.5mm. The milling process is conducted on a CNC Vertical milling machine.

By observing the experimental results and from Response Surface methodology, the following conclusions can be made:

The analysis for tool life is about 96.19% accurate and for tool wear is about 96.53% accurate. For tool life, the most important parameter is spindle speed and for tool wear the most important parameter is feed rate.

The residual plots indicate that the deterministic portion (predictor variables) of the model Spindle Speed, Feed Rate and Depth of Cut are not capturing some explanatory information that is “leaking” into the residuals.

From the surface plots of tool life and tool wear, for more tool life and reduced tool wear, the optimized parameters are Spindle Speed – 1500rpm, Feed Rate – 1000mm/min and Depth of Cut – 0.5mm.

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