Flank wear measurement of INCONEL 825

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Abstract: In modern metal cutting operations, it is of the at most importance to increase the material removal rate with a good surface finish and high machining accuracy. Machining process results in a high tool wear while performing number of operations and it will take substantial amount of time. Cutting tool cost is one of the most important components of machining costs. The life of the cutting tool plays a major role in increasing productivity and consequently is an important factor. Therefore, it is important to account tool wear for various cutting conditions. In this paper our focus is to measure the tool flank wear on Inconel 825 material on CNC machine and conventional Lathe machine.[1]

Keywords: Tool wear; machining; Inconel 825 uncoated carbide tool.

1. INTRODUCTION:

In recent times, nickel-based super alloys found extensive applications primarily in critical aerospace engine components like gas turbines. Owing to their admirable properties such as fatigue strength, thermal stability and resistance to corrosion under severe environment, in fact 50% by weight of aerospace engine is made up of nickel-based super alloys. In advance manufacturing process, machining is still considered as one of the final steps of manufacturing process. The desired size, shape, surface finish and other functional features of components are accomplished by gradual removal of material from the workpiece in the form of chips by shear deformation with the aid of a cutting tool. The machining system consists of cutting tool, workpiece and machine tool. Selection of cutting parameters such as cutting speed (VC), feed (ƒ) and depth of cut (ap) largely depends on the material properties of cutting tool and workpiece. Worldwide recent research work is focused on development of advanced strategies for machining of nickel-based super alloys, so that superior surface quality can be achieved while maintaining reasonably high productivity and at the same time environmental load can be curtailed. In order to accomplish these objectives, through understanding of the mechanical properties of different grades of nickel-based super alloys along with their chemical composition is essential[1-7]

1.1 Tool wear

One of the most important and widely used machinability characteristics is tool life for any cutting tool. Much research attention has been directed towards enhancing tool life which can be improved by proper selection of machining parameters, tool material, use of coolant, tool coating etc. It is very important to understand the various mechanisms of tool wear for the improvement of tool life. Tool wear refers to the degradation of cutting or clearance surface, reduction in some of the mechanical properties of the tool and its fracture. Various modes by which tool failure takes place during machining have been shown in Fig. 1.1.

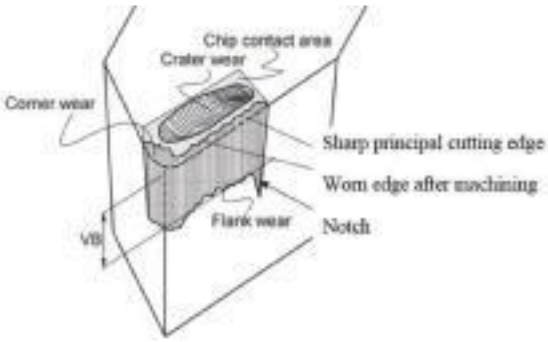


Fig 1.1 Modes of tool failure[2]

1.2 Nickel-based super alloys

The major advantages of nickel -based super alloys include their resistance to thermal deformation and corrosion. Iron, chromium and cobalt are typically used as major alloying elements. In addition to these, other elements such as molybdenum, niobium, copper, titanium, aluminium and tungsten along with small quantity of carbon, magnesium, zirconium etc. are present in different grades of nickel-based super alloys.[16]

1.3 Development in cutting tool materials

Selection of cutting tool is an important factor when machining nickel-based super alloys. Tool material should possess sufficient wear resistance, thermal stability, good combination of hardness and toughness, chemical stability and thermal shock resistance.[1-7]

1.4 Machinability

Machinability which roughly and qualitatively specifies the degree of ease by which a work material can be machined, was quantitatively defined in earlier times in terms of machinability index or rating as follows:

Machinability Index is the ratio of the Cutting speed of machining work material providing 60 minutes of tool life to the Cutting speed of machining standard work material providing 60 minutes of tool life.

2. LITERATURE REVIEW

Nickel based super alloys are widely employed in aerospace industry, in particular for the hot sections of gas turbine engines due to their high temperature strength and high corrosion resistance. Their ability to maintain their mechanical properties at high temperatures severely hinders the machinability of these alloys. They are generally referenced as difficult-to-cut materials. We focus our attention in this study on the Inconel 825 alloy.[1-7]

3. METHODOLOGY

3.1 Equipments

3.1.1 CNC Machine

The CNC machine comprises of the computer in which the program is fed for cutting of the metal of the job as per the requirements. All the cutting processes that are to be carried out and all the final dimensions are fed into the computer via the program. The computer thus knows what exactly is to be done and carries out all the cutting processes. CNC machine works like the Robot, which has to be fed with the program and it follows all your instructions.

Fig. 3.1 CNC Machine

3.1.2 Conventional Lathe Machine

Fig 3.2 Conventional Lathe Machine

The lathe was very important to the Industrial Revolution. It is known as the mother of machine tools, as it was the first machine tools that lead to the invention of other machine tools. The lathe is a machine tool which holds the workpiece between two rigid and strong supports called canters or in a chuck or face plate which revolves. The cutting tool is rigidly held and supported in a tool post which is fed against the revolving work. The normal cutting operations are performed with the cutting tool fed either parallel or at right angles to the axis of the work. The cutting tool may also be fed at an angle relative to the axis of work for machining tapers and angles.

3.1.3 Optical Microscope

Fig.3.3 Optical Microscope

The optical microscope, often referred to as light microscope, is a type of microscope which uses visible light and a system of lenses to magnify images of small samples. The image from an optical microscope can be captured by normal light-sensitive cameras to generate a micrograph. Originally images were captured by photographic film but modern developments in CMOS and charges coupled device (CCD) cameras allow the capture of digital images. Purely digital microscopes are now available which use a CCD camera to examine a sample, showing the resulting image directly on a computer screen without the need for eyepieces. The objective lens is, at its simplest, a very high-powered magnifying glass, i.e. a lens with a very short focal length.

3.2 EXPERIMENTAL METHODS AND CONDITIONS

In this section, experimental methodology, the details of equipment facilities, machine tools used, cutting tool, workpiece material, machining parameters and experimental set-up have been described.

3.2.1 Workpiece material

Inconel 825 is a precipitation-hardenable nickel-chromium-iron alloy, and its chemical composition is given in Table 3.1. The Image3.5 shows photograph of experimental setup of Inconel 825.

Table 3.1: Chemical composition of Inconel 825

Element	Ni	Fe	Cr	Mo	Cu	Ti
Content %	46	26	20	3	2	3

3.3 Tool Material

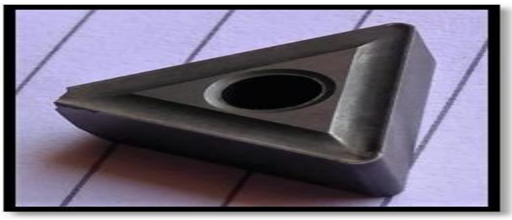


Fig.3.4: Tool insert used during experimentation

3.4 Experimental Details

3.4.1 First Stage of Experiment

A round bar of 32 mm diameter and 110 mm length was cut for machining. Dry turning operation was performed on CNC lathe machine. (Make:- Gurudatta CNC machines) as depicted in fig.3.1

Experimental conditions are provided in table 3.2.The trial runs where carried out under varying cutting conditions at first stage of experiment.

Table 3.2:- Experimental conditions during first stage of research

Cutting tool	Uncoated ISO K20 Grade Cemented Carbide tool
Tool Designation	ISO Designation of TNMG 160408
Tool Holder Designation	ISO Designation MTJNR 2020 K16 WIDAX
Spindle Speed, (RPM)	300,400,500,600,700,800,900
Feed, mm/rev	0.06, 0.08 & 0.1
Depth of cut (ap), mm	0.5
Environment	Dry

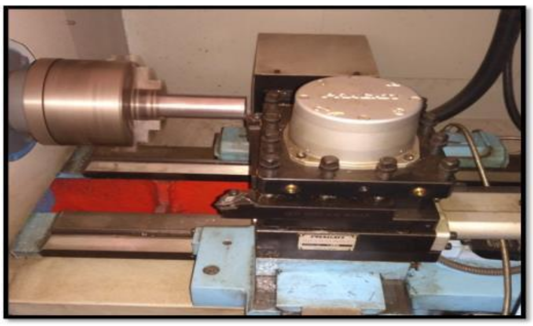


Fig.3.5: Photograph of experimental setup for turning of Inconel 825.

3.4.2 Second Stage of Experiment

A round bar of 32 mm diameter and 110 mm length was cut for machining. Dry turning operation was performed on Conventional lathe machine.

Experimental conditions are provided in table 3.3. The trial runs where carried out under varying cutting conditions at second stage of experiment.

Table 3.3: Experimental conditions during second stage of research

Cutting tool	Uncoated ISO K20 Grade Cemented Carbide tool
Tool Designation	ISO Designation of TNMG 160408
Tool Holder Designation	ISO Designation MTJNR 2020 K16 WIDAX
Spindle Speed, (RPM)	400
Feed	Manual
Depth of cut (ap), mm	0.5
Environment	Dry

4 RESULTS AND DISCUSSION

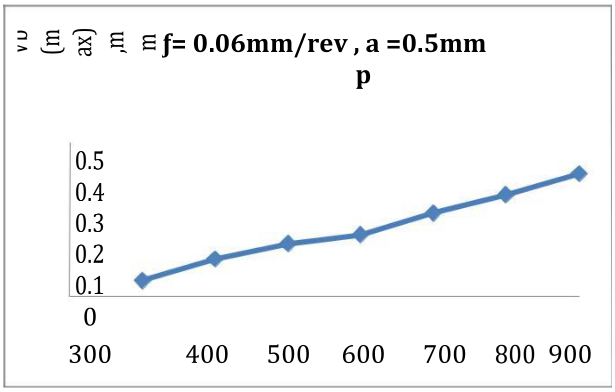
4.1 Flank Wear while machining on CNC machine

Tool wear during dry turning of Inconel 825 with uncoated carbide insert was characterised by flank wear. Tool wear mechanism during dry turning of Inconel 825 is investigated using optical microscope. It is evident that increase in the cutting speed the average value of flank wear also increased. Initially up to 500 RPM there was no significant difference in wear pattern of uncoated tool. The uncoated tool has maximum wear after 500 RPM of spindle speed and tool failure occurs at 600 RPM of spindle when feed rate is 0.1 mm/rev.

The cutting parameter and flank wear is listed in table 4.1 for uncoated tool. It is observed from the table with increase in the feed rate tool wear is also increases. When feed is 0.06 mm/rev the maximum tool wear of uncoated tool is 0.4 mm at 900 RPM, while feed is 0.08 mm/rev the maximum wear at same spindle speed is 0.46 mm. When the feed rate is 0.1 mm/rev the uncoated tool fails at 600 RPM.

Table.4.1 Flank wear when ƒ=0.06 mm/rev & ap= 0.5 mm

Spindle Speed, (N))	**Vb(max), mm**
300	0.05
400	0.12
500	0.17
600	0.20
700	0.27
800	0.33
900	0.4



Spindle Speed,RPM

Fig 4.2: Variation of flank wear with different spindle speed for uncoated carbide insert at constant feed=0.06mm/rev and depth of cut=0.5 mm.

Table 4.2: Flank wear when f=0.08 mm/rev & ap= 0.5 mm

Spindle Speed,(N)	$V_{b(max)}$, mm
300	0.06
400	0.09
500	0.13
600	0.19
700	0.25
800	0.33
900	0.46

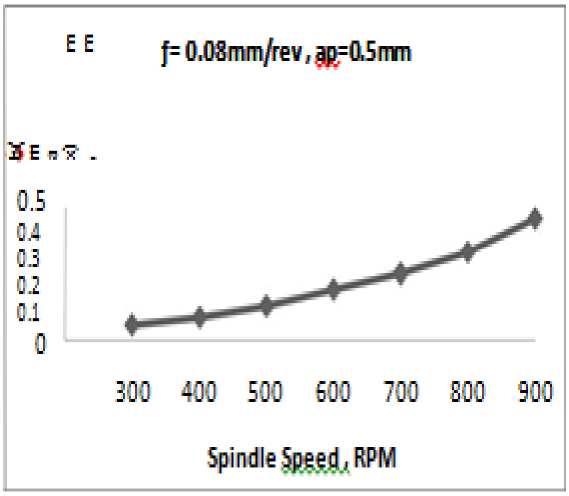


Fig 4.2: Variation of flank wear with different spindle speed for uncoated carbide insert at constant feed=0.08mm/rev and depth of cut=0.5 mm.

Table 4.3: Flank wear when f=0.1 mm/rev & ap= 0.5 mm

Fig. 4.1 Optical images of flank face at various feed and spindle speed	Fig. 4.1 Optical images of flank face at various feed and spindle speed
300	0.1
400	0.18
500	0.35
600	0.49
700	Tool Fail
800	
900	

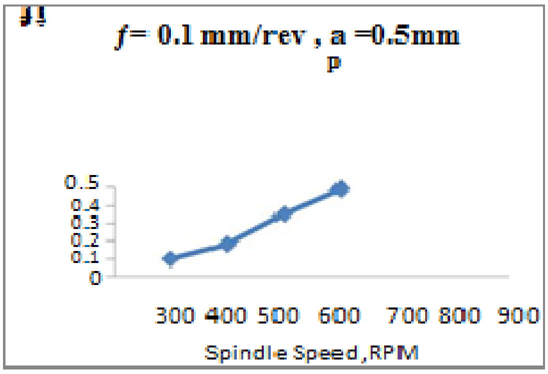


Fig 4.3: Variation of flank wear with different spindle speed for uncoated carbide insert at constant feed=0.1mm/rev and depth of cut=0.5 mm.

4.2 Flank Wear While Machining on Conventional Lathe

Tool wear of uncoated tool is observed while machining of Inconel alloy 825. The machining process was carried out at constant spindle speed of 350 RPM and feed is given manually. The cutting length and depth of cut of 100 mm and 0.25 mm was kept constant.

The Uncoated tool fails after 3 passes. The tool wear is observed by visual inspection. Surface Finish of workpiece is reducing with the worn out tool. Fig: 4.4(A) shows the surface finishing of workpiece when machined with worn out tool. Fig: 4.4 (B) shows surface finishing of workpiece machined with tool which does not loosen its machinability.

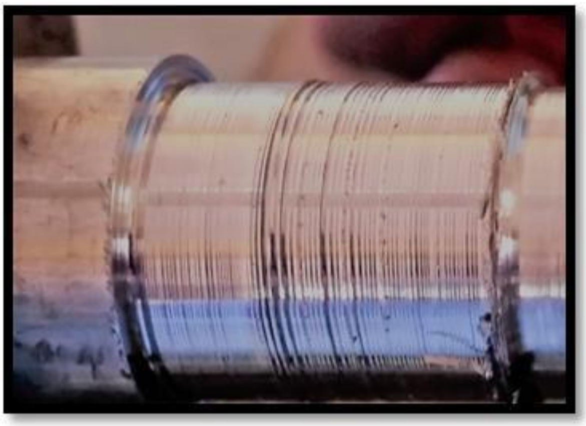


Fig.4.4(A): Variation in surface finishing of workpiece when it is machined with worn out tool

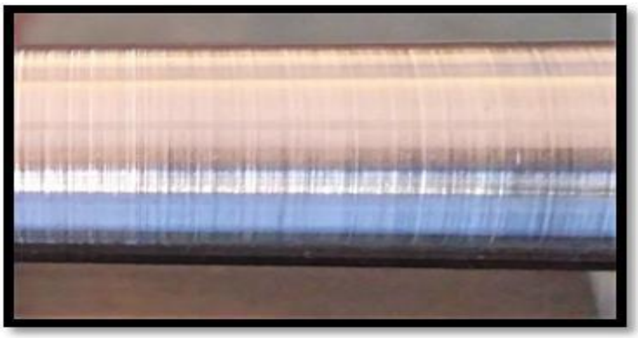


Fig.4.4 (B): Variation in surface finishing of workpiece when it is machined without worm out tool

When workpiece is machined with the worn out tool poor surface finishing is observed on the workpiece. Whereas Smooth surface finish is observed when machining without worn out tool.

Conclusion:

In this study the work compared the machinability characteristics of Incoloy 825 while adopting uncoated tool inserts. The major conclusions from the study can be summarised as follows

1.Surface roughness increased with cutting speed for uncoated tool inserts.

2. It is observed from the study with increase in the feed rate tool wear is also increases. When feed is 0.06 mm/rev the maximum tool wear of uncoated tool is 0.4 mm at 900 RPM, while feed is 0.08 mm/rev the maximum wear at same spindle speed is 0.46 mm.

3. Uncoated tool failed after 90s of machining at high speed of 600 RPM with medium (0.1 mm/rev). whereas at low feed (0.08 mm/rev) it failed after 330s of machining.

4. The same uncoated cemented carbide insert resulted in favourable machinability characteristics at lower speed with minimum feed of 0.06 mm/rev.

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