Important Factors Affecting the Tool and Work Piece for the Requirement of Improved Surface Finish for Turning Operation in CNC Machine

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Abstract— These days, machine operations are carried out using computerized automated machines to overcome the limitations of conventional machines. Challenge of modern machining industries is primarily focused on the achievements of high quality, in terms of work piece dimensional accuracy, surface finishing, high production rate, less wear and tear on the cutting tools, economy of machining in terms of cost saving and increase the performance of the product with reduced environmental effects. Surface roughness is the most important factor in production and having great importance in the evaluation of machining accuracy. There is a huge utilisation of CNC machines in the modern machining industry. The selections of best combination of tool insert and work piece material is most critical assignment to obtain the better desired surface finish. Among the number of available tool insert and work piece combination, one can be selected based on the MADM (multiple attribute decision making) methods. The work presented in this paper covers the best selection of tool-work piece combination for turning operation to be performed on EN-8, SS 304 and EN-19 to get better surface finish for given constant cutting parameters.

Key words: Computer Numeric Control, Multiple Attribute Decision Making (MADM), EN-8, EN-19, SS-304, Tool insert, Machining, Surface Finish

I. Introduction

Challenge of modern manufacturing industries worldwide is mainly aimed on the achievement of better quality. In terms of manufacture product i.e. dimensional accuracy, surface rough or finish, high production rate, less wear on the cutting tools like turning tools, milling tools etc. Future of machining in terms of cost reduction and improvement in performance of the job with reduced bad environmental effects. Surface finishing is an important factor in many areas i.e. different parts of two wheelers and four wheelers like gears, valves, crankshafts, connecting rods etc.

In this work different types of inserts and job materials like EN-8,EN-19 are used and after experiment better results of tool and job material combination for better surface finish are obtained. Selection of the best tool-work piece combination from different alternative tool-work piece for turning operation with relationship between surface roughness value, tool geometry and material property such as nose radius, clearance angle, approach angle, hardness and tensile strength.

J.Wang (1998) investigated the effect of multilayer hard surface coating of cutting tool on the cutting forces on CS1020 mild steel turning by using coated SCMT, CNMM, and uncoated SCMT, CNMM. the hard coating on inserts by Tic, Tin, and Al2O3 used to improve the tool life and component to be machined at higher economic speed at three level of feed(0.13,0.17,0.21mm/rev), depth of cut(0.5,1.0,2.0 mm) were tested under two level of cutting speed(108,206 m/min) and to know their effect on radial, feed and tangential force. The result show that, the three force component for coated tools are lower than the uncoated tools and also three force components for SCMT type inserts are smaller than CNMM inserts. In both type of inserts, three force components increases with feed, depth of cut and cutting speed increases [2].

Ei-Baradie and Chaudhury (1998) have developed response models (tool life, surface roughness and cutting force) for turning on inconel 718 by using lathe machine with cemented tungsten carbide coated insert and uncoated insert tool used for utilizing factorial design of experiment and response surface methodology. They have used different cutting parameter speed, feed and depth of cut for the effect on tool life, surface roughness and cutting force in turning test. They have concluded that, the effect of feed on tool life is much more than effect of speed and the surface roughness, it also affected by changing the feed. The effect of depth of cut on tool life is greater in uncoated carbide than coated carbide and by increase depth of cut, improve the surface finish in coated tool while it opposite in case of uncoated tools. The cutting force decreases when speed is increased, while it increases when feed and depth of cut increased [3].

Theile and molkote (2000) studied about the effects of cutting edge preparation and work piece hardness on the surface finish and cutting forces in the finish hard turning of AISI 52100 steel. ANOVA results shows the effects of edge geometry and feed rate interactions between hardness and edge geometry are significant for both of the surface roughness parameters. Increasing edge hone radius tends to increase the average surface roughness because of increase in the ploughing component compared to the shearing component of deformation. The effect of edge hone on the surface roughness decreased with increase in work piece hardness. Finally, the study showed that the cutting edge geometry has a significant effect on the axial and radial cutting force components and the effect of work piece hardness on the force components [4].

H. A. Che-haron (2001) studied about tool life and surface integrity in turning titanium alloy by using two carbide inserts. They concluded that the flank wear rate was rapid at higher cutting speed and feed rates and the flank wear increases in cutting speed. At lower feed rate both inserts gives better tool life under all cutting speed.The surface roughness is also increases with cutting speed [5].

M. A. Mannan et al. (2004) studied about the effect of inserts shape (round and square), cutting edges, inserts rake types and nose radius on surface roughness and residual stresses which is component of surface integrity when machining age hardened Inconel 718 using two grades of coated carbide cutting tool inserts on CNC lathe machine. The cutting speed, feed and depth of cut were maintained constant. They concluded that, The round inserts generate lower surface finish than square inserts and round insert produce compressive stress while square produce tensile stress. The cutting edge preparation (sharp, honed, chamfered) increasing order of surface roughness: honed-chamfered-sharp and decreasing order of compressive residual stress: chamfered-honed-sharp. The positive rake produces lower values when coolant is used and high value in dry cutting. The surface roughness increasing with nose radius increases and use of coolant generate lower values of surface roughness [6].

Gokkeya and nalbant (2005), studied about the effects of cutting tool geometry(insert radius: 1.2mm, 0.8mm, 0.4mm) and processing parameters(such as depth of cut 0.5, 1, 1.5, 2, 2.5mm;feed rate 0.15,0.20,0.25,0.30,0.35 mm/rev) on the surface roughness of AISI 1030 steel on CNC lathe machine. They concluded that, increasing the insert radius decreases the surface roughness. When the speed rate increases, the surface roughness also increases. A good combination among the insert radius, speed rate and depth of cut can provide better surface qualities [7].

More et al. (2006) have made study on the effect of cutting speed and feed rate on surface roughness, tool wear and cutting force and cost analysis done by using CBN-TiN coated carbide inserts and PCBN compact inserts in turning AISI 4340 hardened steel on CNC lathe. The result shows the surface finish is not change at lower feed rates and it correlated with tool wear and PCBN inserts give constant surface roughness while CBN-TIN inserts is opposite. The cutting force for CBN-TIN coated inserts and from cost analysis CBN-TIN coated inserts is better for reduce machining cost [8].

Nalbant et al. (2007) have studied the machining on work material AISI 1030 steel by using TiALN coated two PVD inserts, Tin coated CVD inserts and uncoated inserts with different cutting speed, feed rate, with constant depth of cut taken in CNC turning machine and check the effect of coating method, coating material, cutting speed and feed rate on surface roughness on work piece material. They have used artificial neural networks to predict the actual surface roughness value of experiment result. They have concluded that coating material type, number of coating layer and coating method affect the friction of coefficient and thermal conductivity. Decreasing the friction of coefficient and thermal conductivity of the cutting tool decrease the average surface roughness of the material. In coated tool inserts, if the cutting speed increases, the average surface roughness reduces while in uncoated tool inserts, if the cutting speed increases, the average surface roughness increases [9].

II. Experimental Set Up and Experimentation

Among the number of available tool insert and work piece combination, one can be selected based on the MADM (multiple attribute decision making) methods. The final selection of tool insert and work piece material combination can provide the required surface finish for turning operation using CNC turning centre. All the experiment process was done using Computer Numerical Control (CNC) turning Centre.

Sr.no.	Description	Specifications
1	Turning dia	7.086"/180 mm
2	Turning length	10.236"/260 mm
3	Bar capacity	1.25"
4	Spindle speed	40-4500 RPM
5	Quill travel	3.937"/100 mm

Table 1:

EN-8 carbon steel is a common medium carbon and medium tensile steel, with improved strength over mild steel, through-hardening medium carbon steel. EN8 carbon steel is also readily machinable in any condition.EN8 steels are generally used in the as supplied untreated condition. But EN8 steels can be further surface-hardened by induction processes, producing components with enhanced wear resistance. Steel EN8 materials in its heat treated forms possesses good homogenous metallurgical structures, giving consistent machining properties.

A. CNC machine

Now a days, computer numerical controlled machines are being used in every kind of manufacturing processes. In a CNC machine, functions like program storage, tool offset and tool compensation, program editing capability, various degree of computation, and the ability to send and receive data from a variety of sources including remote location can be easily realized through on board computer. The part may be designed and the tool parts programmed by the CAD/CAM process or manually by the programmer, and the resulting file uploaded to the machine, and once set and trailed, the machine will continue to turn out parts under the occasional supervision of an operator.

Fig. 1: CNC turning Centre

The machine is controlled electronically via a computer menu style interface, the program may be modified and displayed at the machine, along with a simulated view of the process. The setter/operator needs a high level of skill to perform the process, however the knowledge base is broader compared to the older production machines where intimate knowledge of each machine was considered essential. These machines are often set and operated by the same person, where the operator will super wise a small number of machines.

B. Cutting parameters in turning operation

The three primary factors in any basic turning operation are speed, feed and depth of cut. Other factors such as kind of material and type of tool have a large influence but these three are the ones the operator can change by adjusting the controls, right at the machine.

C. Speed

Speed always refers to the spindle and work piece. When it is stated in revolutions per minute (rpm) it tells their rotating speed. But the important feature for a particular turning operation is the surface speed, or the speed at which the work piece material is moving past the cutting tool. It is simply the product of the rotating speed times the circumference of the work piece before the cut is started. It is expressed in meter per minute (m/min) and it refers only to the work piece. Every different diameter on a work piece will have a different cutting speed, even though the rotating speed remains same.

$$V = \frac{\pi DN}{100} \quad (m/min)$$

Here, v is the cutting speed in turning; D is the initial diameter of the work piece in mm, and N is the spindle speed in RPM.

D. Feed

Feed always refers to the cutting tool and it is the rate at the tool advances along its cutting path. On the most power-fed lathes, the feed rate is directly related to the spindle speed and is expressed in mm per revolution (of the spindle) or mm/rev.

$$F = f \times N \text{ (mm/min)}$$

Here, F is the feed in mm per minute, f is the feed in mm/rev and N is the spindle speed in RPM.

E. Depth of cut

Depth of cut is practically self-explanatory. It is the thickness of the layer being removed from the work piece or the distance from the uncut surface of the work to the cut surface, expressed in mm. It is important to note that the diameter of the work piece is reduced by two times the depth of cut because this layer is being removed from both sides of the work.

$$\text{Depth of cut} = \frac{(D-d)}{2} \quad (mm)$$

Here, D and d represents initial and final diameter (in mm) of the job respectively

F. Mechanism of cutting

In general, machining is 3D process for providing an understanding of mechanics of machining, we simplify the process in to 2D process called orthogonal cutting, as shown in figure. In the orthogonal cutting, the work piece is a flat piece and is machined using a wedge shaped tool.

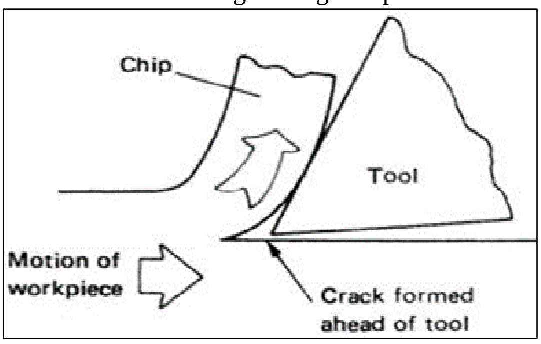

Fig. 2: Crack propagation

The following assumptions were made:

The tool tip is sharp and no rubbing occurs between the tool and work piece.

1) Plain strain condition such as there is no side spread and therefore the deformation is two dimensional.
2) The stresses on the shear plane are uniformly distributed.

The resultant force on the chip applied at the shear plane is equal, opposite and collinear to the force applied which is the force applied to the chip at the tool interface.

G. Types of cutting tool materials

Many types of tool materials, ranging from high carbon steel to ceramics and diamonds, are used as cutting tools in today's metalworking industry. It is important to be aware that differences do exist among tool materials, what these differences are, and the correct application for each type of material. The ideal cutting tool material should have all of the following characteristics:

- Harder than the work piece it is cutting
- High temperature stability.
- Resists wear and thermal shock.
- Impact resistant.
- Chemically inert to the work material and cutting fluid

To effectively select tools for machining, a machinist or engineer must have specific information about:

The starting and finished part shape.

- The work piece hardness.
- The material's tensile strength
- The material's abrasiveness.
- The type of chip generated.
- The work holding setup.
- The power and speed capacity of the machine tool

There are many cutting tool materials but in this work carbide and cermet is used for turning operation. Carbide is used in solid round tools or in the form of replaceable inserts. Every manufacturer of carbide tools offers a variety for specific applications. The proper choice can double tool life or double the cutting speed of the same tool. Shock-resistant types are used for interrupted cutting. Harder, chemically-stable types are required for high speed finishing of steel. More heat-resistant tools are needed for machining the super alloys, like Inconel and Hastelloy.

A cermet is a cemented carbide with titanium based hard particles. The name cermet combines the words ceramic and metal. Originally, cermets were composites of TiC and nickel. Modern cermets are nickel-free and have a designed structure of titanium carbonitride Ti(C,N) core particles, a second hard phase of (Ti,Nb,W)(C,N) and a W-rich cobalt binder. Ti(C,N) adds wear resistance to the grade, the second hard phase increases the plastic deformation resistance, and the amount of cobalt controls the toughness. In comparison to cemented carbide, cermet has improved wear resistance and reduced smearing tendencies. On the other hand, it also has lower compressive strength and inferior thermal shock resistance. Cermet can also be PVD coated for improved wear resistance.

There are no effective standards for choosing carbide grade specifications so it is necessary to rely on the carbide suppliers to recommend grades for given applications. Manufacturers do use an ANSI code to identify their proprietary carbide product line.

H. Cutting tool inserts

Cutting tool inserts are replaceable attachments for cutting tools that typically contain the actual cutting edge Cutting tool inserts applications include turning, boring, construction, cut-off and parting, drilling, grooving, hobbing, milling, mining, sawing, shearing and cutting, tapping, threading, and brake rotor turning. Cutting tool inserts have many different geometries.

I. Type of inserts used in turning operation

Inserts are available in several thickness and a variety of sizes and shape. The basic shapes are round, square, triangle, and diamond. Many other shapes, including the parallelogram, hexagon, and pentagon are also used to obtain specific machining requirements. The most common insert shapes are shown in fig.

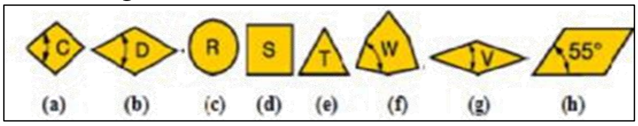

Fig. 3: Inserts with different shape (a) C shape insert (b) D shape insert (c) Round insert (d) square insert (e) Triangular insert (f) Trigon insert (g) V shape insert (h) K shape insert

J. Basic insert selection factors

To quickly and easily establish the indexable insert needed for the machining in question some factors are necessary to consider at the outset: component material, types of operation needed and conditions. These will determine the in insert type, shape, size, geometry, grade, nose radius. Selecting the insert should involve initial consideration of the most suitable entering angle and operational accessibility as well as tool holder size.

1) Component material:

Determine the component material, Condition, hardness and strength as well as machining factors. The basic CMC group is: P-steel, M-stainless steel, K-cast iron, N-nonferrous metals, S-heat resistant and super-alloys, H-hardened steel. These group then have sub groups representing the material variations most commonly encountered. The material mainly affects the choice of inserts geometry and the insert grade.

2) Operations:

Determine the operations needed for the application. Rough, medium duty and finish machining make up the basic types. But there are variation of rough machining depending upon demands of metal removal amount and the surface condition necessary for the subsequent operations; also semi finish machining as well as various level finishing depend upon regarding tolerances and surface finish.

3) Machining conditions:

These effect the choice of tool and the application. Basically there are three: good, average and difficult conditions but there are additional factors that should also be established continuous or intermittent cuts, work piece surface and condition, machine tool etc. The machining conditions may influence the insert shape, size, nose radius, geometry and grade.

III. RESULT AND DISCUSSION

A. Tool and Work piece Combination for Experiments

We have taken three different work pieces and three tool inserts for our experiment. In this experiment we will vary both the work piece and the tool. According to aim of our experiment to attain the maximum surface finish and minimum surface roughness we need to take total 9 combinations of work piece and tool inserts as shown below:

Experiment-1: Turning of work piece EN-8 using tool VBMT 16 04 08 MF

Experiment-2: Turning of work piece SS 304 using tool VBMT 16 04 08 MF

Experiment-3: Turning of work piece EN-19 using tool VBMT 16 04 08 MF

Experiment-4: Turning of work piece EN-8 using tool DNMG 15 06 08 MF

Experiment-5: Turning of work piece SS 304 using tool DNMG 15 06 08 MF

Experiment-6: Turning of work piece EN-19 using tool DNMG 15 06 08 MF

Experiment-7: Turning of work piece EN-8 using tool WNMG 08 04 08 MF

Experiment-8: Turning of work piece SS 304 using tool WNMG 08 04 08 MF

Combination of Tool insert-workpiece material	Nose Radius (mm)	Approach angle (Degree)	Clearance angle (Degree)	Tensile strength (MPa)
1	0.8	93	5	850
2	0.8	93	5	515
3	0.8	93	5	850
4	0.8	93	0	850
5	0.8	93	0	515
6	0.8	93	0	850
7	0.8	95	0	850
8	0.8	95	0	515

Table 2: Combination of Tool insert-work piece material selection data

B. Factors affecting the surface finish

Whenever two machined surfaces come in contact with one another the quality of the mating parts plays an important role in the performance and wear of the mating parts. The height, shape, arrangement, and direction of these surface irregularities on the work piece depend upon a number of factors such as:

1) The machining variables which include

– Cutting speed,
– Feed,
– Depth of cut

2) The tool geometry

– Nose radius,
– Rake angle,
– Side cutting edge angle,
– cutting edge

3) Work piece and tool material combination and their mechanical properties
4) Quality and type of the machine tool used,
5) Auxiliary tooling, and lubricant and
6) Vibrations between the work piece machine tool and cutting tool.
7) Use of cutting fluid..

C. Experiment results of surface roughness

Sr No.	Combination of tool inserts and work piece material	Exp-1 Ra (μm)	Exp-2 Ra (μm)	Exp-3 Ra (μm)	Avg. Ra (μm)
1	VBMT 16 04 08 MF and EN-8	O.55	0.58	0.60	0.5766
2	VBMT 16 04 08 MF and SS-304	0.65	0.62	0.69	0.6533
3	VBMT 16 04 08 MF and EN-19	0.59	0.57	0.58	0.58
4	DNMG 15 06 08 MF and EN-8	0.71	0.75	0.74	0.7333
5	DNMG 15 06 08 MF and SS-304	1.23	1.28	1.30	1.27
6	DNMG 15 06 08 MF and EN-19	1.06	1.02	1.04	1.04
7	WNMG 08 04 08 MF and EN-8	0.68	0.75	0.72	0.7166
8	WNMG 08 04 08 MF and SS-304	1.08	0.99	1.10	1.0566
9	WNMG 08 04 08 MF and EN-19	0.73	0.75	0.76	0.7466

IV. CONCLUSION

1) From experiments it is concluded that the performance ranking for combination of tool inserts and work piece material is 1-3-2-7-4-9-6-8-5 is selected as better choice to obtain higher surface finish. So combination of tool insert and work piece material- rank 1 should give better surface finish than the others combination.
2) From the experiment result minimum surface finish achieved with the use of tool insert VBMT 16 04 08 MF and work piece EN-8.
3) From MADM methods and experiment result, it is concluded that VBMT 16 04 08 MF and work piece EN-8 is the best choice to obtain higher surface finish and MADM method can be used for the decision making in the presence of multiple criteria.

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