Effect of Rake Angle on Chip Control in CNC Lathe Machining of Low Carbon Steel

M. Uthaykumar, R. Prasanna, D. Simson, R.M. Sakthi Sadhasivam, M. Lenin and P. Sumalatha Devi

Abstract--- *This paper aims to ingenuity of the machining of low carbon steel in order to control chip length and reduce cycle time of the component, to improve surface finish by increasing Rake angle. This approach is used to reduce hazard to the operator. Surface roughness is measured by digital dial gauge. Heat generated during the turning operation is measured by using thermocouple. It gives clear perception about the rake angle. Parameter levels are adjusted according to insert grade to handbook and discussed about the efficient coolant flow condition.*

This paper reviews various machining parameters which affect turning operation of low carbon steel. Such as insert geometry, coolant flow, heat dissipation, depth of cut, spindle speed, feed rate.

Keywords--- *Chip Control, Machining, Low Carbon Steel, Rake Angle, Feed Rate.*

I. INTRODUCTION

MACHINING plays a vital role in manufacturing industry. It is a method to remove excessive material from workpiece in order to achieve required size and shape. Excessive material is removed as chip. Removal of chip also influences the surface roughness of workpiece. Material can also be classified as ductile and brittle material. While machining brittle material the absorption of crack capacity is less so the propagation of crack is easy and form discontinuous chip. In case of ductile material the crack absorption capacity is higher than the brittle material so the crack cannot propagate through chip so it form continuous chip[1-3]. Positive higher rake angle improve machinability by reducing the friction between sliding chip and tool[2] Since effective chip control is necessary for automatic production system because any failure in chip control can cause lowering the productivity and worsening the operation due to frequent stop due to removal of chip from chuck and tool and to reduce the hazards to the operator[1]. It also reduce the surface roughness[4]. Continuous chip which affect productivity of ductile material component [2]. Low carbon steel (scr420hb) are taken machined by using cermet insert with the help of CNC lathe. There are three major factors that affect chip control change cutting condition (feed, depth of cut, spindle speed), changing tool geometry (rake angle).

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II. MATERIAL COMPOSITION

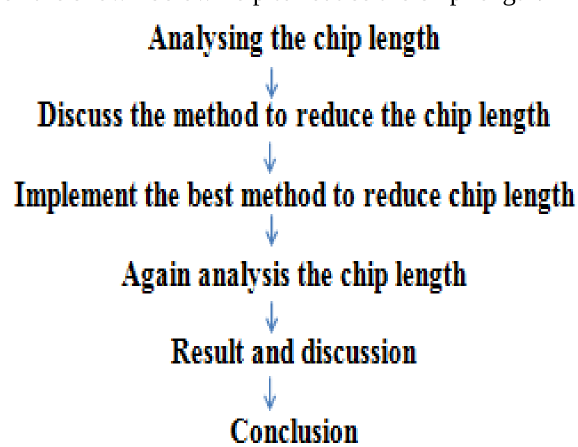
Material name-SCR420HB (low carbon steel)

Material Composition

Element	*Composition Percentage*
Carbon	0.17-0.23 %
Silicon	0.15-0.35%
Magnesium	0.55-0.9%
Phosphorous	0.20maxi
Sulphur	0.020%
Chromium	0.85-1.25%
Nickel	0.20maxi
Copper	0.30maxi
Boron	10-30ppm
Niobium	0.015-0.35%

Methodology

In order to attain maximum production CNC lathe machine is used. 30nosof Low carbon steel pinion samples are selected for each operation shown in fig 2.3 & 2, 4 for absorbing chip length during machining. And collected the chip of each operation individually in that selecting the maximum chip length to control. The observed data is shown below. Steps which are shown below help to reduce the chip length.



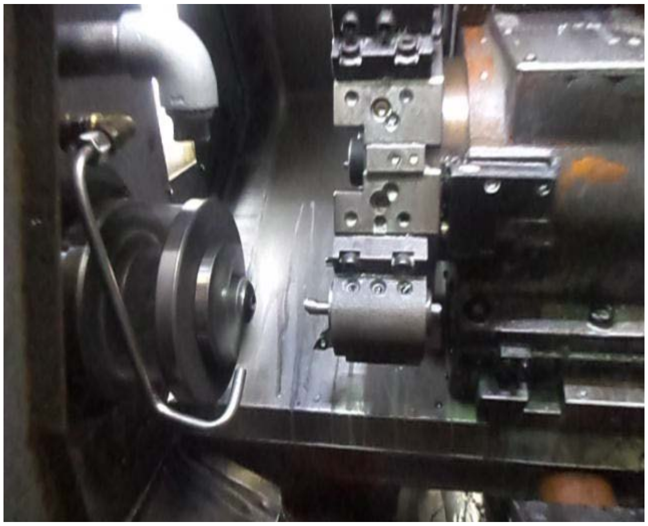


Fig. 2.1: Before Machining

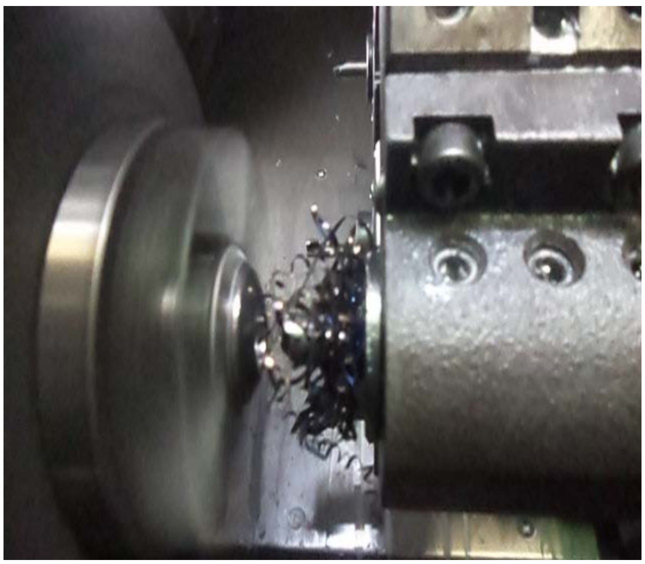


Fig. 2.2: After Machining Chips Curl on Tool

This is the pinion took for machining. And various turning operation had done for analysing chip control.

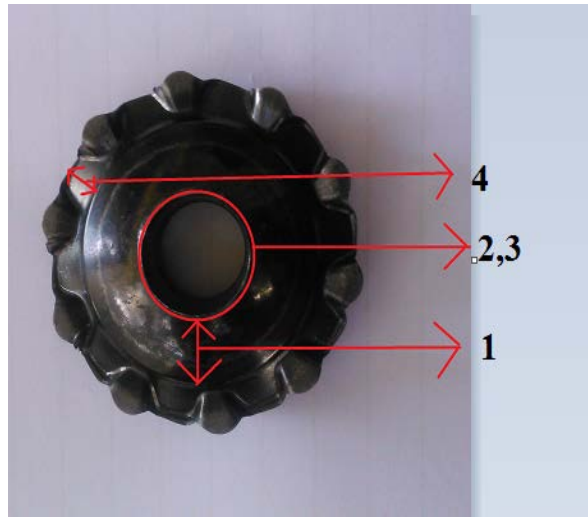


Fig. 2.3: Top View of Pinion

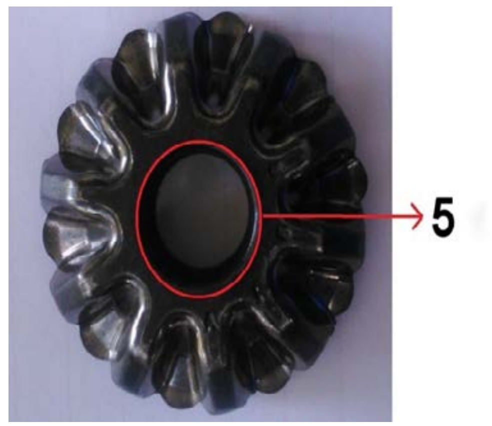


Fig. 2.4: Bottom View of Pinion

List of operation of pinion

1. Spherical finish
2. Bore rough
3. Bore finish
4. Back angle
5. Back radius

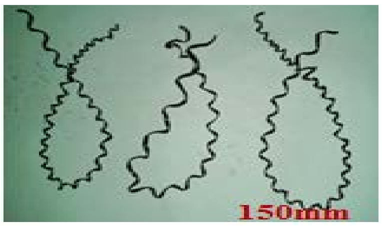
The machining parameters and chip length of a component while machining by existing insert is shown below in table 2.1.

Table 2.1: Machining Parameter and Chip Length for Existing Insert

S.No	Operations	Stock Removal(mm)	Feed Rate(mm/rev)	Spindle Speed(rpm)	Chip Length(mm)
1	Backangle(Intermittent)	3	0.12	3000	2 to 5
2	Backangle(Finish)	3	0.12	3000	220
3	Spherical Finish	0.5	0.1	2800	1200
4	Bore Rough	1.7	0.25	2800	150
5	Bore Finish	0.3	0.1	3000	1500
6	Back Radius	0.5	0.1	2800	30

From the observed data, the result of chip length is very high in spherical finish; bore rough, bore finish shown in table 2.2. Due to continuous chip it curl on tool and chuck there is a need of secondary equipment like blower to remove chip from tool and chuck, it increase cycle time and also increase cost per component. This paper focused mainly 3 operations to reduce the chip length.

Table 2.2: Chips of Different Operation

Operation	*Existing chip length*
Spherical finish	
Bore rough	
Bore finish	
Back Angle	
Back Radius	

III. Methodology for Chip Control

- Insert geometry
- Heat dissipation
- Coolant flow
- Feed rate
- Depth of Cut

3.1. Insert Geometry

Insert geometry which is main factor for chip control. It is helpful to curl the chip properly. For that Rake angle should be positive and higher in insert geometry. Hence we choose insert TNMG130404 FS, CCMT 060208 MT, CCMT060204 FA for three operation spherical finish, bore rough, bore finish respectively [1]. There are so many insert with different material available in the market. As per the chemical composition of the work piece, carbide insert is selected.

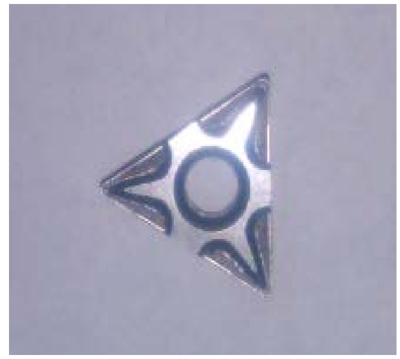


Fig. 3.1: Grooved Insert

3.2. Heat Dissipation

During machining of a component due to shearing of material by using cutting tool enormous amount of heat is generated. Mechanical energy is converted into heat (80%) exactly on shear plane. 18% heat energy exactly on tool edge i.e. in between chip formation and tool. 2% energy is converted into heat in between insert and work piece [1].

3.3. Feed Rate

The proper feed rate which help to curl the chip tightly. Feed should be greater than land width. Feed should be lesser than Groove width. If feed rate is lesser, the chip generation will escape from the groove. If feed rate is higher, the chip generation will touch the edge and escape from the groove [2].

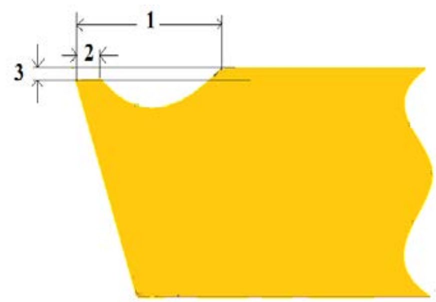


Fig. 3.2: 1-Grove Width, 2-Land Width, 3-Back Wall Height

For Example Groove width =0.8mm. Feed rate = 0.2mm to 0.8 mm, Land length = 0.2 mm.

3.4. Coolant flow

Coolant flow is used for quenching process. By using coolant tool life is increased [4-6]. It should be exactly on shear plane and deformation zone. Due to the continuous deformation of chip heat will generate at the curl chip. While the coolant flow is directly on the curl chip it makes more brittle. At the same time due to continuous bending of the chip so the crack in the chip will propagate and break into piece. It helps to change ductile material to brittle material. Coolant flow on deformation zone and shear plane helps to control chip and increases the tool life.

3.5. Depth of cut

As the general rule of thumb depth of cut should be greater than 60% of nose radius.

IV. Result and Discussion

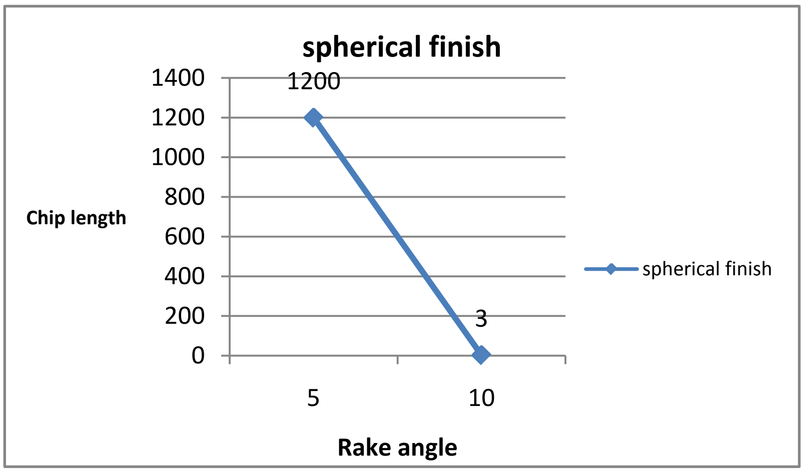
4.1. Spherical Finish

In case of spherical finish operation, existing insert changed to higher rake angle insert. And analysed chip length which are shown in table 4.1.

Table 4.1: Spherical Finish

S.No	Parameter	Old Insert	New Insert
1	INSERT	TNMG 130404 FM	TNMG 130404 FS
2	GRADE	CT 3000	CT 3000
3	BACK RAKE ANGLE	5	10
4	SIDE RAKE ANGLE	5	10
5	SPEED(N)	2800 rpm	2800 rpm
6	DEPTH OF CUT (d)	0.5mm	0.5mm
7	FEED(F)	0.1 mm/rev	0.1mm/rev
8	CHIP LENGTH	1200 mm	1-3mm
9	FIGURE		

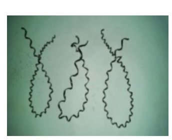
It is noted chip length is reduced from 1200mm to 3mm after the insert changed.



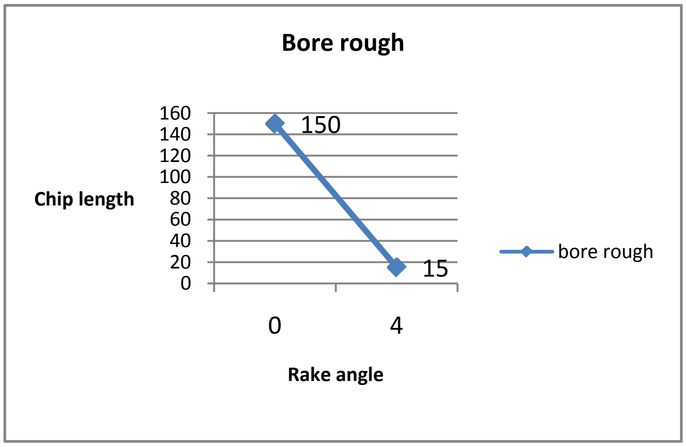
4.2. Bore Rough

In bore machining operation tool geometry and machining parameter as per the chip breaking methodology get changed. In case of bore rough operation, changing the insert geometry having higher rake angle then the initial insert. And analysed chip length which are shown in table 4.2.

Table 4.2: Bore Rough

S. No	Parameter	Old Insert	New Insert
1	INSERT	CCMT 060208 N SU	CCMT 060208 MT
2	GRADE	CCMP832ESU	CT 8115
3	BACK RAKE ANGLE	0	4
4	SIDE RAKE ANGLE	0	6
5	SPEED(N)	2800 rpm	3500 rpm
6	DEPTH OF CUT (d)	0.85mm	0.60mm
7	FEED(F)	0.25 mm/rev	0.40mm/rev
8	CHIP LENGTH	150 mm	15 mm
9	FIGURE		

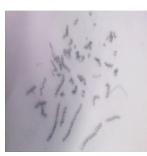
It is noted chip length is reduced from 150mm to 15mm after the insert changed.



4.3. Bore Finish

In bore finish operation, insert geometry and machining operation are changed as per the chip breaking methodology. In case of bore finish operation, changing the insert geometry having higher rake angle then the initial insert. And analysed chip length which are shown in table 4.3

Table 4.3: Bore Finish

S. No	*Parameter*	*Old Insert*	*New Insert*
1	INSERT	CCMT 060204 FG	CCMT 060204 FA
2	GRADE	CT 3000	CT 3000
3	BACK RAKE ANGLE	9	18
4	SIDE RAKE ANGLE	17	18
5	SPEED(N)	2800 rpm	3500 rpm
6	DEPTH OF CUT (d)	0.25mm	0.40mm
7	FEED(F)	0.09 mm/rev	0.09mm/rev
8	CHIP LENGTH	1500 mm	37mm
9	FIGURE		

It is noted chip length is reduced from 1500mm to 37mm after the insert changed.

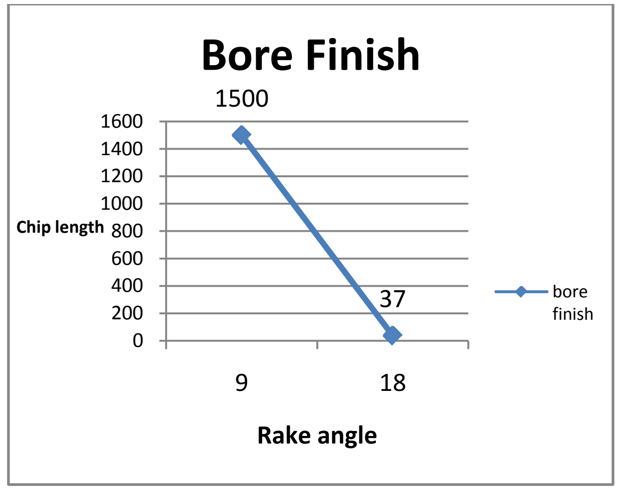
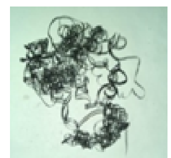
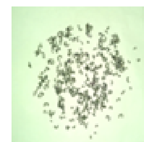
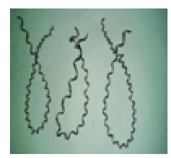
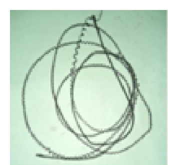
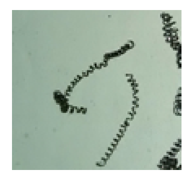


Table 4.4: Chip Length Before and After the Insert Change

Operation	*Existing chip length*	*Newchip length*
Spherical finish		
Bore rough		
Bore finish		

4.4. Inference

By changing insert geometry and machining parameter as per the chip breaking methodology the chip length will be controlled. And that suggested insert, rake angle is greater than existing insert. Cost per component is 15% increased. By reducing the chip length there is no curls of chip round the cutting tool. So it reduce the secondary equipment which used for removing curled chip. It can reduce 7 sec per parts by introducing the grooved insert.

V. COST PER COMPONENT

5.1. Existing Cost per Component

Table 5.1: Cost of a Component While Machining by Existing Insert

Operation	*Insert*	*No .of Cutting Edge (nos.)*	*Life/ Edge (nos.)*	*Cost/ Insert [A](Rs)*	*Life/ Insert [B](nos.)*	*Cost/ Component [C=A/B]*	*Total Cost/ Part (Rs)*
BACK ANGLE	CNMG 120408NM	4	800	225	3200	0.07	0.71
SPHERICAL FINISH	TNMG 130404 FM	6	450	195	2700	0.07	
BORE ROUGH	CCMT 060208 N SU	6	800	160	4800	0.03	
BORE FINISH	CCMT 060204 FG	2	250	160	500	0.32	
BACK RADIUS	CCMT 060204 N SU	2	350	160	700	0.22	

While machining by using less rake angle insert we spend nearly 0.71Rs for each component. As mentioned above table.

5.2. *New Cost Per Component*

Table 5.2: Cost of a Component While Machining by New Insert

Operation	*Insert*	*No .of Cutting Edge(nos.)*	*Life/ Edge (nos.)*	*Cost/ Insert [A](Rs)*	*Life/ Insert [B](nos.)*	*Cost/ Component [C=A/B]*	*Total Cost/ Part(Rs)*
BACK ANGLE	CNMG 120408NM	4	800	225	3200	0.07	0.82
SPHERICAL FINISH	TNMG 130404 FS	6	360	195	2160	0.09	
BORE ROUGH	CCMT 060208 MT	6	640	160	3840	0.04	
BORE FINISH	CCMT 060204 FA	2	200	160	400	0.40	
BACK RADIUS	CCMT 060204 N SU	2	350	160	700	0.22	

While machining by using higher rake angle insert we spend nearly 0.82Rs for each component. As mentioned above table.

5.3. *Cycle Time Reduction*

Table 5.3: Difference in Cycle Time of a Component before and after the Insert Change

Operation	*Existing Cycle Time/Part(sec)*	*Total Cycle Time/Part(sec)*	*New Cycle Time/Part(sec)*	*Total Cycle Time/Part(sec)*
Back Angle	15	51	15	44
Spherical Finish	07		07	
Bore Rough	09		06	
Bore Finish	15		11	
Back Radius	05		05	

5.4. *Cost Per Component Difference*

As per the standard CNC machining cost of 1 hour is 180 rupees

i.e., 3600 seconds =Rs.180

1 second =Rs.0.05

We can reduce 7 seconds per part by introducing new insert.

7 seconds=Rs.0.35

By using grooved insert which have high rake angle the cost per component in increased nearly 0.11 rupee per component. But the cycle time for a component is reduce from 51 sec to 44 sec. It can save 7 sec for one component. Now for a single component the total cost is 0.57. And we get profit of 0.14 rupee per component.

VI. Conclusion

Chip length is reduced by increasing the rake angle of the insert and it also reduce the cycle time of the component.

It proves that cost of a component is decreased just by increasing the rake angle of the insert.

Reduce cutting forces and power requirements.

Easy chip disposal.

Safety to the operator.

Avoid use of blower which helps to save electricity.

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