Analytical Modelling and Experimental Investigation of Rake Contact and Friction Behaviour in Metal Cutting (Turning) for Aluminium

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Abstract— The friction due to the contact between the work piece and the tool is one of the key subjects in machining research. It is well known that cutting involves three deformation zones. The primary shear zone, i.e. the shear plane, is responsible for the chip formation whereas in the secondary shear zone on the rake face the work piece and tool are in a complex state of contact. The third region, on the other hand is responsible for the Ploughing and flank contact. Although there are numerous models proposed involving, analytical with thin and thick shear zone approaches, semi analytical and Numerical methods. Two important inputs for these models are the material model parameters and the friction coefficient between the tool and the work piece material. By considering literature surveys, the friction behavior in metal cutting operations is analyzed using a thermo mechanical cutting process model that represents the contact on the rake face by sticking and sliding regions. The relationship between the sliding and the overall, i.e. apparent, friction coefficients are analyzed quantitatively. The sliding friction coefficient is identified for different work piece–tool couples using cutting tests. In addition, the effect of the total, sticking and sliding contact lengths on the cutting mechanics is investigated. The effects of cutting conditions on the friction coefficients and contact lengths are analysed. The cutting tool materials are Uncoated Carbide and Coated Carbide tools, and the Work piece material is aluminium which is being machined at cutting speed ranging from 600 m/min to 1200 m/min with a depth of cut 2mm. By considering the experimental results for the analysis of Rake Angle and friction behavior in metal cutting (Turning), the parameters are optimized by using the Taguchi method. For this an appropriate orthogonal array has been selected as per number of factors and their levels to perform minimum experimentations.

Key words: Machining, Friction and Contact Model

I. Introduction

Metal cutting is a complex deformation process where heat is generated in a small cutting zone. In this process, material is removed in the form of chips to achieve the desired dimensional accuracy and surface finish. It is a highly non-linear and coupled thermo mechanical process, where the Mechanical work is converted into heat through the plastic deformation involved during chip formation and also due to the frictional work between work and tool, chip and work Figure 1.1 shows the three plastic deformation zones in the metal cutting process.

The actual chip is formed in the primary deformation zone also called the shear zone where the work material is bent over the tool rake face. In this zone large strains and strain rates have been reported. The secondary deformation zone shows the chip tool interaction due to sticking friction where the chip adheres to the tool rake face and sliding friction where the chip slides over the tool rake face. The tertiary deformation zone forms the region between the tool clearance face and the machined work surface caused mainly due to the cutting edge roundness or the presence of a built up edge.

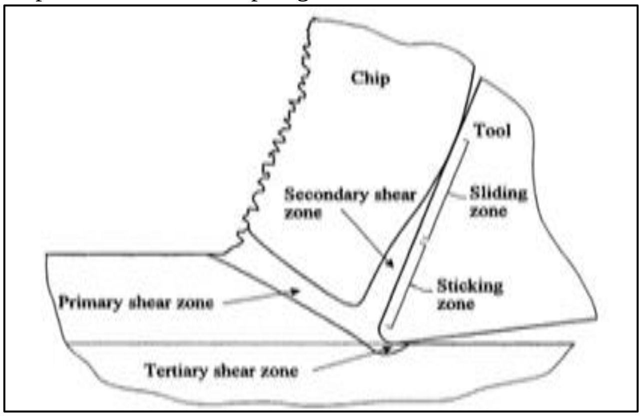

Fig. 1: Plastic deformation zones in metal cutting

Machining process such as turning, milling, boring and drilling are among others the most important process for discrete part manufacturing. Researchers have been studying machining processes for more than a century to gain better understanding and develop more advanced manufacturing technology.

Cutting tools for metal cutting have many shapes, each of which are described by their angles or geometries. Every one of these tool shapes has a specific purpose in metal cutting. The primary machining goal is to achieve the most efficient separation of chips from the work piece. For this reason, the selection of the right cutting tool geometry is critical. Other chip formation influences include

- The work piece material
- The cutting tool material
- The power and speed of the machine
- Various process conditions, such as heat and vibration. In turning, insert shape selection is based on the trade-off between strength and versatility. For example, larger point angles are stronger, such as round inserts for contouring and square inserts for roughing and finishing. The smaller angles (35o and 55o) are the most versatile for intricate work. Several angles are important when introducing the cutting tool's edge into a rotating work piece. These angles include:
- The angle of inclination
- Rake angle
- Effective rake angle
- Lead or entry angle
- Tool nose radius

II. Project Methodology

Here in project methodology I am going to discuss various models that are being constructed for the analysis during turning.

III. THERMO MECHANICAL DUAL-ZONE MODEL

The cutting model which is used in this study is briefly presented. In this model, the contact between the chip and the tool on the rake face is represented by a dual-zone approach. Basically, the contact is divided in to the sticking and a sliding friction region, which was originally proposed by Zorev (see Fig).

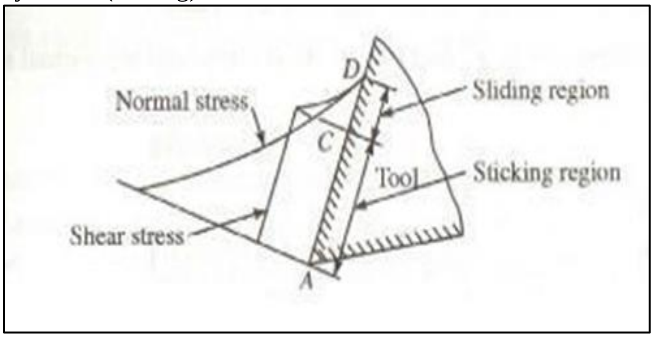

Fig. 2: stress distribution on the rake face of the tool

In the first region, the contact condition is plastic due to the high normal pressure exerted on the tool, whereas in these contact region the contact is elastic which can be represented by the sliding friction. There are two different friction coefficients that are defined on the rake contact. The apparent friction coefficient μ_a is due to the total cutting forces acting on the rake face. The sliding friction coefficient μ on the other hand, is only due to the forces acting on the sliding region on the rake face. The normal pressure distribution on the rake face is needed for the formulation of forces. The following distribution is selected as it issued and verified by several studies.

Where ℓ_c, is the total contact length, x the distance on the rake face from the tool tip, and ζ an exponential constant which represents the distribution of the pressure, and is selected as 3 in the current study based on the analysis of the split-tool test results. It can be observed from Fig. 1, that the shear stress on the rake face is equal to the shear yield stress of the material (τ_1) along the sticking region with length ℓ_p. In addition, the shear stress in the sliding region is equal to the product of the sliding friction coefficient (μ) and the normal stress(P), according to the Coulomb friction law. Therefore, the mathematical representation of the shear stress distribution on the rake face can be defined as follows:

$$\tau = \begin{cases} \tau_1 & x \le \ell_p \\ \mu P & \ell_p \le x \le \ell_c \end{cases}$$

Fig. 3: Experimental setup

IV. RESULTS AND DISCUSSION

Optimization of Parameters in Turning Aluminum with Uncoated Carbide Tool And Coated Carbide Tool Using Taguchi Technique. Taguchi parameter design for turning process

In order to identify the process parameters affecting the selected machine quality characteristics of turning, the following process parameters are selected for the present work: cutting speed (A), rake angle (B) and Sticking Contact Length (C). The selection of parameters of interest and their ranges is based on literature review and some preliminary experiments conducted.

JOB NO.	CUTTING SPEED (m/min)	RAKE ANGLE (deg)	STICKING CONTACT LENGTH(mm)
1	200	5	0.2
2	200	10	0.4
3	200	15	0.6
4	400	5	0.4
5	400	10	0.6
6	400	15	0.2
7	800	5	0.6
8	800	10	0.2
9	800	15	0.4

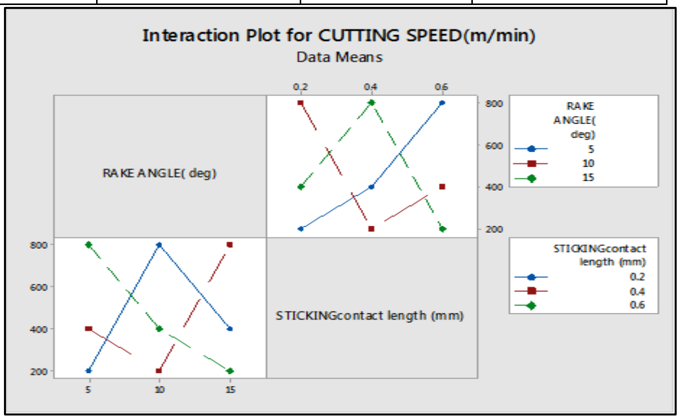

Fig. 4: Interaction plots for cutting speed v/s rake angle & contact length

S.No	Speed (N) RPM	Depth of Cut (d) mm	Feed (f)	MRR	Flank Wear (µm)	Surface Roughness
			Mm/rev		(mm3/sec)	(µm)
1	400	0.4	0.08	23.41	199.57	1.92
2	400	0.6	0.12	27.34	210.45	1.28
3	400	0.8	0.16	30.45	235.67	1.3

4	400	1	0.2	34.56	285.87	1.36
5	600	0.4	0.12	25.67	211.43	1.47
6	600	0.6	0.08	31.43	224.76	1.39
7	600	0.8	0.2	34.57	250.29	1.65
8	600	1	0.16	45.83	290.89	1.75
9	800	0.4	0.16	34.57	232.73	1.47
10	800	0.6	0.2	41.47	247.54	1.41
11	800	0.8	0.08	50.46	276.9	1.52
12	800	1	0.12	62.57	311.36	1.83
13	1000	0.4	0.2	38.98	285.32	1.73
14	1000	0.6	0.16	48.32	314.81	1.87
15	1000	0.8	0.12	58.98	338.04	1.98
16	1000	1	0.08	71.56	360.38	2.08

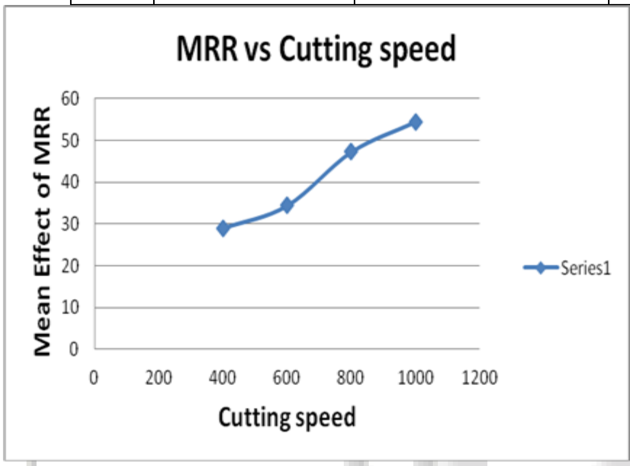

Fig. 5: Material Removal Rate vs cutting with coated tool

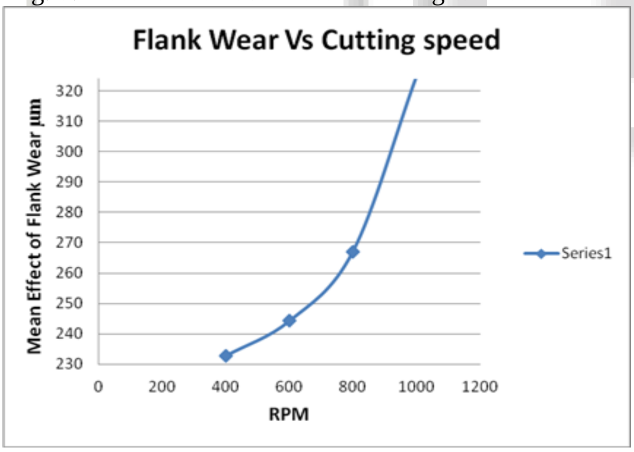

Fig. 6: Surface Roughness Varying with cutting speed

V. Conclusions

In this thesis, an investigation of the rake contact and friction behaviors in metal cutting operations is performed. The friction behavior in metal cutting operations is analyzed using a thermo mechanical cutting process model that represents the contact on the rake face by sticking and sliding regions.

- The total contact length increases by the feed rate and decreases by the cutting speed.
- The apparent friction coefficient strongly depends on the relative length of the sticking and sliding zones, and sliding friction coefficient. It shows that the apparent friction coefficient is always smaller than the sliding friction coefficient.

Reference

[1] E-G Ng ', D. Szablewski ', M. Dumitrescu ', M.A. Elbestawi'(1) and J.H. Sokolowski ―High Speed Face Milling of aAluminium Silicon Alloy Casting.
[2] F. Itoigawa a, , T.H.C. Childs b, T. Nakamuraa, W. Belluco c ―Effects and mechanisms in minimal quantity lubrication machining of an aluminum alloy.
[3] Z.T. Tanga,b, , Z.Q. Liub, Y.Z. Panb, Y. Wanb, X. Aib ―The influence of tool flank wear on residual stresses induced by milling aluminum alloy‖ IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE) e- ISSN: 2278-1684, p-ISSN.
[4] BalkrishnaRao, Yung C. Shin ―Analysis on high-speed face-milling of 7075-T6 aluminum using carbide and diamond cutter.

