IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE)
ISSN(e) : 2278-1684, *ISSN(p) :* 2320–334X, *PP : 48-52*
www.iosrjournals.org

Development of Slip line model For MicroTurning Process

S. B. Bawaskar [1], L.G. Navale [2]
[1](Department of Mechanical Engineering, P. V. G, College of Engineering and Technology, Pune, India)
[2](Department of Mechanical Engineering ,M. E. S. College of Engineering, Pune, India)

ABSTRACT : *Micro-turning, the inevitable micro-machining technique is a tool based micro machining process. The applications include use of micro shafts for micro pins, micro motors in the area of robotics, MEMS, biomedical, aerospace etc. The micro- turning process, as it is influenced by the edge radius, both ploughing and shearing occurs while removing the excess material depending up on the feed rate used. The objective of this research is to model the forces involved in the micro-turning process using slip-line field theory by considering the effects of edge radius, ploughing, and the built-up edge (BUE) to account for both ploughing and shearing. Unlike previous models the proposed model describes both the shearing and ploughing process as plastic deformation processes and will includes the effect of the minimum chip thickness and BUE. The ploughing force, the built-up edge and the minimum chip thickness effect which lead to the nonlinearity of the process are described in this model.*

Keywords - *Micro-turning, Slip-line, Built-up edge, Cutting forces, Thrust forces, Ploughing*

I. INTRODUCTION

The growing demand of miniaturized products in recent years has shown a tremendous impact in the research work in micro manufacturing field. Miniaturized parts like micro shaft, micro moulds, micro fins etc. finds applications in heart pace makers, micro-fluidic systems, micro-molds, micro-holes for fiber optics, and micro-nozzles for high-temperature jets. The micro manufacturing methods includes micro machining, micro forming, LIGA, and stereo lithography techniques. The other applications include micro scale fuel cells, fluidic micro chemical reactors requiring micro scale pumps, valves and mixing devices, microfluidic systems, micro holes for fiber optics etc. The functional and structural requirements of these devices demand the use of various engineering materials including aluminum alloys, stainless steel, titanium, brass, plastics, ceramics, and composite. Thus micro-machining, being an ultra-precision machining process is becoming increasingly important because of its capability of producing parts with ranging in micron level in a wide range of materials. Micro-turning, the inevitable micro-machining technique is a tool based micro machining process which makes use of a solid tool to remove material with or without physical contact with the work piece. One of the main application is the fabrication of micro shafts for micro pins, micro motors in the area of robotics, MEMS, biomedical, aerospace etc. Like other micro machining processes the micro turning is influenced by the edge radius and the minimum chip thickness, which leads to the size effect and thus the ploughing.

II. OBJECTIVE AND SCOPE OF PRESENT WORK

The objective of this research is to model the forces involved in the micro-turning process using slip-line field theory by considering the effects of edge radius, ploughing, and the built-up edge (BUE) to account for both ploughing and shearing. Therefore the control of the reacting force during cutting is one of the important factors in the improvement of machining accuracy. The micro turning process, as it is influenced by the edge radius, both ploughing and shearing occurs while removal of material depending up on the feed rate used. The ploughing force, the built-up edge and the minimum chip thickness effect which lead to the nonlinearity of the process are described in this model.

III. PROPOSED SLIP-LINE MODEL

3.1 Significance of the present model

1. The model can be used to predict the cutting forces in micro-turning process by considering the effects of edge radius of the cutting tool, BUE, and thus the size effect.
2. The model includes the effect of BUE at the edge of the tool which significantly affects the machining process.
3. The model takes into account the ploughing phenomenon due to the edge radius. The ploughing mechanism has significant effect on surface roughness and cutting forces.
4. The model separates the total cutting force into both the shearing and ploughing components and explicitly defines the forces in terms of shear angle and edge radius.
5. The predicted force shows good agreement with the experimental values taken from literature for different values of uncut chip thickness.

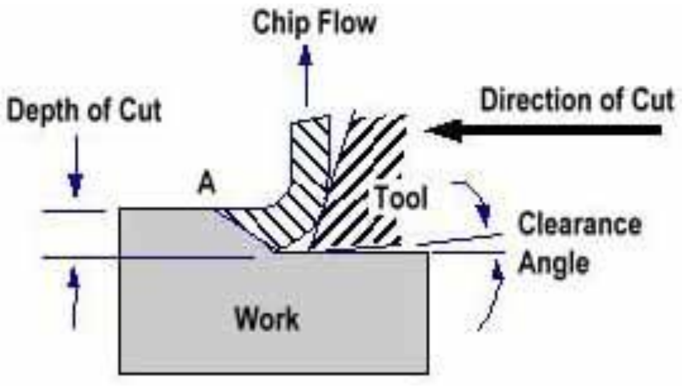


Fig. 1 Slip-line model

IV MATHEMATICAL MODELLING

4.1 Formulation of the pressure values from the slip-line model

$$PD = PC + 2*k*\gamma = k*(1+2(\theta+\gamma))$$

4.2 Modeling of the slip-line field angles η, γ, and θ

$$\eta = 0.5 \, Cos\text{-}1(m)$$

$$\tau = m*k$$

$$\eta = < FGC = Cos - 1\ (m) = Cos - 1\ (\tau / k)$$

τ = Frictional shear stress and k is the Shear flow stress k is defined by Von Mises condition or Tresca condition = $0.577 * \sigma 0$

$$\theta = 135 - \eta \text{ and } \gamma = 45 + \eta$$

From [7, 9] the value of m is taken as 0.99

The value of shear flow stress, k is taken as 251 N/mm2.

Sin (ψ) = 0.05*(tan (45 + φ) - 1) k is defined by Von Mises condition or Tresca condition = 0.577 * $\sigma 0$

$$\theta = 135 - \eta \text{ and } \gamma = 45 + \eta$$

From [7, 9] the value of m is taken as 0.99

The value of shear flow stress, k is taken as 251 N/mm2.

$$\text{Sin}(\psi) = 0.05*(\tan(45 + \varphi) - 1)$$

4.3 Force Model

4.3.1 Shear Plane Forces

The shear plane forces can be modeled as

Fcs = σ Sin φ + τ Cos φ per unit area

= PE Sin φ + τ Cos φ per unit area

= k Sin φ + k Cos φ per unit area

= k* EF*w*[(Sin φ + Cos φ)] Newton, where w is the depth of cut

Similarly the thrust force is modeled as:

Fts=k*EF*w*[(Sinφ+Cosφ)]

Resolving these stresses along X and Y direction we get

The cutting force due to ploughing is modeled as

Fcp = [σp * Sinψ + τp*Cosψ]*w*FG

The thrust force due to ploughing is modeled as

Ftp = [σp * Cosψ - τp*Sinψ]*w*FG

Substituting the value of stresses in the equations above equations we get,

= PE Sin φ + τ Cos φ per unit area

= k Sin φ + k Cos φ per unit area

= k* EF*w*[(Sin φ + Cos φ)] Newton, where w is the depth of cut

Similarly the thrust force is modeled as:

Ftp = [σp * Cosψ - τp*Sinψ]*w*FG

Substituting the value of stresses in the equations above equations we get,

Fcp = [(1+2 (θ+γ)) + Sin 2η) Sinψ + Cos 2η*Cos ψ]*w*FG*k

Ftp = [(1+2 (θ+γ)) + Sin 2η) Cosψ - Cos 2η*Sin ψ]*w*FG*k

where w = width of cut and k is the yield shear stress

So the total cutting force = Fc = Fcs + Fcp

And the total thrust force = Ft = Fts + Ftp

4.3.2 Ploughing Forces

σp = σ + k *Sin 2η = PC + k *Sin 2η

τp = k *Cos 2η

PA = k PA = PB= k

PC = k * (1+2 θ)

PE = k and PF = k

V PREDICTED FORCES AND EXPERIMENTAL VALIDATION

5.1 Discussion of the results

The validation of the model is done by comparing with literature. Chee et al. [1] had conducted an experimental investigation in micro-turning process and found that edge radius has a significant influence in cutting force. The parameters and all other details about experimentation are same as [1]. The work material is Al 7075 –T6.

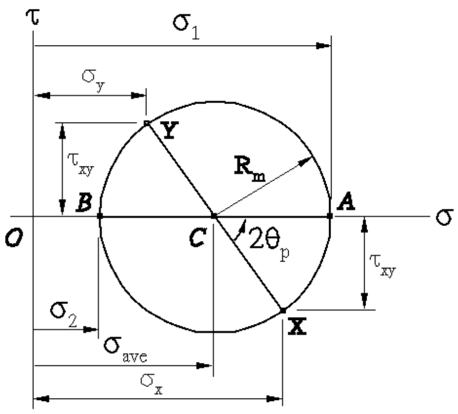
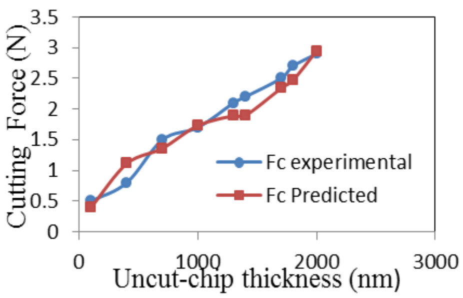


Fig.1 Mohr stress circle for the ploughing region

A comparison is made between the predicted forces and the experimental force data. From the Fig. 2 it is clear that the predicted cutting forces and thrust force varies nonlinearly with the uncut-chip thickness. The predicted forces show good agreement with experimental values. In the second model the maximum cutting force deviation is 7% to 20% under predicted. The maximum deviation was for 100 nm uncut chip thickness. At uncut-chip thicknesses 400, 1000, 2000 nm the cutting forces predicted were over predicting by 1.1%, 1.7%, and 3% respectively with an average value of 2%. At uncut chip thicknesses 100nm, 1400nm, 1700nm, and 1800nm the thrust forces were under predicted. At uncut-chip thicknesses 100 nm, 400 nm, 700nm, 1000nm and 2000 nm the thrust forces were over predicting by 23%, 48%, 20%, and 12% respectively with an average value of 25%.



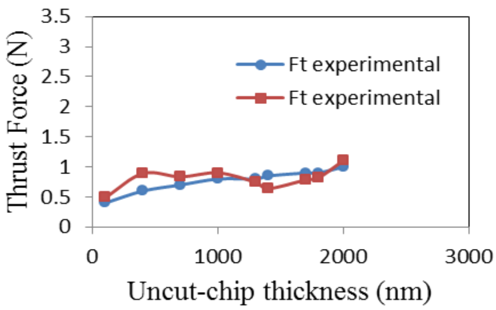


Fig.2 The predicted forces using slip-line model and experimental forces from literature: Cutting force (left) and Thrust force (right)

As the shear angle has a significant role in deciding the forces therefore the accurate and precise measurement of shear angle is a must. The model accounts the concept of minimum chip thickness, BUE, and the edge radius. The predicted forces are written as the sum of two terms. First one is the shearing component which contributes to the material removal and the second term is the ploughing component which presses the material in to the work surface thereby increasing the surface roughness and power consumption. The shearing force component depends on uncut-chip thickness, shear angle, and work piece material constants. The ploughing component depends on mainly on the edge radius of the cutting tool and work piece material constants. The cutting force and the thrust depend on the size and position of the BUE. In the present model the ploughing component is expressed explicitly as a function of edge radius. Thus the model validates that the ploughing process is mainly influenced by the edge radius of the tool and the friction condition on the bottom portion of the tool.

VI. CONCLUSION

A slip-line model has been developed for the micro-turning process for predicting the forces involved during micro turning. The model accounts for the concept of minimum chip thickness, built-up edge, and ploughing effect. The slip-line model is divided into primary or shearing zone where the chip removal takes place and the ploughing region where the material rubbing takes place. The predicted forces are written as the sum of two terms. First one is the shearing component which contributes to the material removal and the second term is the ploughing component. The shearing force component depends on uncut-chip thickness, shear angle, and work piece material. In the model the ploughing component is expressed explicitly as a function of edge radius. The validation of the model was done for a range of uncut-chip thicknesses. It is shown that the micro-cutting process can be modeled and predicted effectively using the slip-line field model. The accuracy of the predictions can be improved by determining the shear flow stress from cutting tests, accurate positioning of the BUE. The variations may due to the assumptions in the model, due to error in measuring the force signal, instrument errors, and the error in measuring the shear angle. The accurate and precise measurement of shear angle is necessary to predict the forces with accuracy.

REFERENCES

[1] K. N. Chee, N .M. Shreyes, M. Rahman, A. Senthil Kumar, Experimental study of micro- and nano-scale cutting of aluminum 7075-T6, *International Journal of Machine Tools & Manufacture, 46, 2006, 929–936.*

[2] Y. Karpat, Investigation of the effect of cutting tool edge radius on material separation due to ductile fracture in machining, *International Journal of Mechanical Sciences, 51, 2009, 541-546.*

[3] X. Liu, R. E. DeVor, S. G. Kapoor, An Analytical Model for the Prediction of Minimum Chip Thickness in Micromachining, *ASME journal of Manufacturing Science and Engineering, 128, 2006, 474-481.*

[4] B. G. Jun, X. Liu, R.E. DeVor, Shiv GK, Investigation of the Dynamics of Microend Milling—Part I: Model Development, *ASME journal of Manufacturing Science and* Engineering, 26, 2006, 893-900.

[5] D. J. Waldorf, A Simplified Model for Ploughing Forces in Turning, *International Journal of Manufacturing Process, 8, 2006, 76-82.*