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Tool Wear Analysis During Turning of Hard Material by Simulink

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Abstract- Present work is an attempt to develop a simulink model of tool wear by machining of Bearing Steel (62 HRC) using cubic boron nitride (CBN) tool. The available mathematical model in the scholarly literature is used to make the simulation model using MATLAB software. Three components of tool wear adhesive wear, abrasive wear & diffusion wear are considered separately for their modeling and later modeling of total wear is done. Variation of tool wear is studied with respect to cutting speed. The developed simulink model is capable to do the similar type of study by changing the workpiece and tool material combination.

Keywords: Simulink, Tool wear, Mathematical modeling, Turning.

I. INTRODUCTION

To define the general wear rate or volume loss, for distinct wear mechanisms various models have been proposed. And that includes their applications during metal cutting. Such eminent work are being reported as on abrasive wear [1,2] on diffusive wear [4–5] and on adhesive wear [3–4]. Generally, during the cutting operation wear takes place on tool due to diffusion, abrasion and adhesion and, its root cause boost in temperature and distribution of stress on tool [6,7,8].The main objective of this work is to develop a mechanistic model to anticipate rate of tool wear, during cutting operation. This study strives to find a model that describes the process of wearing at a mechanism level. It would be desirable to have such a model that shows how much different mechanisms acts on the tool. A good wear model would make it possible to cut down the amount of testing needed when developing new tools, and increase the level of understanding for the wear process. At the end the evolved new tools may occur much faster and result in more wear resistive tools.

In case of modeling at the beginning the mathematical model is developed and then it has been transformed to simulink model, the process is shown in "Fig .2".All model and their classification is shown in "Fig.1".

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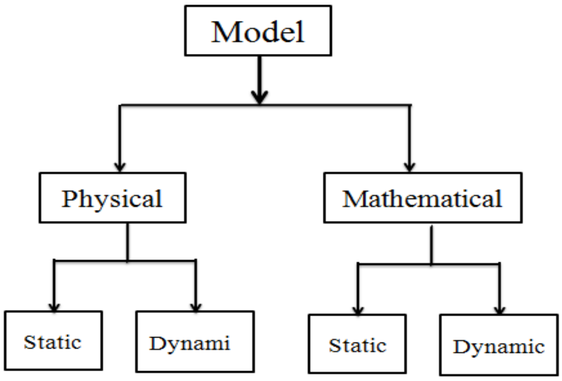

Fig.1 Classification of models

II. STEPS OF MODELING AND SIMULATION

Steps of mathematical modeling have been clearly shown in Fig.2. Initially one has to identify the real world problem by focusing on the background of research on workable problem. After simplifying the real world problem working model is formulated into mathematical terms. Working model in mathematical terms is known as mathematical model, Mathematical model is converted in to suitable computational model by using computational tool. Computational tool includes different software's like C,C++,JAVA ,MATLAB etc. In the present work MATLAB is used as a computational tool, after simulation results are presented in the forms of graphs. Conclusions are drawn by combining all results.

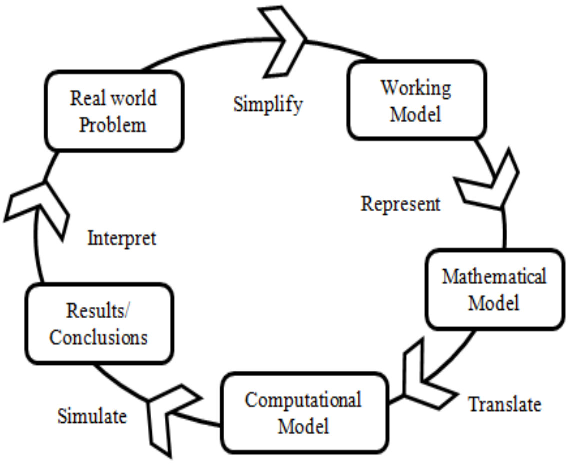

Fig.2 Development of Mathematical modeling Process

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III. DIFFERENT TYPE OF WEAR

Different types of wear depending on its mechanism are described below.

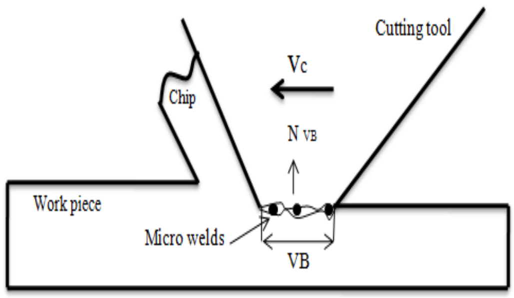
Abrasive
This is a phenomenon in which, hard particles abrade on softer material throughout the surface. In which relative velocity would be take place, and confide on hardness (relative) of abrading particles and abraded material [9]

Adhesive
This phenomenon occurs under high temperature and pressure, when two materials are acting their forced together, and in relative motion. Small particles get welded together causing failure of one metallic object.[10]

Diffusion
Phenomenon in which atoms of one material diffuse over to another. That happens due to high feed rate and cutting speed. It is suppose that, diffusion causes the tool to be diminish of its atoms culpable for its hardness, and diffusion becoming more prudent for abrasive and adhesive wear.

A. Development of Mathematical Model (Volume Change)

It contains two steps
(i) Derivation of function of volume change in time
(ii) Derivation of geometric volume change
The total volume of tool material removed is the summation of all three (abrasive, adhesive and diffusive) wear models are given below.



$$\Delta V_{Total\ wear} = \Delta V_{\_abras} + \Delta V_{adhs} + \Delta V_{diff} \quad (1)$$

$$V_{wear-abrasion} = K \left(\frac{P^{(n-1)}{}_a}{P^n{}_t}\right) x\ L \tan\theta \quad (2)$$

When tool cuts unwanted material from the workpiece, interaction are shown in "Fig .3" after cover distance x length of flank wear is VB other notations of "equation (2)" are given below.
[L= Load between surfaces, w= width of cutting, Vc= Cutting velocity, Pa= Hardness (abrasive particles), P_t Hardness (tool), σ= Normal stress (flank area), VB = flank wear length, θ= angle(friction)]

$$P_t / P_a < 0.80;\ n = 1.0,\ K = 0.333,$$

$$0.8 < P_t / P_a < 1.25;\ n = 3.445,\ K = 0.189$$

$$\text{otherwise} \quad n = 7.0,\ K = 0.46$$

$$V_{wear-abrasion} = K_{abrasion}\ K$$

$$\left(\frac{P^{(n-1)}{}_a}{P^n{}_t}\right) V_C\ w\ VB\ \sigma\ \Delta t \quad (3)$$

Adhesive wear

$$V_{wear-adhesion} = K_{adhesion}\ e^{aT} V_C\ w\sigma\Delta t \quad (4)$$

Diffusive wear

$$V_{wear-diff} = K_{diff}\sqrt{V_C VB}\, e^{-(K_Q/T+273)}\ w\Delta t \quad (5)$$

Total volume change is the sum of volume change by abrasive adhesive and diffusive wear and the whole change of volume are obtaining after add on "equation (3), (4) and (5)" and the ultimately given below.

$$\Delta V_{Total\ wear} = \Delta V_{abras} + \Delta V_{adhs} + \Delta V_{diff}$$

$$\begin{bmatrix} K_{abrasion}.K.\left(\frac{P^{(n-1)}{}_a}{P^n{}_t}\right) V_C.VB.\sigma + \\ K_{adhesion}.e^{aT}.V_C.\sigma + \\ K_{diff}\sqrt{V_C VB}\ e^{-(K_Q/T+273)} \end{bmatrix} w\Delta t \quad (6)$$

IV. GEOMETRIC DEFINITION OF WEAR VOLUME ON FLANK

According to "Fig.4" it has been observed that dVB is the final increment in VB (flank wear), when the insert loose the height (ds).(dVB1) is the loss or increases of VB caused by the rake angle (γ), and (dVB2) is the increase of VB, caused by the relief angle(α).

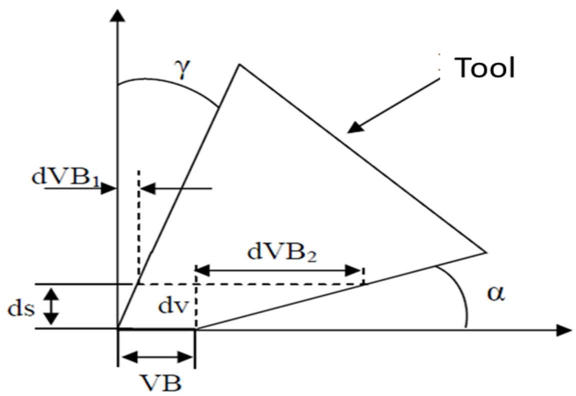


Fig. 4 volume loss for insert that grow the flank wear length (dVB)

$$d\,VB = d\,VB_2 - d\,VB_1 \quad (7)$$

After put down the value of "equation (10)" in to "equation (6)" the final wear model is represented by "equation (11)".

$$dv = w.ds.\left(VB + \frac{dVB}{2}\right) \quad (8)$$

$$ds = dVB\left(\frac{\tan\alpha}{1-\tan\alpha.\tan\gamma}\right) \quad (9)$$

$$dv = w.VB.dVB.\left(\frac{\tan\alpha}{1-\tan\alpha.\tan\gamma}\right) \quad (10)$$

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$$\frac{dVB}{dt} = \frac{dVB}{dt} = \left(\frac{1-\tan\alpha.\tan\gamma}{VB.\tan\alpha}\right)\left[\begin{array}{c} K_{abrasion}.K.\left(\frac{P^{(n-1)}{}_{a}}{P^{n}{}_{t}}\right)V_C.VB.\sigma \\ +\,K_{adhesion}.e^{aT}.V_C.\sigma\, + \\ K_{diff}\sqrt{V_C VB}\; e^{-(K_Q/T+273)} \end{array}\right]$$

…….(11)

Table.1

Material properties(tool and workpiece)	Workpiece 52100 Bearing steel (62 HRC)	Tool CBN
Density (kg/m^3)	4370.1	7800
Thermal conductivity (W/m-K)	44	46.6
Specific heat capacity (J/Kg K)	750	475
Hardness (Kg/mm^2)	150	2800

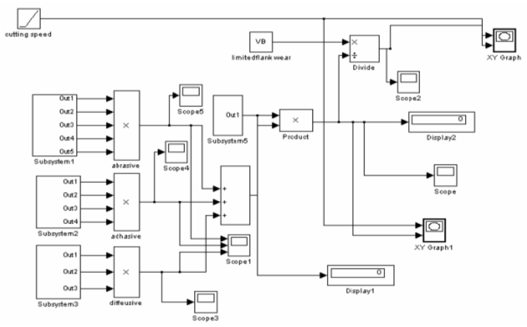

Fig.5 Main simulink model

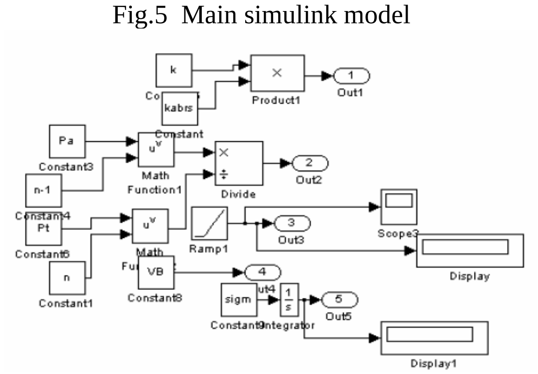

Fig.6 Sub system.1

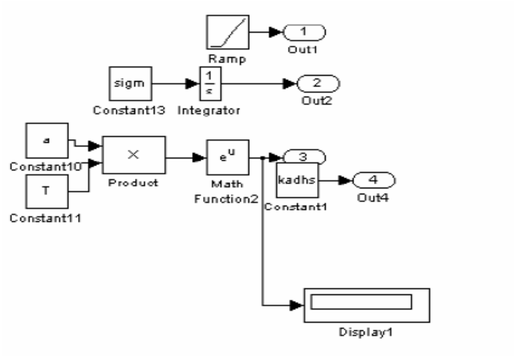

Fig.7 Subsystem .2

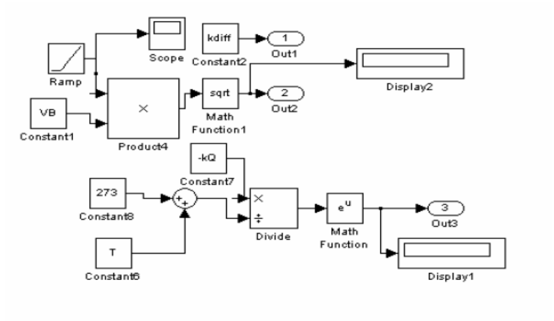

Fig.8 Sub system .3

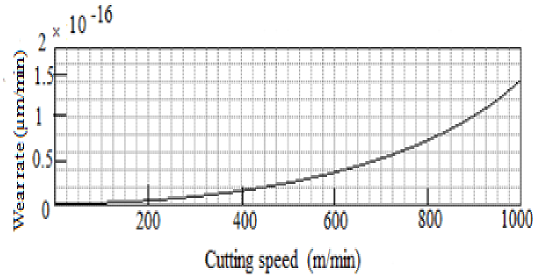

Fig.9 Abrasive tool wear rate with cutting speed

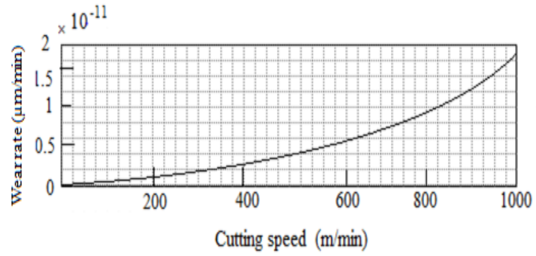

Fig.10 Adhesive tool wear rate with cutting speed

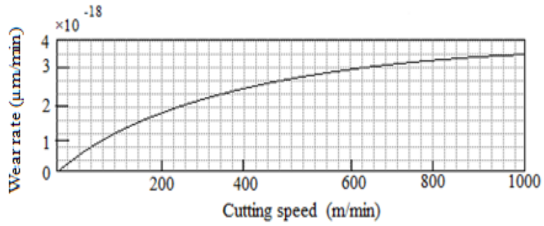

Fig.11 Diffusive wear rate witcutting speed

V. SIMULINK MODEL FOR TOOL WEAR ESTIMATION

Simulink is a tool of MATLAB for simulating dynamic systems. Final wear model can express as a flow chart of simulink by making connections of different operators. With the help of similink all the results occurs with respect to time .The modeling of presented wear model is like that the graphs have been occurred in between rate of wear with respect to cutting speed. Main simulink model have been clearly shown in Fig.5 .We can put all the output values of sub system 1, 2 and 3 as an input for the main simulink model. All sub simulink models have been clearly shown in Fig 6, 7 and 8

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Values can find out with the help of simulation or by experiment. All the values given below have been calibrated by the experiment according to reference [12] and all value are given below.

K_{abr}=0.13* 10^{6},K_{diff} = 1*E-24, K_{adh}= 1.8383*E-14, a= 9*E-4, K_Q=20000

Other mechanical properties (wok piece and tool) are disposed in Table.1 .After put down all these value to the main model and their sub models results of simulink model have been clearly shown in Fig.9, 10 and 11 for abrasive, adhesive and diffusive model.

VI. CONCLUSIONS

According to presented simulink model one can find out tool wear rate for any cutting speed with different combination of tool and workpiece. Results show that wear of tool is increasing with cutting speed. At maximum speed the value of adhesive tool wear is maximum is near about in order $2*10^{-11}$ µm where as diffusive wear is bearing steel and cubic boron nitride work tool combination. Initial wear rate due to abrasion and adhesion are found lower by their value as compared to diffusion wear. According to results it has been observed that diffusive wear rate increasing tremendously with increasing cutting speed and after some time the wear rate is found constant whereas abrasive and adhesive tool wear rate increases tremendously during machining.

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