PREDICTION OF DYNAMIC PARAMETERS IN TURNING PROCESS OF AISI4340 STEEL WITH TUNGSTEN CARBIDE TOOL BY USING FEM ANALYSIS

[1] M. Madduleti , [2] Dr. P.Venkata Ramaiah ,[3] Dr.G.Padmanabhan

[1]*Mechanical Engineeringe,* ***SVU College of Engg . Tirupati-517502 ,Andhra Pradesh, India.***

[2]*Mechanical Engineeringe,* ***SVU College of Engg . Tirupati-517502 ,Andhra Pradesh, India.***

[3]*Mechanical Engineeringe,* ***SVU College of Engg . Tirupati-517502 ,Andhra Pradesh, India.***

Email-Id: madhubabu56@gmail.com

ABSTRACT:

With the increasing demand for quality, highly reliable and economical machined components, the manufacturing industry must find innovative methods for producing precision components. To meet such demand, manufactures are seeking way to improve the manufacturing methodologies, by predicting the dynamic parameters with analytical models and finite element simulation. The present work deals with the prediction of dynamic parameters such as cutting forces, temperatures, flow stress and strain rate at secondary shear zone and normal stress, normal force component, maximum stress, strain rate, strain, coefficient of friction, shear flow stress in the chip at tool chip interface in turning. For the suitable analytical models are highly essential to predict the dynamic parameters. In the present work Oxley's model, JC model and tool chip interface model are used to predict dynamic parameters. The parameters such as stress, strain and temperature are calculated by Oxley's model using orthogonal experimental values. And flow stress is determined by JC model using the values obtained from Oxley's model. Flow stress values are obtained from Johnson Cook model are validated with the flow stress values obtained from tensile test. Finally FEM simulations have been performed using 3D-Deform software. The flow stress, strain and strain rates are obtained from 3DDeform software are compared with analytical model results comparison is satisfactory.

KEY WORDS: Dynamic parameters, Oxley's model, JC model and tool chip interface model.

1.Introduction

Metal cutting is the major manufacturing operation today in view of the economic significance. A fundamental knowledge of the metal cutting process is essential to find optimum conditions and develop new cutting equipment. Analytical and numerical models can be deduced from this fundamental knowledge to predict variables of interest for increasing process efficiency and part quality. With the increasing demand for quality, highly reliable and economical machined components, the manufacturing industry must find innovative methods for producing precision components. To meet such demand, manufactures are seeking way to improve the manufacturing methodologies, by predicting the dynamic parameters with analytical models and finite element simulation.

Finite Element Method (FEM) based modeling and simulation of machining processes is continuously attracting researchers for better understanding the chip formation mechanisms, heat generation in cutting zones. Predictions of the physical parameters such as temperature and stress distributions accurately play important role for predictive process engineering of machining processes. Finite Element Analysis is a most powerful and accurate approach for the determination of process parameters that is made possible by advancements in computational and processing power of com00puters. FEA is used for variety of applications like stress analysis, heat analysis, fluid flow analysis etc. DEFORM 3D is a powerful process simulation system used for the analysis of three dimensional flow of complex metal processes. It is a practical and efficient tool to predict the material flow in industrial forming operations without the cost and delay of shop trials.

2.Literature Review

Unfortunately, in most scenarios, time is limited and design of experiments (DOE) methods tend to be lengthy and cumbersome when considering the complex factors and noise that affect such an operation .. An excellent solution to this issue is an approach known as Taguchi Parameter Design.

1.Thamizhmanii et al (2007) studied on Analyses of Surface Roughness using Taguchi Method. They stated that depth of cut plays a very significant role in producing lower surface roughness followed by feed and cutting speed has lower role on surface roughness from the tests. Purpose of this research was to analyze the optimum cutting conditions to get lower surface roughness in turning process.

2.A.K.Sehgal, Amit Agarwal et al (2009) studied on surface roughness optimization based on taguchi design of experiment . They stated that the milling is found by the Taguchi parameter design method to determine minimum surface roughness with a relatively small number of experimental runs in an End Milling Process.

3.Deepak pal et al. (2012) studied on optimization of grinding parameters for minimum surface roughness by Taguchi parametric optimization technique . They stated that optimum value of surface roughness is 1.7Ra. They selected work speed, grinding wheel grades and hardness of material as their parameters with L9 orthogonal array.

To address the lack of research in this issue, the present work has been done with following objectives.

i) Identification of constitutive model.

ii) ii) Prediction of dynamic parameters.

3. METHODOLOGY

JOHNSON COOK MODEL

In the Johnson-Cook constitutive model as given in Eq. (3.1), describes the flow stress as the product of strain, strain rate and temperature effects; i.e. work hardening, strain-rate hardening, and thermal softening.

$$\sigma = [A+B\varepsilon^{n}]\,[1+C\ln(\acute{\varepsilon}/\varepsilon 0)]\,\{1 - [(T - T0)/(Tm - T0)]^{m}\}$$

In Eq. (3.1) the parameter A is the initial yield strength of the material at room temperature. The equivalent plastic strain rate ε0 is normalized with a reference strain rate **έ0**. T0 is room temperature, and Tm is the melting temperature of the material, and they are constants. While the parameter *n* takes into account the strain hardening effect, the parameter *m* models the thermal softening effect and *C* represents strain rate sensitivity. The Johnson-Cook model is a well-accepted and numerically robust constitutive material model and highly utilized in modeling and simulation studies.

	AISI 1045 STEEL	AISI 1045 STEEL	AL6082-T6 ALUMINIUM	Ti6A14V TITANIUM	Ti6A14V TITANIUM
A[MPa]	553.1	2100	428.5	782.7	896
B[MPa]	600.8	1750	327.7	498.4	656
C	0.0134	0.0028	0.00747	0.028	0.0128
N	0.234	0.65	1.008	0.28	0.50
M	1	0.75	1.31	1.0	0.8
T_m[K]	1733	1783	855	193	1933

4. PROCEDURAL STEPS TO PREDICT DYNAMIC PARAMETERS

Step1: Conduct the orthogonal cutting test and record the experimental values of depth of cut, speed, feed, chip thickness and cutting forces. **Step2:** Determine the strain, strain rate, average temperature etc., using Oxley’s model for the experimental data obtaining step1.

Step3: Choose the Johnson Cook constant values for different materials from data book

Step4: Substituting JC constant values and ε, έ, εo, T in flow stress equation and calculate the flow stress (σ)

Step5: Conduct the Tensile test on work material and calculate the Tensile flow stress.

Step6: Compare the Johnson Flow Stress (σ) and Tensile Flow Stress (σt) for validating the results.

PROCEDURE FOR ORTHOGONAL CUTTING

Switch on the power supply to the lathe. Set the work piece in the chuck and perform the centering operation by setting the centering tool (mostly drill bit) in the tailstock. Remove the centering tool and set the tailstock centre into it. Set the work piece between the centre and check. Set the cutting tool in the tool post. Perform the turning operation to remove the scrap layer at suitable speed, feed and depth of cut. Switch off the supply.


Figure 4.3: The lathe used to conduct the orthogonal cutting test

Now connect the lathe tool dynamometer to the lathe. Switch on the power supply and wait for 15 minutes until the readings in the dynamometer stabilizes. Adjust the initial values to zero if there is any error. Note the error in the dynamometer if any, even after the adjustment. Cut the carbide tipped tool to the required length, so that it fits in the tool post. Set the tool in the tool post. Adjust the levers and set the required speed (100 m/Min). Switch on the machine and set the required feed (0.15mm/rev) and depth of cut (0.1 mm) by adjusting the levers and cross slide. Start the turning operation and note the highest readings of Fx, Fz obtained in the lathe tool dynamometer. Switch on the temperature gun and focus the light beam on the tool chip interface and note down the maximum temperature obtained in the process.Set the next depth of cut (0.15 mm) and repeat the above steps for 0.2 mm and note down the readings.Switch off the machine and adjust the lever to the next speed level (160 m/min) on the machine and repeat the procedure.

Table : Output values of orthogonal test

S.NO	N(rpm)	V(m/min)	tu (mm)	tc (mm)	Fc(Kgf)	Ft(Kgf)
1	884.19	100	0.1	0.31	4.5	1.5
2	884.19	100	0.15	0.29	5.5	2
3	884.19	100	0.2	0.52	5.5	2.5
4	884.19	100	0.1	0.48	6	1.5
5	884.19	100	0.15	0.48	5	1.5
6	884.19	100	0.2	0.67	17	4
7	884.19	100	0.1	0.63	4.5	1.5
8	884.19	100	0.15	0.43	5.5	2
9	884.19	100	0.2	0.24	6.5	2.5
10	1414.7	160	0.1	0.28	2.5	1.5
11	1414.7	160	0.15	0.28	3.5	1.5
12	1414.7	160	0.2	0.41	4.5	2.5
13	1414.7	160	0.1	0.48	3.5	1.5
14	1414.7	160	0.15	0.50	3	1.5
15	1414.7	160	0.2	0.36	6	2.5
16	1414.7	160	0.1	0.37	4	1.5
17	1414.7	160	0.15	0.41	4.5	1.5
18	1414.7	160	0.2	0.53	5.5	2.5

5. MATHEMATICAL MODEL

The following model mathematical models used to predict the dynamic parameters

1.Oxley's model 2. JC model 3.Tool-chip interface friction model

Oxley's model

Strain rate constant proposed by Oxley $l_{AB} = t_u / \sin(\Phi)$

γ_{AB} is the Effective shear strain rate along shear plane AB

Shear angle $\Phi = \tan^{-1} \{ [(t_u/t_c)\cos\alpha] / [1- (t_u/t_c)\sin\alpha] \}$

$k_{AB} = [F_S \sin\Phi / (t_u w)]$

T_{AB} is the Average temperature along AB

$\beta = 0.5-0.35\log (R_T\tan\Phi)$ for $0.04 \leq R_T \tan\Phi \leq 10.0$

R_T =Non-dimensional thermal number

$R_T = [\rho S V t_u / K]$,flow stress $\sigma_{AB} = \sqrt{3}k_{AB}$

Strain rate along the Shear plane AB $\dot{\varepsilon}_{AB} = (\cdot\gamma_{AB} /\sqrt{3})$,

flow stress $\sigma_{AB} = \sqrt{3}k_{AB}$

Shear velocity $V_S = \{ v \cos \alpha / [\cos(\Phi - \alpha)] \}$

$\gamma_{AB} = \{ \cos\alpha / [2\sin\Phi \cos(\Phi - \alpha)] \}$

k_{AB} is the Shear flow stress along shear plane AB

Shear force $F_S= [F_C \cos\Phi - F_T \sin\Phi]$

$T_{AB} = T_0+ \{[(1-\beta) F_S \cos\alpha] / [\rho S t_u w \cos(\Phi - \alpha)]\}$

$\beta = 03-0.15\log (R_T\tan\Phi)$ for $R_T \tan\Phi > 10.0$

Strain along the Shear plane AB, $\varepsilon_{AB} = (\gamma_{AB} / \sqrt{3})$

$R_T = [\rho S V t_u / K]$

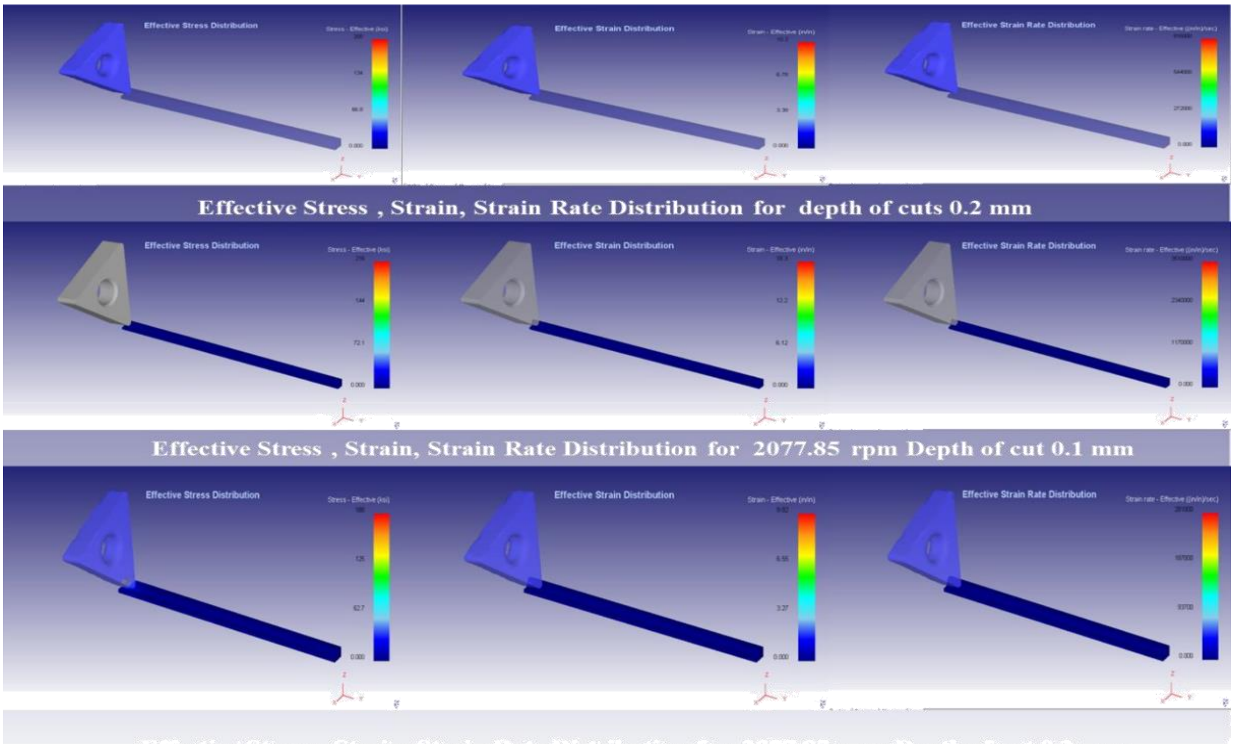
Strain along the Shear plane AB, $\varepsilon_{AB} = (\gamma_{AB} / \sqrt{3})$

Output values of Oxley's Analysis

S.NO	ε_{AB}	$\dot{\varepsilon}_{AB}$ (s^{-1})	T_{AB} (^0C)	k_{AB} (N/mm^2)	Flow stress (N/mm^2)
1	0.90	1080.38	42.67	788.63	1365.95
2	0.62	1157.17	43.19	813.85	1409.63
3	0.77	644.71	40.78	510.58	884.35
4	1.36	697.56	41.10	566.29	980.84
5	0.93	699.92	39.52	434.21	752.07
6	0.97	500.90	39.09	1092.96	1893.06
7	1.50	632.90	37.51	306.18	530.32
8	0.84	779.83	38.74	402.20	696.63
9	0.45	1269.14	37.62	402.03	696.34
10	0.82	1922.31	39.04	416.52	721.43
11	0.60	1918.99	40.02	497.89	862.37
12	0.64	1310.18	38.57	428.95	742.96
13	1.65	925.35	38.49	269.89	467.09
14	0.96	1073.68	37.33	235.24	407.44
15	0.59	1490.56	40.37	487.46	844.30
16	1.06	1450.27	39.02	363.97	630.41
17	0.81	1308.88	38.71	343.88	595.62
18	0.78	1012.37	38.43	303.50	525.68

6. FEM ANALYSIS OF ORTHOGONAL CUTTING

In the present work FEA of metal cutting has been performed by 3D-Deform software DEFORM-3D is a Finite Element Method (FEM) based process simulation system designed to analyze three dimensional (3D) various metal cutting processes. It provides vital information about material and thermal flow during the cutting process to facilitate the design of products and required tooling.DEFORM-3D has been used by companies worldwide to analyze turning, milling, drilling, finishing and many other metal cutting processes.



COMPARISON OF FLOW STRESS VALUES OBTAINED FROM OXLEY'S MODEL AND 3D-DEFORM MODEL

Table : Oxley's Flow stress and 3D-Deform Flow stress Values

Test No	Speed (RPM)	Depth of cut (mm)	Flow Stress (N/mm2) Oxley's	Flow Stress (N/mm2) 3D-Deform
1	884.19	0.1	1213.72	1261.7
2	884.19	0.2	1224.45	1296.2
3	1414.7	0.1	1271.37	1709.9
4	1414.7	0.2	1159.77	1378.9
5	2077.8	0.1	1240.02	1489.2
6	2077.8	0.2	1239.49	1296.2

Table: Effective Strain obtained from Oxley's and 3D-Deform

Test No	Speed (RPM)	Depth of cut (mm)	Effective strain Oxley's	Effective strain 3D-Deform
1	884.19	0.1	1080.38	50000
2	884.19	0.2	1269.14	88600
3	1414.7	0.1	1922.3	124000
4	1414.7	0.2	1012.37	816000
5	2077.8	0.1	2254	3510000
6	2077.8	0.2	1791.54	281000

Table : Effective Strain rate obtained from Oxley’s and 3D-Deform

Test No	Speed (N)	Depth of cut	Effective Strain rate	
			Oxley’s	3D-Deform
1	884.19	0.1	0.903	6.57
2	884.79	0.2	0.448	4.88
3	1414.71	0.1	0.824	8.15
4	1414.71	0.2	0.785	10.2
5	2077.85	0.1	1.008	18.3
6	2077.85	0.2	0.676	9.82

7. Conclusion

Present work utilizes an extended metal cutting analysis originally developed by Oxley and co-workers and presents an improved methodology to expand applicability of the Johnson-Cook material model to the cutting conditions.The present work, the dynamic parameters Flow stress, Cutting forces, Strain, Strain rate, Temperature distribution, Interfacial Friction at secondary shear zone are predicted using Oxley’s model.The present work, the orthogonal test values speed, feed, depth of cut are directly entered into to the 3D-Deform software so to obtained the dynamic parameters.Predicted Flow stress at secondary zone values for AISI 1045 steel are compared with the results obtained from Tensile test and 3D-Deform software, and comparison is satisfactory.Predicted Strain at secondary zone values for AISI 1045 steel are compared with the results obtained from orthogonal cutting test and 3D-Deform software, and comparison is satisfactory.Predicted Strain Rate at secondary zone values for AISI 1045 steel are compared with 3D-Deform software, and comparison is satisfactory.

FUTURE SCOPE

Johnson cook and Oxley’s co-workers are conducted Split-Hopkinson Pressure Bar Testing test, to find the constants for determine Dynamic parameters in Turning operation only. But we are not conducted another cutting operations, So extended this work to predict the dynamic parameters in milling, drilling, finishing and other machining process.Extended the work using ABAQUS software, to predict the Dynamic parameters Stress, Strain, Strain rate, Flow stress, Cutting forces. The ABAQUS software is highly sophisticated simulation.

7. BIBLIOGRAPHY

1. P.L.B. Oxley, Mechanics of Machining, an Analytical Approach to Assessing Machinability, Ellis Horwood Limited, 1989.
2. T. Özel, T. Altan, “Determination of work piece flow stress and friction at the chi-tool contact for high speed cutting,” International Journal of Machine Tool and Manufacture.
3. S.P.F.C Jaspers, J.H. Dautzenberg, “Material behaviour in metal cutting: strains, strain rates and temperatures in chip formation”, Journal of Materials Processing Technology.
4. T. Özel and E. Zeren, "A Methodology to Determine Work Material Flow Stress and Tool-Chip Interfacial.
5. Friction Properties by Using Analysis of Machining," ASME Journal of Manufacturing Science and Engineering.
6. Kalyanmoy Deb “Optimization for Engineering Design”- Algorithms and examples.