Effect of Material Modeling, Sinuous flow, Modulation techniques and different Physical Parameters on High Speed Metal Cutting-A Literature Review

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Abstract: Metal Cutting is on the most important process in manufacturing of any metal related product. In manufacturing industry, metal component are given different shapes and sizes depending on requirement. This paper focuses on analysis of metal work piece texture, contact angle and surface tension of cutting tool, changes in chip formation demanding on speed, temperature, use of vibration and depth of cut, different analysis related to parameter evolved in cutting process and deformation of work piece. The paper provides literature review of different scientific journals and paper written in the field in summarized and brief manner along with a concluded idea towards modern method of metal cutting and different parameters involved in it.

I- INTRODUCTION

In manufacturing industry, metal component are given different shapes and sizes depending on requirement. This is generally done by two processes, either by non cutting process like forging, hammering, etc or by metal cutting processes. The non metal cutting processes also require the metal cutting or machining process during finishing phase in general. Metal cutting or Metal machining process is defined as process of finishing by which work pieces are produced to the desired dimensions and surface finish by gradually removing the excess material from the preformed blank in the form of chips with the help of cutting tool(s) moved past the work surface(s).

The metal cutting or machining involves a principle of metal removal by shear force. In such process, a metal cutting tool (either single point or multiple points cutting tool) comes in contact with the work piece. By help of movement of either the work piece or cutting tool depending upon requirement and metal cutting process, shear force is developed on the work piece which leads to a strong deformation in the primary shear zone and the chip is formed. This chip is not completely formed and still in contact with the work piece and further shear stress secondary shear zone formed at contact between work piece and tool leads to deformation in work piece leading complete chip formation. This chip formation can be continuous as well as discrete. The ductile material like metals have continuous chip formation at high and semi high speed. This continuous chip formation in general leads to extra force requirement in tool end as well as create problem in further chip formation. This can be overcome by use of Low-Frequency Modulation or vibration-assisted machining which involves very small-amplitude, high-frequency vibrations. This paper gives brief summary of different analysis done in field of metal cutting focusing on Low-Frequency Modulation, Finite Element Simulation, Energy Triaxiality, Calibration of Friction, Viscous Shear Banding, Micro structural origin of Sinuous Flow and Energy Analysis.

II-REVIEW OF LITERATURE

1) **"Identification of Constitutive Material Model Parameters for High-Strain Rate Metal Cutting Conditions using Evolutionary Computational Algorithms" by Tuğrul Özel and Yiğit Karpat:**

In this paper they have discussed on improving the accuracy of speculation of behaviour of metals undergoing high-strain rate deformations with the aid of evolutionary computational algorithms. The algorithms used in this paper are the JC constitutive model and cooperative particle swarm optimization (CPSO), combined to forecast JC constitutive model parameters which are then weighed against other results. It is found that evolutionary computational algorithms have surpassed the reliability of the classical data fitting solutions. The authors accentuate the criticality of fitting obtained flow stress at various strain, strain rate and temperature to a constitutive model.

2) "The Microstructural Origin of Sinuous Flow in Metal Cutting" by Vandana A. Salilkumar and Narayan K. Sundaram:

In this paper they have discussed on sinuous flow which means that it is a basically mode of unsteady plastic flow in cutting of metal involves large plastic strains, material folding and ranging from large cutting forces to poor surface finish. The uppermost zone of work piece is divided into set of 'pseudo grains'(D) and there are 3 values of D are 100μm,50μm and 25μm. The work piece material used is either CP aluminum (Al-1100) or annealed OFHC Cu. A Lagrangian finite element analysis (FEA) is mainly defined for micro structural metal cutting. The model observes different aspects of sinuous flow in metals like non-laminar streamline flow in chips, folds and mushroom like structure on back side chip, deformed grain ratio, etc. Mainly it defines that sinuous flow in metal cutting have not require more friction, large grain size also more cutting speeds.

3) "Chip Flow and Scaling Laws in High Speed Metal Cutting" by Guy Sutter, Alain Molinari and Gautier List:

In this paper they have discussed importance of Chip formation in metal cutting process and given geometrical and graphical representation on scaling laws used in cutting. The paper mainly focuses on chip morphology in field of high speed metal cutting. In an experimental setup designed by them, they show the process of chip formation in real time by help of photographic images captured during experiment and provide with mathematical equation governing them derived from the observation. They have used the observation for providing Scaling laws which are verified theoretically and practically in the paper.

4) "Effect of Low-Frequency Modulation on Deformation and Material Flow in Cutting of Metals" by Ho Yeung, Yang Guo, James B. Mann and W. Dale Compton

In this paper, the paper effect of Low Frequency Modulation on deformation and material flow in metal cutting is discussed. This paper discusses that since continuous chip causes force increment and blockage for further chip formation, it should be tried to be overcome by making discrete chip formation in place of continuous chip formation. This paper analyze the effect of use of superimposed low frequency modulation same using high-speed photography and PIV. The smaller specific energies in cutting with modulation were found in the study and were shown to be a direct consequence of the reduction in strain levels in discrete chip formation in place of continuous chip. Analysis of streaklines in the experiment also gave important characteristics of large strain plastic deformation in the machining zone.

5) "Viscous Shear Banding in Cutting of Metals" by Koushik Viswanathan and Dinakar Sagapuram:

In this paper they have discussed on the shear banding phenomenon in cutting of Ti-6Al-4V, Inconel 718 and CP Ti alloy systems. Shear band means nothing but small zone of acute shearing strain and of plastic nature, developing for the deformation of ductile materials. Cracks are produced. It is caused in polymers when they are in compressive stresses. Shear band displacement profiles are calculated by using micro marker technique and mechanism behind it is defined by viscous flow. Systematic measurements of deformation and temperature fields of increasing shear bands are very few. Shear band viscosities forecasted by this model are very narrow and comparatively of liquid metals of their melting points. Microscopic mechanisms that subscribe to this fluid, flow at the band are examined. Therefore, Phonon dislocation damping sounds to be most credible mechanism of viscous shear band flow.

6) "Finite Element Simulation of Metal Cutting Considering Chip Behaviour and Temperature Distribution" by T. M. El Hossainy, M. H. El Shazly and M. Abd Rabou:

In this paper they have adapted the finite element method for simulating orthogonal metal cutting taking into account a number of factors such as temperature distribution along the chip and the work piece, thermal effect, cutting force values and friction along the tool rake face. The authors highlight the importance of tool

design to reduce cutting forces developed between the tool and the work piece. A simulation for chip formation in orthogonal cutting was held using a finite element analysis. The tool had a horizontal increment displacement such that cutting could be simulated against the work piece. The results of the proposed model are convincing as they match to a good degree with the experimental results. Hence, this model can be effectively used to forecast cutting force and stress during machining.

7) "Practical applications of the energy triaxiality state relationship in metal cutting" by Yalla Abushawashi, Xinran Xiao and Viktor Astakhov:

In this paper they have discussed on two basic principles: The system definition of metal cutting and The Deformation law. The different parts of the paper discuss about the development of the work piece with its material parameter and interface between chip and tool. Computational model validation is done by chip morphology and cutting forces. The rake angle significantly affects the triaxiality state and energy required for cutting .0 degree and 40 degree were taken during experiments in metal cutting. With increase in the high rake angle the performance of the tool increases by chip length and significantly 59% of the energy can be reduced while plastic deformation of layer while metal cutting. Smoother and uniform chips are made when rake angle is increased and plastic deformation decreased and lower metal cutting forces are required.

8) "Exergy Analysis of Metal Cutting Processes" by Salman Pervaiz and Mohamed Gadalla:

In this paper, it is stated that like every manufacturing process, metal cutting also involves Exergy concept which involves the flow of energy in and out of the system by considering the complete information of mass flow, heat transfer and work. The paper gives analysis of this exergy concept in contrast of metal cutting explaining process of implementation of exergy analysis to find out parameters like net output, efficiency, net work required,etc.

9) "Merging Neural Network Material Rheological Behaviour Modelling with FEM Simulation of Orthogonal Metal Cutting" by G. Giorleo, R. Teti, U. Prisco and D. D'Addona:

In this paper they have discussed on use of neural network for observing the behaviour of orthogonal metal cutting. Material used here is an AISI 1010 carbon steel with melting point of 1787 degree Celsius and 105 HRB.

By the significant use of parameters the stress-strain curve was plotted with 256 data points for temperature and strain rate. The neural network has 7 nodes in input layer, 5 nodes in hidden layer and 1 node in output layer. FEM simulation of chip formation is done in FEM code done by material modelling input. To achieve this between the neural network and FEM code continuous exchange of information is done.

10) "Revisiting the Calibration of Friction in Metal Cutting" by V. A. M. Cristino, P. A. R. Rosa and P. A. F. Martins:

In this paper, re-examination is done for pin-on-disc and ring compression tests in order to understand best fit technical modifications and operating parameters that have to be envisioned and controlled in order to obtain valid estimation value of the coefficient of friction for metal cutting process. A experiment is performed in order to do tribology test in kinematic and geometry conditions to see effect of different parameters over coefficient of friction and comparison is made between coefficient of friction obtained by pin-on-disc and ring compression tests. The conclusive results obtained gave that pin-on-disc and ring compression tests performed in dry friction conditions were capable of providing estimates of the coefficient of friction in close agreement with those found in process tribology tests based on orthogonal metal cutting.

CONCLUSION

The paper gives a brief knowledge about analysis made in metal cutting and machining in modern time. It gives brief review over analysis of chip flow and use of method like low frequency modulation for formation of discrete chip and its effect on deformation and strain. It also discusses the use of neural network in metal cutting process, frictional analysis of the process, exergy analysis of the process and gives knowledge about scaling laws in chip formation. The paper further gives brief knowledge in area of practical applications in the energy triaxiality state relationship in metal cutting and viscous shear banding in cutting process. After studying the paper it can be concluded that metal cutting process in very detailed process involving different parameters and modern advancement as helped in overcoming problem like excessive force requirement, non uniform deformation and continuous chip formation. It can also be concluded that use of Scaling laws, Calibration technique, Finite Element Stimulation can improve metal cutting process.

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