IJARSCT
International Journal of Advanced Research in Science, Communication and Technology
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
ISSN: 2581-9429
Volume 5, Issue 9, April 2025
Impact Factor: 7.67

Analysis and Development of Relationship for Tool Force and Tool Stress in end Milling Cutter by using Analytical Method

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Abstract: *Short tool life and rapid wear during micromachining of hard-to-machine materials present challenges to process efficiency. This study investigates the influence of key parameters—cutting speed, feed rate, and depth of cut—on tool life during end milling. A real-time simulation and numerical analysis were performed, and results were validated through experiments on sample specimens. Strong agreement was observed between the predicted and actual results, facilitating the development of a predictive model correlating experimental and analytical outcome..*

Keywords: Tool Force, End Milling, Numerical Analysis, Tool Stress, Real-Time Simulation.

I. INTRODUCTION

The manufacture of 3D geometric features and the ongoing tendency for miniaturization of products with a wide choice of materials, including metallic components, are increasingly in demand by micro manufacturing industries, such as medical devices and micro-molds. Material removal in micromachining is restricted by the capability of micro-tools used in the material removal process, where the tool cutting-edge radius and material properties of the workpiece directly affect the quality of finished products.1 The determination of the ratio of the minimum chip thickness to the cutting-edge radius is critical in the micro-cutting process, where the phenomenon of change from the material removal process to the plowing effect once the cutting-edge radius exceeds the minimum chip thickness value changes the dynamic performance of machining. The effect of cutting-edge on chip formation illustrated through the comparison of chip formation shows that perfectly sharp tools result in the generation of an intact individual chip. Observation of workpiece material hardness shows that it has a direct effect on micro-tool life. Metal cutting is one of the most significant manufacturing processes in the area of material removal. Black defined metal cutting as the removal of metal chips from a work piece in order to obtain a finished product with desired attributes of size, shape, and surface roughness. The imperative objective of the science of metal cutting is the solution of practical problems associated with the efficient and precise removal of metal from work piece. It has been recognized that the reliable quantitative predictions of the various technological performance measures, preferably in the form of equations, are essential to develop optimization strategies for selecting cutting conditions in process planning. The progress in the development of predictive models, based on cutting theory, has not yet met the objective; the most essential cutting performance measures, such as, tool life, cutting force, roughness of the machined surface, energy consumption, … etc., should be defined using experimental studies. Therefore, further improvement and optimization for the technological and economic performance of machining operations depend on a well based experimental methodology. Unfortunately, there is a lack of information dealing with test methodology and data evaluation in metal cutting experiments. End milling is widely used in machining molds and dies, as well as various aircraft components. To ensure cutting quality, tool life prolongation and the productivity, accurate milling process analysis is critically necessary for beforehand process planning and adaptive controlling. During the entire milling process, cutting force is one of the most important

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issues and an efficient and precise cutting force model is thus crucial for the selection of machining parameters, such as feed rate, and spindle speed. Traditional researches on cutting force model usually focus on linear milling process. Chip thickness calculation as well as cutting force coefficients identification is also analyzed specially for linear milling force simulation. These approaches do not always meet other cutting conditions, especially circular milling process. Cutting condition independent force coefficients concept was introduced into milling force modeling, however; precise instantaneous cut chip thickness and run out offset and angle factors are needed in this method to get desirable instantaneous cutting force coefficients. Size effect and other characteristics during the process may influence the simulation results eventually. Therefore, a particular model for circular milling is necessary to satisfy practical request. Regarding force simulation of circular milling, relative researches have been done recently. Proposed an approach to predict the cutting forces in the end milling of rectangular circular corner profiles by discrediting the corner into a series of steady-state cutting processes, each with different radial depth of cut investigated the relationship between working parameters and the corner coordinates by way of combination of tool tracing and cutting geometry dynamics. Developed a method for cutting force modeling related to peripheral milling of curved surfaces including the effect of cutter run out. For curved surface milling process, a series of accomplishment concluding process geometry, curvature effect, cutting force, surface error and so on. Although the above-mentioned literature has extended to a bunch of stuff for circular milling, it does not mention the variation of feed rate along cutting tool envelope during circular milling process. For the existence of work piece curvature, the feed rate along the cutting tool envelope will not remain the same as that of the tool center, and this is an important difference from the linear milling process. When establishing a cutting force model, one of the key issues is the calculation of instantaneous chip thickness, which has dependent relationship with feed rate. Abundant researches have been done on this aspect. The effects of run out, tooth trajectory as well as tool deflection on chip thickness are discussed, respectively or simultaneously. It is noticed that studying the cutting force in milling with a circular tool path, the variation of uncut chip thickness is too important to be neglected. Actually, the key elements involved in force model, for instance, feed rate and chip thickness, will deviate from their normal values during circular milling process. [9]

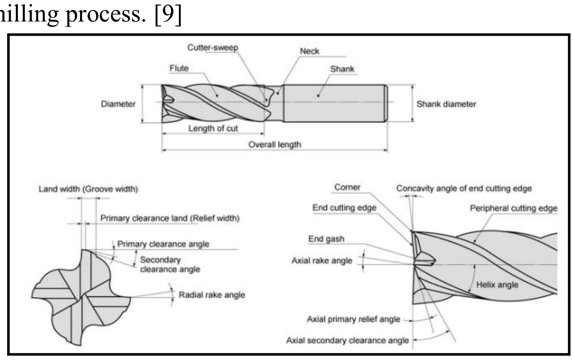

Fig.1. End milling cutter

II. LITERATURE REVIEW

Zheng, Yun Shun Shiou and Steven y. liangdeveloped in this study. This involved the convolution integration of local cutting forces with respect to the cutter orientation to yield the solution of cutting forces in the feed, cross-feed, and axial directions. The effect of the intermittent engagement is modeled with a rectangular window function in the cutter angle domain, and the effect of axial depth of cut is described by the upper limit of the convolution integration. The resulting force solutions in the angle domain are trains of pulses as functions of material cutting pressure constants, tool geometry, machining configuration, and cutting parameters.

Wen-Hsiang Lai In the simulation model, the most significant influence on the forces is the chip thickness (Tc). However, the dynamic radius caused by cutter run out and tilt is another key point to affect chip thickness. The effect of feed per flute on milling forces is apparent When feed rate is increased, the instantaneous chip thickness is increased, and forces are increased.

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Zhang, T. Huang the main conclusions that can be drawn from this work are as follows. Under stable cutting conditions, the static deflection of the cutter is the most significant deflection. Therefore, if only the static deflection is taken into account, the error of the predicted result will not be too great.

WasawatNakkiewa, Chi-Wei Linb, Jay F. Tuc, the proposed technique has been applied to determine the effect of the spindle speed, level of unbalanced mass, and spindle stiffness on the cutter/spindle radial error. The results confirm that centrifugal forces generated by the unbalanced mass are mainly responsible for the increase in cutter/spindle radial error at increased spindle speeds. This result is consistent with the prediction from a previously developed comprehensive spindle thermo-mechanical dynamic model. One way to compensate for the effect of unbalanced mass is to increase the spindle stiffness.

WAN Min*, ZHANG Wei-hong, TAN Gang, QIN Guo-huaA new approach is developed to calibrate the cutting force coefficients and the cutter radial run out parameters in flat end milling. It is shown that the total cutting forces have a closed form consisting of a nominal component independent of run out and a perturbation component depending upon run out. This decomposition makes it possible to identify the instantaneous cutting force coefficients with the nominal component. The cutter run out parameters are then determined based on the cutting force coefficients calibrated and the perturbation component. The advantage is that the influence of the cutter run out that is unknown in advance is eliminated in the calibration procedure of cutting force coefficients

A B Abdullah, D Y Chia and Z Samad the purpose of this study is to developed analytical based surface prediction technique which can be more accurate, flexible, reliable, and no- destructive and then evaluate its prediction ability. The sensitivity analysis problem proposed in this study is useful computational tool to help analysis of the relationship between the cutting parameter and the surface roughness of machined surface.[6]

Amir MahyarKhorasan, Mohammad Reza SoleymaniYazdi and Mir SaeedSafizadeh in this study, (ANN) for modelling and predicting tool life in milling parts made of Aluminium (7075) material was developed. Given the accuracy that was achieved it is safe to conclude that all the significant factors were included in the (DOE) process. The research in the present paper can be extended towards three different steps. The first step is using Taguchi (DOE) and different combinations of cutting parameters for building database. The second step is modelling tool life by using (ANN). Third step is validation by carrying out the experimental tests. In generating the (ANN) model statistical (RMS) was utilized. The accuracy error was found to be insignificant (3.034%). It was found that (ANN) prediction correlates very well with the experimental results. Finally, the correlation for training and test was obtained 0.96966 and 0.94966 respectively and mean square error was calculated 3.1908% for test data.[7]

Wu Baohai, Yan Xue, Luo Ming, GaoGe A cutting force prediction model considering the tool path curvature for circular end milling process is studied in this paper. Validation of the proposed method has been demonstrated through a serious of milling experiments. The main contributions of this Study are listed as follows:(1) By taking tool path curvature into account the chip thickness model has been improved for circular end milling process. (2) With the improved chip thickness model, cutting force model for circular end milling process has been deduced and the simulation results meet the measured results well. (3) The deduced cutting force model can be used not only for linear and circular end milling processes, but also for freeform splines if improved. [9]

ZahiaHessainia ,Ahmed Belbah, Mohamed AthmaneYallese, TarekMabrouki, Jean-François Rigal at the end of this research work some valid conclusions can be announced for the hard turning of 42CrMo4 steel (56 HRC) with Al2O3/Tic mixed ceramic. (1) Response surface methodology (RSM) combined with the factorial design of experiment is useful for predicting machined surface roughness

III. OBJECTIVES

- To develop a numerical analysis method to calculate a forces in end mill cutter.
- To develop a numerical method for force analysis and surface finishing of end mill cutter.
- To determine prediction of tool failure and condition of work piece.
- To validate real-time simulation of end mill cutter

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IV. METHODOLOGY

- To Calculation of cutting forces induced on cutting tool.
- To Simulation of Cutting tool forces for determination of stress and deformation
- Experimental analysis of forces for turning and milling operation
- Proposing a co-relationship for forces on tool and stress induced in tool.
- Defining allowable stresses for cutting tools in different condition
- Developed a numerical calculation and prediction of cutting tools condition in simulation.

V. ANALYSIS OF TOOL FOR DIFFERENT BOUNDARY CONDITION

Boundary Condition 3 for Gray Cast iron material

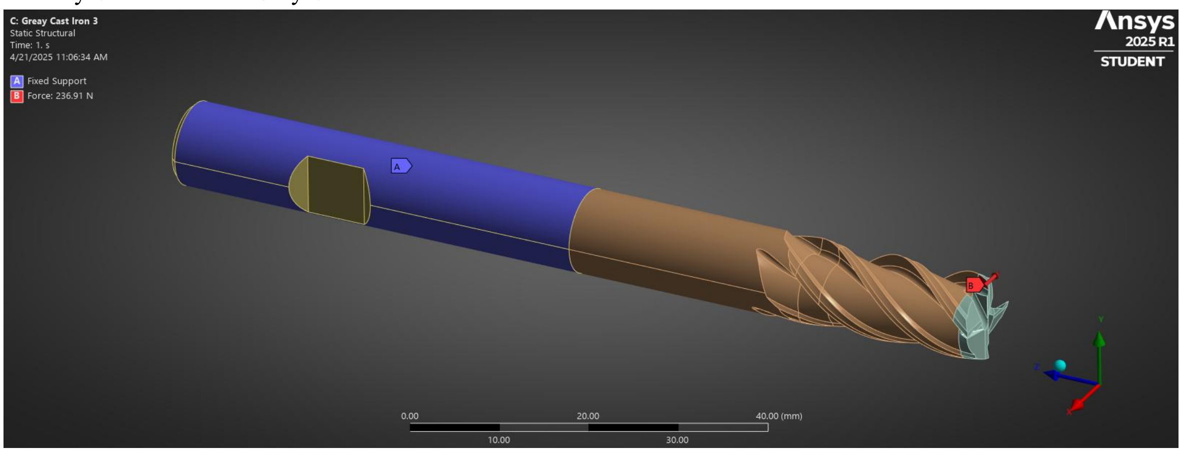

Fig 1. Boundary condition of case 3 in grey cast iron material

Stress

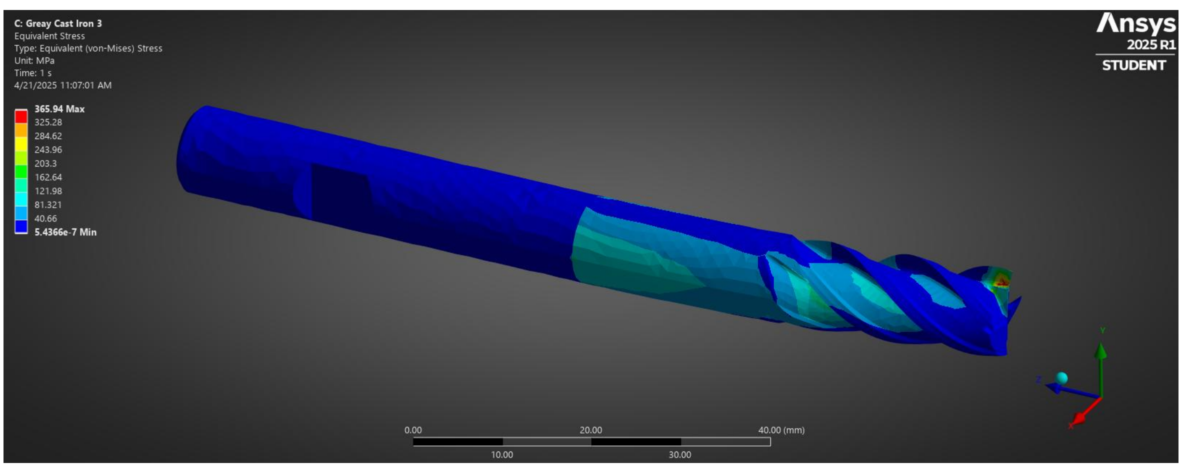

Fig 2. Stress generation due to applied boundary condition of 3 in tool

DOI: 10.48175/568

ISSN
2581-9429
IJARSCT

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Deformation

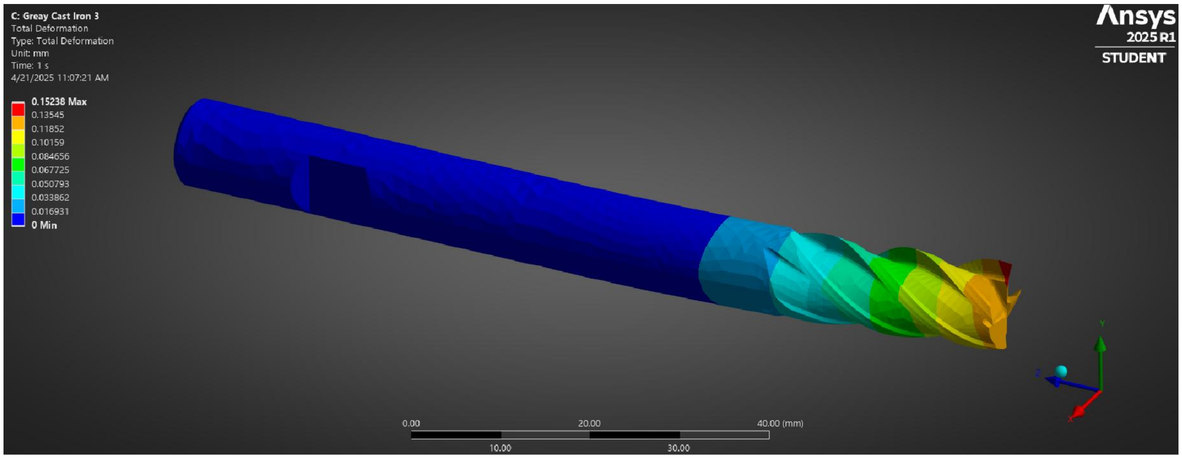

Fig 3. Deformation due to applied boundary condition of 3 in tool

Boundary Condition 7 for Aluminium Material

Stress

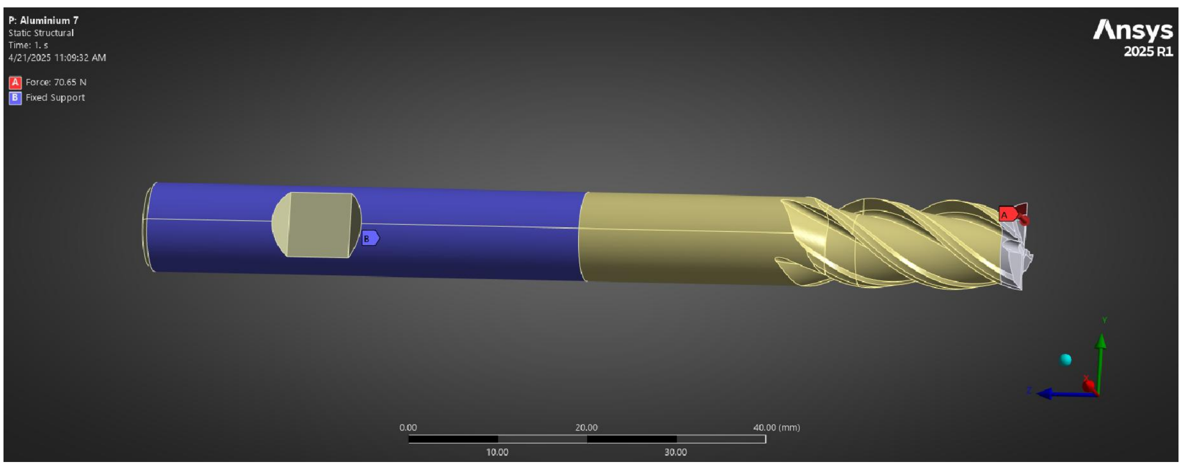

Fig 4. Boundary condition of case 7 in aluminum material

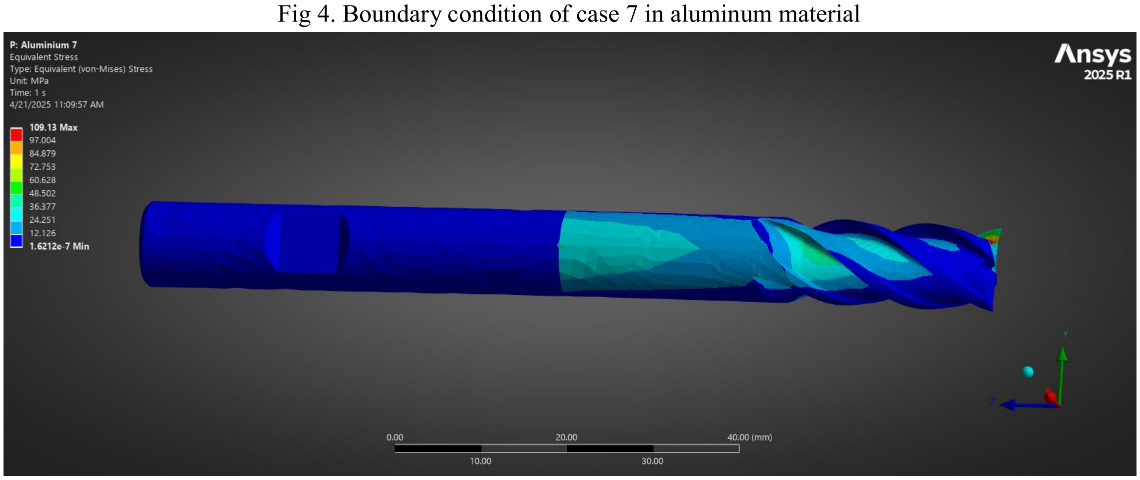

Fig 5. Stress generation due to applied boundary condition of 7 in tool

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Deformation

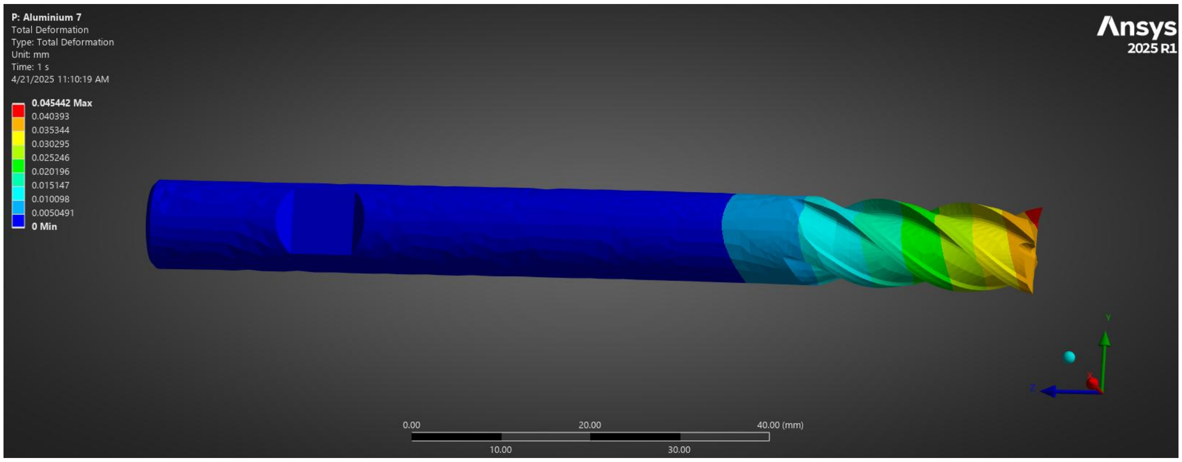

Fig 6. Deformation due to applied boundary condition of 7 in tool

VI. RESULT TABLE

Result Table for Grey Cast Iron material.

Table 1. Stress and deformation in grey cast iron due to applied different boundary condition

Sr. No.	Case	Force	Stress	Deformation
1	1	118.4592	182.96	0.07618
2	2	177.6888	197.61	0.10419
3	3	236.9184	365.94	0.15238
4	4	140.6703	217.29	0.09047
5	5	211.0055	325.93	0.13572
6	6	281.3406	434.57	0.18096
7	7	103.6518	160.1	0.06667
8	8	155.4777	240.15	0.0998
9	9	207.3036	320.21	0.13334

Result table for Aluminium Material.

Table 2. Stress and deformation in Aluminium due to applied different boundary condition

Sr. No.	Case	Force	Stress	Deformation
1	1	80.75147	124.73	0.05193
2	2	121.1272	187.09	0.077904
3	3	161.5029	249.46	0.1058
4	4	95.89237	148.12	0.0616
5	5	143.8386	222.17	0.0925
6	6	191.7847	296.23	0.12335
7	7	70.65754	109.13	0.04544
8	8	105.9863	163.7	0.06816
9	9	141.3151	218.27	0.09089

From above results tables we found that there will be change in force if we can change a work-piece material of machine.

We found that if we used same running condition of tool then also change in force of tool, due to this change in force of tool stress and deformation of tool also change

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Minimum stress in all condition is 109.33 MPa and deformation is 0.04544mm

If we used allowable stress of High carbon tool is 262.5MPa then 4 condition in Gray cast iron and one condition in aluminium material having tool failure.

So, we can easily calculate a breaking point of tool and finding out safe zone condition of tool by using Excel sheet developed by us.

VII. FUTURE SCOPE

We can also develop condition for all material which are normally used for manufacturing

We can develop any programming software for calculation of tool force as well as we can developed a software to display your safe condition and unsafe condition of tool.

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