Experimental Study of Machining Cutting Force, Chip Compression Ratio and Coefficient of Friction.

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ABSTRACT
The contact length of chip to the tool rake surface of the tool and the extent of sliding and seizure has the major role in finite element modeling of machining process. Thus the experimental study of machining force, chip contact ratio and coefficient of friction will contribute for the improvement of machinabilty studies. The literature survey of well established metal cutting models and many other authors is done and compared.

Keywords: Cutting force, chip compression ratio, Coefficient of friction, Tool chip contact length, finite element modeling of machining.

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INTRODUCTION

Metal cutting is the fundamental basis of industries of engineering for manufacturing. The study of machining is very important for forming a scientific base and providing a scientific approach to solve problems and bring improvement in machining process. Modeling of machining process is a complex task. The friction conditions and the tribology is very important for understanding machining. The FEM models are also based on lot of assumptions regarding the dynamics and non linear parameters. Trent[1] has described that while machining the tool also slides along with cutting and seizure of chip happens at tool chip interface. Saubhi and Chandrashekaran[2] have studied about the nature of tool chip contact area. The tool chip adhesion takes place and the layer is deformed during machining. The orthogonal machining produces chips which curl after a distance on the rake surface. This distance is called the contact length. In his work Childs[3] has described the importance of flow stress data for developing the models for machining. Zorev [4] has described that during a machining process a part of layer of chip slides and some part gets seized. This seizure is solid state welding of chip to surface of work piece. The extent of sliding and seizure i.e.

sticking is important and critical information required for FEM modeling of machining and tool design. The types of friction modeling formed based on stick, slide geometry on chips are Merchant's proposed full sliding, Zorev's model of sticking and sliding. Any mistake in the assumption in the sticking length i.e. the contact length will result in wrong calculation of coefficient of friction which in turn gives poor results for the calculation of cutting forces, power and temperature.. The most important input in modeling of machining and simulation is friction conditions. But the nature of tool chip interfaces is assumed which affects the results in finite element modeling. The nature of cutting at low speeds is sliding [5].The nature of metal cutting starts changing as the speed increases and the seizing tribological contact between tool chip interface takes place as shown by Trent. The seizure is a weld between the surfaces. The chip contact length is from the edge of the cutting to a distance along the rake face where it starts curling. The heat dissipation is dependent on this contact length. The other factors which affect the contact length are machining variables, the geometry of tool and chip, the composition of workpiece and tool material and cutting fluid [6, 7].The interface between tool and workpiece chip is dependent on cutting parameters and the properties of cutting tool and work material [8, 9].The flow stress and friction conditions are the main inputs required for finite element as shown by Childs et al. [10].A layer of contact on the tool by chip is stationery and gradually the other layers are in relative motion due to the shearing velocity and the bulk chip velocity is attained[11]. Wright et al [11] suggested a cluster of microscopic nodes which may be either sticking or sliding Raman et al [12] have shown various contact scenarios of chip and tool surface while machining.

MATERIALS AND METHODS

The experiments were conducted using a conventional lathe. The material chosen for machining is AISI 4340 plain carbon steel. This material is used commonly in many industrial applications, machinery parts and in FE modeling work and therefore models can be analyzed. The material is a cylinder of 30 mm dia. The machining was performed orthogonally with a commercially available tungsten based flat triangular uncoated cemented carbide inserts. The rake angle is of 0^0.The depth of cut was kept as 1 mm and feed as 0.1mm/rev. Four different cutting speeds were used for machining. These four speed levels are for low speed, mid range and high speed of machining. The speeds are 200 m/min, 400m/min, 600 m/min, and 800 m/min. The speeds selected are the surface speed with units of meters per minute i.e. the travel of tool tip on the surface of workpiece which is the better indicator of cutting speed compared to spindle rpm. The spindle rpm indicates only the speed of rotation of spindle irrespective of whatever diameter of work piece is chosen whereas the surface speed increases or decreases with respect to the diameter of workpiece. Lathe tool dynamometer is connected to the lathe for force measurement. In a turning process three types of cutting forces can be measured by force measuring sensor dynamometer. They are the tangential cutting force, radial force and axial feed force. In orthogonal turn machining only two components of force is present. Fig.1 shows the chip formation, cutting forces and shear angle. The force component along the direction of cutting known as cutting force and denoted by f_c and the component perpendicular to the direction of cutting is known as thrust force and is denoted by f_t..These components are determined by lathe tool dynamometer which is an instrument having high rigidity and high natural frequency.

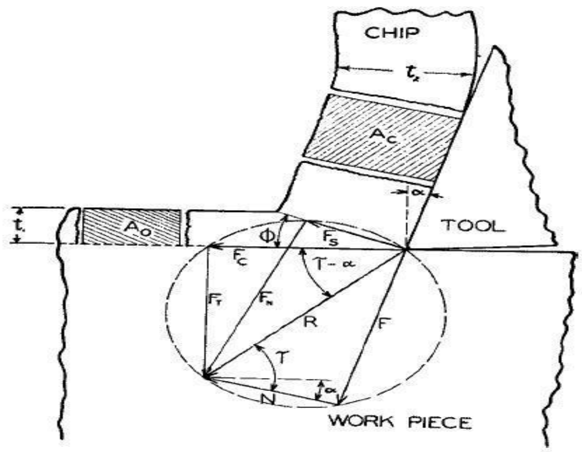

Fig 1.The chip formation process

The strain gauges present in the instrument measures the horizontal and vertical deflections due to the resultant force acting on the workpiece by the cutting tool. The deflections or strains are calibrated to give the reading of two components of forces.

Shear plane

Most of the studies in metal cutting modeling are based on study of shear plane. Ernst and Merchant called the deformation zone which is shown by a plane as shear plane. The shear plane is an inclination at an angle in the direction of cutting and it is called as shear angle Ø.

Coefficient of friction

Generally in engineering the coefficient of friction is defined as the ratio of force in the metal cutting sliding direction and the force normal to the sliding interface. But this definition is too simple to describe the complex nature of seizure during metal cutting. Hsu has shown that by controlling the contact area between tool and chip the coefficient of friction can be controlled.
The chips were collected and the chip thickness was measured with the micrometer.
Chip thickness ratio r can be calculated as $r = t_o/t_c$, where t_0 is undeformed thickness i.e. the feed and t_c is the measured value of chip thickness.
The shear angle can be calculated as tan Ø = r cos α/1-r sin α where Ø is shear angle and α is rake angle.
The coefficient of friction can be calculated μ = tan β, where μ is coefficient of friction and β can be calculated as β= 90 + α - 2Ø.

RESULTS AND DISCUSSIONS

The variation of cutting forces with the change in cutting speed keeping the depth of cut and feed constant are experimented as shown in Fig 2.

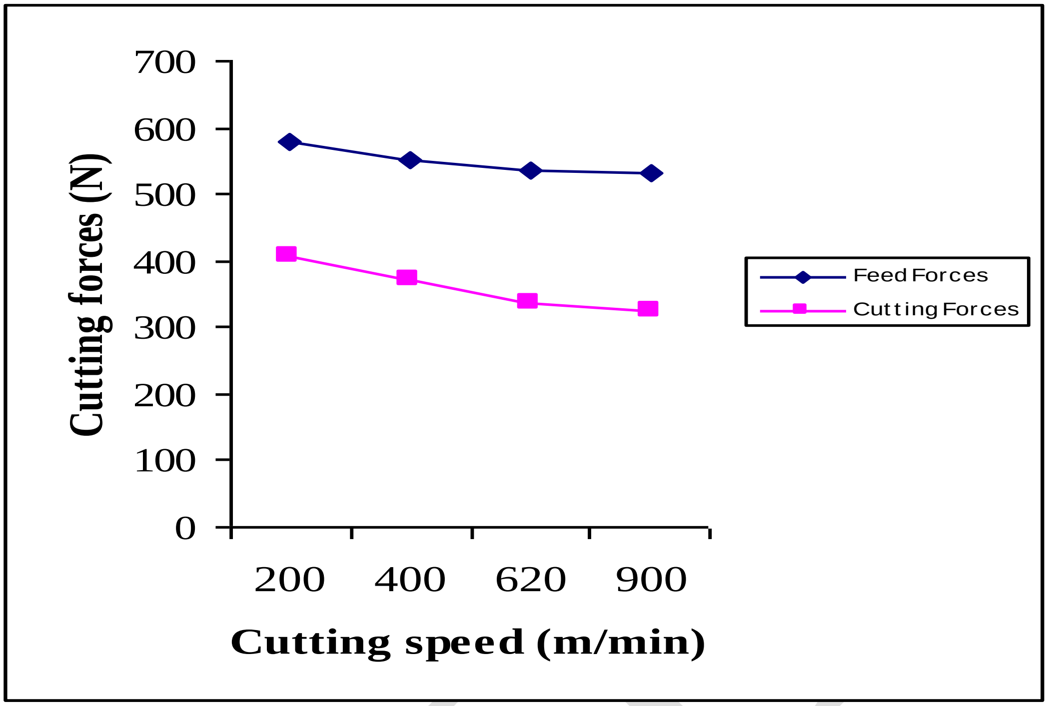

Fig. 2 Variations in the cutting force and feed force with the cutting speed.

Fig. shows that the cutting forces decrease as the speed of cutting increase. This trend is also noted in the work of [13, 14].

Reduction in cutting forces is one of the major benefits of high speed machining. The reduction in forces is due to the flow stress which gets minimized at higher speeds and elevation of cutting temperature and thermal energy.[15,16].

Fig.3 shows the Variation in the coefficient of friction with the cutting speed. The coefficient of friction decreases as the speed of cutting increases.
This parameter is most important to define contact between tool and chip interface. The major assumption made during finite element analysis is the extent of sliding or seizure in the contact area while machining and also the quantity of heat transfer is dependent on it.

Fig.4 shows the variation of chip compression ratio and shear angle and shear angle with the cutting speed. The chip compression ratio decreases as the speed increases while the shear angle increases with the increase in cutting speed.
Chip compression ratio shows the amount by which the chip is deformed. The shear angle shows the shear plane inclination at an angle in the direction of cutting and it is the plane of inclination showing the deformation.
The decrease in shear angle will result in decrease of cutting forces. The shear angle is also dependent on chip compression ratio.

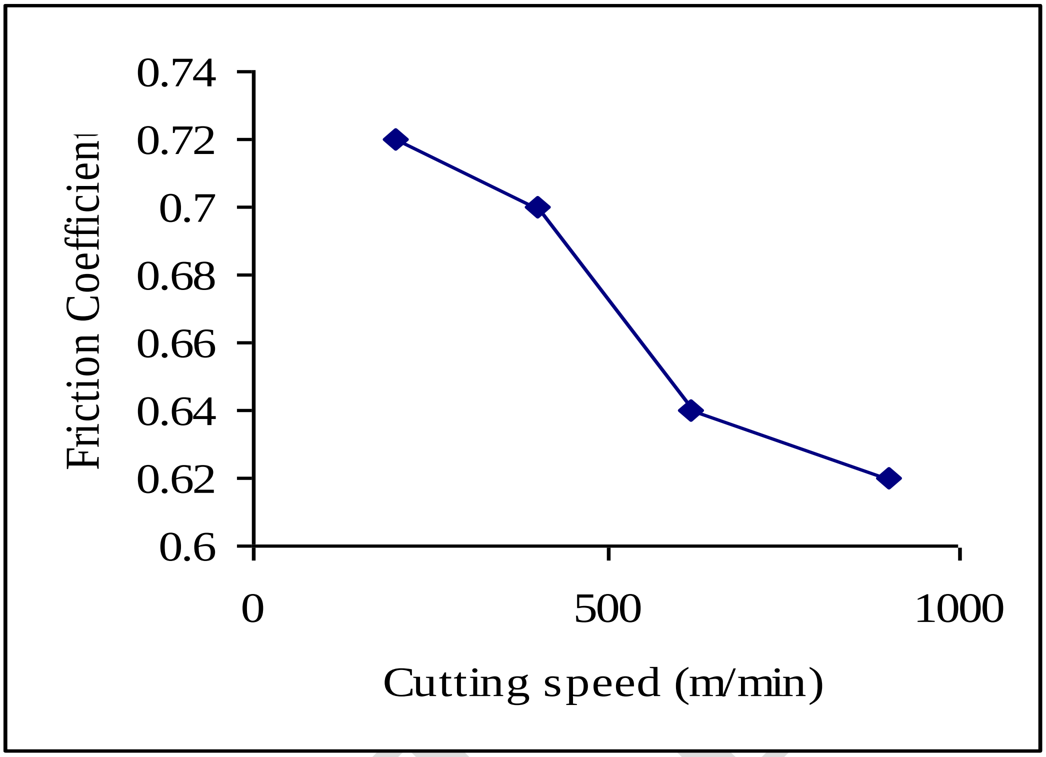

Fig.3 Variation in the coefficient of friction with the cutting speed.

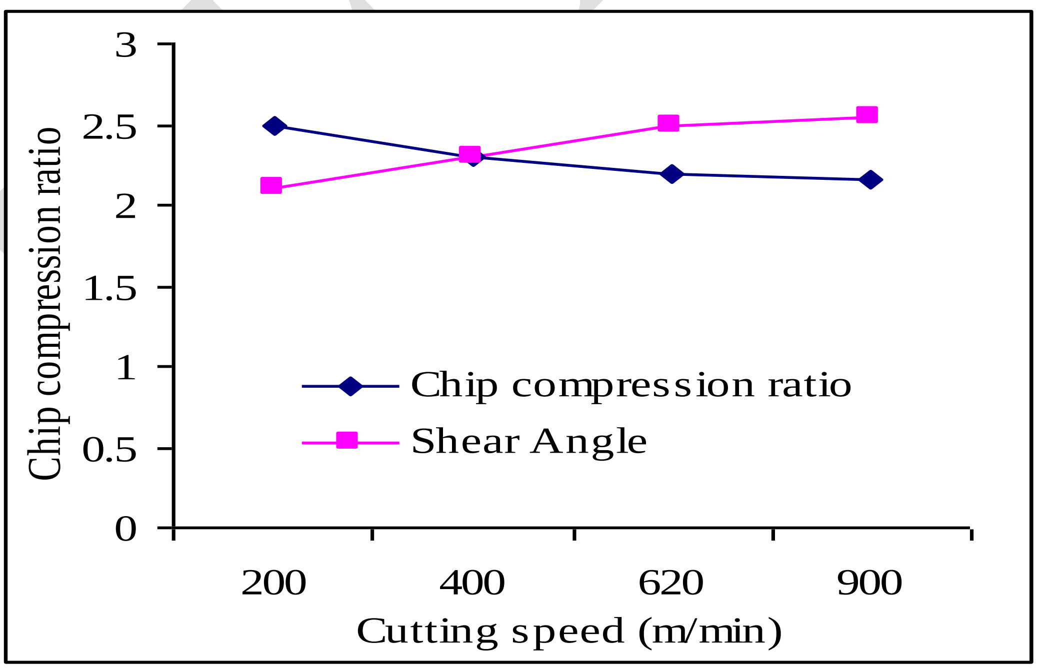

Fig.4 Variation in the chip compression ratio and shear angle with the cutting speed.

CONCLUSIONS

The study will help in making a better assumption of the extent of sliding and seizure in the contact length while machining for the finite element analysis. The chip compression ratio, shear angle and coefficient of friction are the parameters which has the major effect on the nature of machining and will contribute for the improvement of machineability.

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