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# General Formula for Optimum Location of Chip Breaker in Tool Inserts for Industrial Safety

**Gourav Vivek Kulkarni[1], Ajay Parulkar[2]**

[1]Design Engineer, Expert Valve and Equipment Private Limited, Belagavi, Karnataka, India
[1]Associate Member of the Institution of Engineers, India
[2]Program Engineer, Planning and Control, Advent Tool Tech Private Limited, Pune, Maharashtra, India
[2]Certified for Lean Green Belt Six Sigma – ASCB (Europe) Ltd - UK

**ABSTRACT**

Metal cutting process depends on chip generation for its effectiveness. It is a measurable quantity which largely depends on the nature of chips generated and its effect on the tool performance. This paper shall consider occupational health and safety to address the concept of chip breakers used in machining of ductile materials. The mechanics of metal cutting shall be the basis for the said derivation with the premise being that of fracture on account of a combined state of bending and shear stresses during the chip propagation. This can be effective to design tool inserts with optima in perspective so that the end users being machine operators are ensured with a safe working zone without the presence of long continuous chips that can cause hazards like bodily injury or severing of delicate organs thereby meeting the international standard requirements. Towards the end, various health and safety aspects shall be summarized and a conclusion shall be drawn accordingly.

***KEYWORDS***: *tool; chip; rake; safety; machine; shear*

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## A. INTRODUCTION

Occupational health and safety has gained prominence over the years to such an extent that the International Organization for Standardization has released ISO 45001:2018 replacing the OHSAS 18001:2007 thereby displaying the need to transition towards an international norm in the aspect of industrial health and safety. While the international standard is pervasive for almost all types of industries, this study shall be limited to manufacturing industries that involve metal cutting process using single point cutting tools.

Every operation involves a certain risk associated with it and mitigating the same with appropriate controls in place is the standard requirement. In the manufacturing industries with machine tools using single point cutting tools, a major health and safety concern involves chip generation and associated management. In this study, initially for the purpose of acquaintance, certain fundamentals of metal cutting and chip generation shall be briefed. It is evident that longer continuous chips are hazardous from various stand points. Chip breakers are designed in order to arrest the generation of the same and yield shorter chips that can be easily managed.

Over the years, by method of simulation, tool inserts are provided with chip breakers at locations such that the chips generated are adequately directed and fractured accordingly. However a general formula governing the optimum location of chip breakers in tool inserts was not evident during the literature survey. Hence this study intends to propose a general formula governing the same.

## B. Occupational Health and Safety

Health and safety is a term pervasive to all kinds of occupations. In these, there may not be any kind of classification based on the severity of the work undertaken or the skill set of the workers. According to the latest international standard on Occupational health and safety viz. ISO 45001:2018, it is essential that every worker is governed by a system that ensures well being of their health and safety at the workplace. There are certain occupations that require training while others that do not but a common aspect required by all occupations is a certain basic set of skills which can be developed over a period of time by means of practical experience. This paper shall consider manufacturing industries and the workers employed in the same.

## C. Industrial Health and Safety

Industrial health and safety is a sub set of occupational health and safety. Industries may be divided into manufacturing and service types out of which, the former requires a greater control over system compliance to ensure health and safety of the interested parties. According to the standard requirements, every activity has a certain risk associated with it and there need to be definite measures to mitigate the risks. Non compliance with the system procedures and instructions can lead to events like near miss, incidents and accidents. Thus taking into perspective the health and safety of the workers involved, equipment and processes should be planned in a manner such that there are no system non compliances such as absence of safety measures. Needs and expectations of all the internal as well as external parties are nothing beyond than a safe work place of physical and psychological well being.

**D. Fundamentals of metal cutting process**

For the purpose of acquaintance, the fundamentals of metal cutting process shall be briefly discussed. Metal cutting or machining is a type of subtractive manufacturing process wherein the excess material is removed from the work-piece in the form of chips. Chip refers to a piece of metal that may look similar to a ribbon or powder that is generated due to a sharp tool. At the point of contact of the tool and the work-piece, due to the velocity of the tool, a shearing zone is create wherein the material is deformed plastically and it flows in the form of chips.

**E. Risk assessment of metal cutting process**

As stated earlier, every activity performed as a part of a process, has certain risks associated with it. There can practically be no process which is free from risks. When it comes to metal cutting, a major risk that can be identified is the bodily injury that can take place on account of chip generation during the machining process. There are several other risks such as jamming of the tool which may lead to damage of the machine itself. This paper shall address the mitigation of risk of bodily injury due to chip generation by introducing a general formula for determination of optimum location of a chip breaker.

**F. Chip generation**

Depending upon the type of material being machined, cutting speed, feed and depth of cut, chips can be of three types.

First type is that of continuous chips which are formed on machining of ductile materials with moderate feed and low depth of cut. These are difficult to manage and require chip breakers.

Second type is that of discontinuous chips which are formed on machining of brittle materials or ductile materials with heavy feed and high depth of cut. These may be easier to manage but are considered as a hazard owing to the probability of fly off on account of small size.

Third type is that of a continuous chip with a built up edge. This is a rare occurrence but is considered to be equally dangerous. If the temperature at the cutting edge exceeds a certain safe value, a small piece of metal being cut gets adhered to the cutting edge. The joint is as strong as a welded joint. For the following short period of time, this additional piece enables efficient machining but when the joint becomes weak due to the resultant of the feed force and the shear force, the piece gets violently detached and carries away a chunk of the tool thereby rendering both to be of no use. Thus it is necessary to avoid this occurrence and chip breakers can positively do the needful.

**G. Chip breakers**

Chip breakers can be comprehended as protrusions on the rake surface of the tool which facilitate the fracture of a continuous chip by means of introducing bending stresses. Adequate evidence was not found so as to confirm a general formula to get the optimum location of the chip breaker which has led to this work.

**H. General formula for optimum location of chip breaker**

In this paper, to come up with a general formula, a ductile material has been considered. Following assumptions same as that of Merchant Theory for orthogonal metal cutting have been made.

Tool is perfectly sharp and there is no contact along the clearance face. Shear surface is a plane extending upward from the cutting plane. Cutting edge is a straight line, perpendicular to the direction of motion. Chip does not flow to either side of the tool rake surface thereby establishing complete contact. Depth of cut is constant. Width of the tool is greater than that of the work-piece. Work moves relative to the tool with uniform velocity. A continuous chip is produced without a built up edge. Plain strain conditions exist. Chip is assumed to shear continuously under fluid conditions and minimum friction

A little consideration will show that the chip can be fractured by the chip breaker by introducing bending stresses in it.

According to the general bending equation, where 'σ' is the Bending stress at fracture, 'M' is the bending moment and 'Z' is the section modulus,

$$M = Z * \sigma \quad (1)$$

The bending stress shall be equated to the stress at fracture to obtain a value for the Bending Moment corresponding to the section modulus of the chip. Referring to the assumptions, since the width of the tool is greater than that of the work-piece; the section modulus is weak enough to allow yielding and successive plastic deformation of the chip.

On obtaining a value for the Bending Moment, the optimum location of the chip breaker is equal the moment arm. Considering 'a' to be the moment arm i.e. the optimum location of the chip breaker and 'F' to be the cutting force corresponding to the cutting velocity,

$$M = F * a \quad (2)$$

Where 'F' can be determined practically with the help of dynamometers by graphically calculating the resultant of force corresponding to chip velocity and shear force of cutting. 'F' can also be calculated theoretically by taking the product of material removal rate and the cutting velocity.

Equating (1) and (2),

$$F * a = Z * \sigma \quad (3)$$

$$a = (Z * \sigma) / F \quad (4)$$

Equation (4) gives the value of moment arm i.e. the current location of the chip breaker for the given chip dimensions, work material and the cutting force.

In order to obtain the optimum location i.e. dimension 'a', the condition is that the chip should fracture at a minimum value of bending moment. This can be achieved applying force 'F' at the optimum location 'a'.

Thus for minima,

$$da/dF = 0 \quad (5)$$

On substitution and simplification, the condition for minima is obtained as follows.

$$-(Z * \sigma) / F^2 \rightarrow 0 \quad (6)$$

Equation (6) signifies that the cutting force should be large enough so that the value of the ratio tends to zero and is not equal to zero. The negative sign indicates that the compressive stresses on the surface of the chip adjacent to the rake surface are predominant to cause fracture due to the presence of the chip breaker.

### I. Tool performance

The formula derived proposes an optimum location of the chip breaker on the tool and this is in turn linked to the tool performance. Tool performance is mainly measured by the time between replacements of inserts of tool for a constant rate of production. Tools with effective chip breakers can further enhance the shearing at the rake surface such that the reaction to the shear force is minimum. By this, the quantum of abrasion is less and thus the rate tool wear can decrease by which the tool can be used for a greater magnitude of material removal.

The design must consider the fact that too small chips may get formed unevenly which can lead to a possibility of tool jamming thereby demanding a need to have periodic cleaning which can lead to loss of optimum production time in maintenance. During machining operation, heat generation is another aspect that determines the efficiency of the metal cutting operation and has direct relevance to the tool performance. Chip breakers designed need to effectively manage the heat generated by dissipating the same in the form of chips in addition to the use of coolants while avoiding the formation of built up edges.

### J. Overall operational productivity

Operational productivity can be defined as the ratio of time for which the machine was operational to the total productive time available.

Chip generation can be considered to be the pinnacle of a machining process. It is essential that the material removal takes places as efficiently as possible in the least possible time for the most possible number of components in a batch. Productivity is highly dependent upon the elimination of hindrances during the process. On setting a suitable cutting speed and feed, the depth of cut does play a vital role in determining the operational productivity as the time taken for a particular cut remains the same. For operations with light feed and depth of cut lesser than 0.5 mm per pass, the number of passes increases although the tooling as well as the machine is capable of performing better. Thus it is essential that the process is finalized by design. Operational productivity can be further increased by maintaining the safety conditions as the time lost to address near miss or incidents or accidents can be effectively brought down or eliminated. The tool performance is in a way directly linked to the output as it is necessary that productive time is not lost in breakdown maintenance.

### K. Effects on health and safety

This shall be comprehended from two stand points viz. psychological and physical. Health and safety has over the years become a standard requirement for most of the industries if not all of them. Every activity in an industry does have certain effects on the workers which in turn has a greater impact on the productivity.

Psychological well being of workers is essential to reduce the idle time and increase the productivity. Although this parameter is not completely measurable, it is virtually essential. During machining operations, worker's needs and expectations include tooling to be in place such that long continuous chips are not generated although they are easier to handle as compared to shorter discontinuous chips. However, effective tooling can drastically reduce the chances of chips with built up edges which is considered as a potential hazard as it can cause pronounced damage to the tool as well as the work-piece when the built up edge is broken. Proper design of chip breakers can eliminate built up edges and can lead to a psychological state of assurance that there won't be any incidents or accidents due to long continuous chips. This can be beneficial to both, the new comers as well as the experienced workers since both are vulnerable owing to their respective experience and age.

The physical aspect is quite evident and is measurable whose impact on the process is deterioration of health and productivity of machines. During the machining process, longer continuous chips are difficult to manage and store. Due to the shear edge generated, there is a risk of physical injury. Handling of such chips on the other hand is easier for longer continuous chips. Worker health can be improved by use of personal protection equipment such that particles of metal do not cause significant damage to the vulnerable organs. Chip breakers can instill significant safety in the process and can lead to improvement of overall occupational health and safety of the unit as well.

## Conclusion

Thus it can be concluded that considering the mechanics of metal cutting from the perspective of occupational health and safety, a general formula has been derived with a condition of minima for the optimum location. Qualitative aspects have been thus set such that further experimentation can lead to validation of the same such that quantitative parameters are established. As a part of continuous improvement, outcome of experimentation can aid improvement in the tool performance and reduction in optimum productive time lost in maintenance.


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