IJARSCT
ISSN (Online) 2581-9429

Impact Factor: 6.252

International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)

Volume 2, Issue 1, October 2022

Study of Different Types of Tool Failures to Improve Cutting Tool Life

Prof. Santosh Vitthal Kadam[1] and Prof. Mrs. Sarika Kishor Kahre[2]
M.E (Mechanical Engg.), Work Shop Superintendent, Department of Mechanical Engineering[1]
Lecturer, Department of Mechanical Engineering[2]
Bharati Vidyapeeth Institute of Technology, Navi Mumbai, Maharashtra, India

Abstract: *In the Metal removal process, as tool wear increase causes Tool failure and contributes to increased Machining cost. To reduce the machining cost, improve production rate and achieve world class efficiency it is essential to study the Tool failure modes and optimize every possibility. The ultimate failure is understood to have taken place when the tool has worn out and can machine no more and could break under the cutting forces enhanced due to the blunt cutting edge. The Gradual wear that leads to this ultimate failure is unavoidable but controllable. On the other hand a tool could fail due to many avoidable causes which we would call as premature failure. In this paper, we are discussing the most common tool failure, causes of failure and failure minimizing techniques.*

Keywords: Tool wear, Tool Failure, Modes of Tool Failure, Tool Failure Prediction, Cutting Tools

I. INTRODUCTION

Recent developments in technology have put tremendous pressure on manufacturing industries to decrease the cutting cost, increase the quality of machined components. Cutting tools are subjected to wear and fails, we need to consider the optimum utilization of tool by enhancing the tool life by best practices to reduce the production cost.

The following aspects of a cutting tool play significant role in determining the productivity of a machining operation:

1) Tool Material
2) Tool Construction
3) Tool Geometry

II. CUTTING TOOL MATERIALS

The cutting tool materials that are commonly used are:

- Plain carbon and low alloy steels
- High-speed steels
- Cemented carbides, cermets and coated carbides
- Ceramics
- Synthetic diamond (Poly Crystalline Diamond-PCD) and cubic boron nitride (CBN)

Tool Material Properties

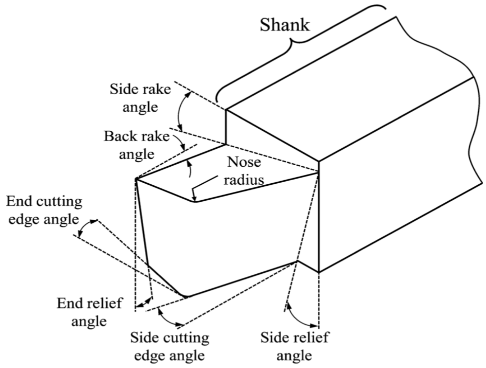
1. Red Hot Hardness
2. Toughness
3. Wear Resistant
4. Low co-efficient of friction and
5. Good thermal conductivity and specific heat

III. MECHANISM OF METAL CUTTING (GEOMETRY)

The Mechanics of Metal Cutting is controlled by three main elements. 1) Rake Angles 2) Lead Angles 3) Clearance Angle

Rake angle-controls the cutting forces Cutting Forces change approximately 1% per degree of Rake change (mild steel)

Lead Angles Increasing the Lead Angle places the forces more into the Radial Plane.



The greater the angle, the greater is the rigidity.

Clearance Angles

Tool Material Selection Factors to be considered in selection of cutting tool material: 1) Heat (thermal deformation) 2) Pressure (deformation, fracture) 3) Wear (pure abrasion, chemical wear, notching) 4) Interrupted cuts (thermal & mechanical cycling)

IV. FAILURE, CAUSES FOR FAILUREANDMINIMISING TECHNIQUES

Categories of Tool failure are

Abrasive Wear

1) Flank Wear

Mechanical Failure

1) Chipping 1a. Flank Chipping 1b. Rake FaceChipping

2) Depth of Cut notching

3) Fracture

Heat Failure

1) Built up Edge 1a. Rake Surface 1b. Flank Surface

2) Thermal Cracking

3) Crater Wear

4) Thermal Deformation

4.1 Abrasive Wear

Abrasive wear occurs as a result of the interaction between the work piece and the cutting edge. This interaction results in the abrading away of relief on the flank of the tool. This loss of relief is referred to as a wear land. It depends on the hardness, elastic properties and Geometry of the two mating surfaces. The larger the amount of elastic deformation a surface can sustain, the greater will be its resistance to abrasion. A Brittle material like cast iron causes more of abrasion wear than ductile steel. It must also be noted that any material transferred from one surface to another which is highly strain hardened could add to the abrasive wear. Further, the oxidation of the nascent metal produces hard oxide particles which again contribute to the abrasive wear. The width of the wear land is determined by the amount of contact between the cutting edge and the work piece.

4.2 Flank Wear

Flank: Is the Flat Surface of an insert perpendicular to the rake face

The cutting force normal to the direction of velocity keeps the tool pressed against the wok piece. The friction between clearance face and the machined surface progressively flattens the cutting edge. A flat wear land is produced on the clearance face extending from the cutting edge along the clearance face. As the length of the wear land increases friction and heat generated in cutting increased and leads to further wear. When the wear land reaches a critical value cutting becomes difficult. It leaves a Burnished mark on the surface. More energy is required to remove the same amount of material. Flank wear is mostly caused by abrasion of the flank It is observed on the tool clearance face as shown Worsened by higher temperatures (speed) and cutting tool pressure Flank wear is the desired tool failure mechanism. It is only failure mechanism that is predictable Mechanical Failures

4.3 Mechanical Failures

It occurs from Insert wear caused by intense physical contact between an insert and a work piece Main Mechanical Failures are
1) Chipping
2) Notching
3) Fracture Chipping Tool wear results in the loss of small slivers from the cutting edge of the tool.
Chipping is also called frittering.
There are two Types of Chipping
1) Flank Chipping
2) Rake Face Chipping

Flank Chipping or Mechanical Chipping:- Mechanical Chipping occurs when small particles of the cutting edge are broken away rather than being abraded away in abrasive wear. This happens when the mechanical load exceeds the strength of the cutting edge.

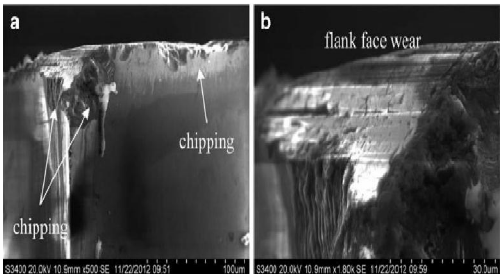


Figure: SEM image for tool wear on tool tip a) Mechanical chipping b) flank wear

Mechanical chipping is common in operations having variable shock loads, such as interrupted cuts. Chipping causes the cutting edge to be ragged altering both the rake face and flank clearance. This ragged edge is less inefficient, causing forces and temperature to increase, resulting in significantly reduced tool life.

Mechanical chipping is often the result of an unstable setup. i.e., a tool holder or boring bar extended to far past the ideal length/diameter ratio, unsupported work pieces etc..,

Mechanical chipping is best identified by observing the size of the chip on both the rake surface and the flank surface. The forces are normally exerted down onto the rake surface producing a smaller chip on the rake surface and a larger chip on the flank surface (Shown in fig.10)

Chipping occurs when work pieces/cutting edge interface does not have adequate clearance to facilitate an effective cut. This may be result of misapplication of a cutting tool with inadequate clearance for the work pieces material being cut.

Depth of cut notching

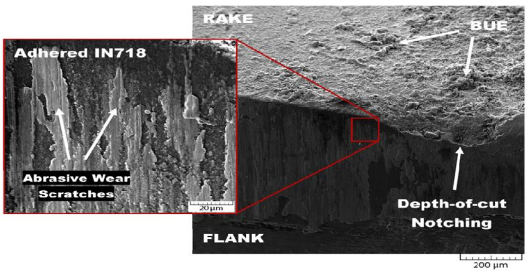


Figure: SEM Image for worn ceramic tool after cutting

It was described that the hardness of the chip and a thin layer of the machined surface were significantly harder than the bulk material. It may be visualized that in turning, the tool will have its tip in the bulk of the material; but at the distance equaling the depth of cut, the tool will be cutting through some significantly harder material (the work hardened layer)causing a notch to appear on the flank face, called the depth of cut notch. Depending on the shape and geometry of the tool, the notch wear can be highly influential on tool life or be completely insignificant compared with

IJARSCT
ISSN (Online) 2581-9429
International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)
Volume 2, Issue 1, October 2022
Impact Factor: 6.252

other modes of wear.

Effect

- Localized failure at the depth of cut line. – Localized Chipping – Localized Cratering
- Typical with SS, high temperature alloys, & all work-hardening materials
- Typical when the work pieces has scale or a hardened surface.

Depth-of-Cut Notching can be minimized by following Methods

- by CVD coatings
- by Cobalt enriched grades
- Increased lead angle (thins the chip reducing forces)
- Use tapered cuts

Fracture

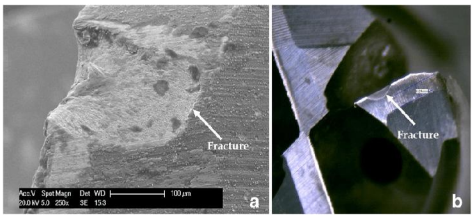


Figure: Final wear of cutting tool edge , Fracture at tool nose

Tool Fracture occurs when the tool is unable to support the cutting force over the tool-chip contact area and results in loss of only a small part of tool. It is called as Chipping or Breakage It is Common in interrupted cuts and in non rigid setups. Chipping and Breakage can be minimized by using

- Tougher cutting tool material: – Cobalt enriched grades – higher cobalt – TiC, & TaC, bearing grades
- Stronger geometry a. By using Negative rake rather than the positive rake b. Increasing Tool Nose
- Maximize rigidity
- Reduced metal removal rate

Heat Related Failure

Below are Heat related Failures occurring in Cutting tool.

1. Built Up Edge
2. Thermal Cracking
3. Cratering
4. Thermal Deformation

Built-Up Edge

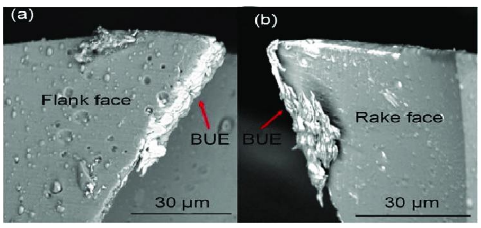


Figure: Built up edge at a) Flak face b) Rake face

Built-up Edge is also called as Adhesion. This occurs due to welding between the tool and chip (i.e work material is deposited on the rake and flank face of the tool) at the asperities and the subsequent breakage of the welds. When weld breaks it plucks away material from the tool. We can expect that this wear will be inversely proportional to the hardness of the work material and directly proportional to the normal stress on the sliding surface. It is the product of the localized high temperature and extreme pressure at the tool and chip interface. It depends on the Normal face between the sliding surfaces and the apparent area of contact. It is dependent upon the Relative hardness of the chip and tool.

Built-up edge are not stable and will slough off periodically, adhering to the chip or passing through the tool and adhering to the machined surface. Generally adhesion occurs on soft, gummy work pieces materials.

Rake Face

- Welding of work pieces material to the rake face of the cutting tool
- Loss of effective geometry causes increases in cutting forces and eventual tool breakage
- Using Higher cutting speed- At high speeds, that is at high tool-chip interface temperatures, the welds between tool and chip would be predominantly temperature welds. There is insufficient time for pressure welds to occur. Temperature welds being soft will separate easily. No built up edge is formed. However there is small amount of material plucked off from tool surface.
- PVD Coating by using materials like TiC, TiN: TiC and Tin have lesser affinity to steel to form built-up edge. Moreover low wettability of these materials by ferrous material reduces built-up edge formation. The edges are uniformly coated hence there is less chance of adherence property
- Polished edges : Adherence property is weaker at polished surfaces.
- Using Coolant: Coolant washes away built up material at earlier stages.
- by using positive rake : Area of contact is minimum.
- by Minimizing the flank wear

Flank Face " Built up Edge"

This is normally associated with inadequate clearance angles under the cutting edge. Soft Springy materials tend to ―spring-back‖ after being cut and rubs the flank of the tool.

Thermal-Mechanical Cracking

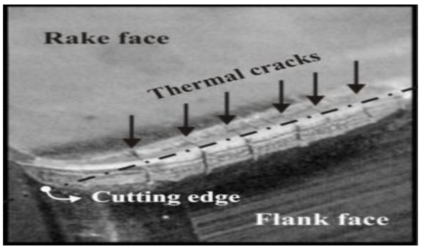


Figure: Thermal crack developed in cemented carbide inserts

This thermal cracking is Evenly-spaced cracks perpendicular to the cutting edge

- It is Commonly observed in milling and interrupted cutting.
- Caused by variations in temperature in milling induce cyclic thermal shock as the surface layer of tool repeatedly expands and contracts due to heating and cooling of the edge Minimizing Thermal Cracking Thermal Cracking can be minimized by following method:
- Using Tougher, more thermal-shock-resistant tool material
- Use a grade with more TaC content
- Higher cobalt content carbide grade
- Avoid coolant if possible or assure a steady supply
- By reduced cutting speed.

Cratering

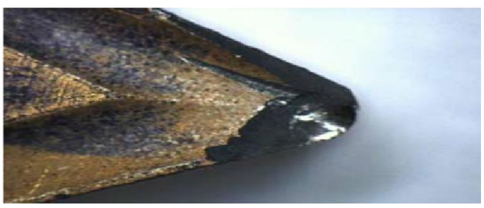


Figure: Crater wear on ceramic tool face

IJARSCT
ISSN (Online) 2581-9429
International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)
Impact Factor: 6.252
Volume 2, Issue 1, October 2022

- Cratering are Tool wear characterized by a concave depression in the rake face of the cutting tool. Cratering is also called crater wear.
- Cratering are Typical in machining carbon steels at elevated speeds.
- This are Caused by extreme heat & pressure of chip Involves diffusion or dissolution of tool material into the chip

Minimizing Crater Wear

Crater Wear can be minimized by following methods:

- By Reduce Cutting speed (by reduced spindle speed)
- By using Higher TiC Content grade
- By Lower cobalt grade
- By Use of CVD coated grades - Al2O3&TiC

Thermal Deformation

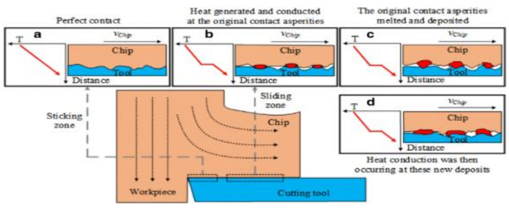


Figure: Heat partition in to cutting tool and tool chip contact interface during cutting operation

It is also called as plastic deformation and takes place as a result of combination of high temperature and high pressures on the cutting edge. When the cutting edge loses its hot hardness the forces created by the feed rate cause the cutting edge to deform. The amount of thermal deformation is in direct proportion to the depth of cut and feed rate.

- It is typical in machining alloy steels at elevated speeds.
- Results in Bulging or blunting of the tool edge.

Minimizing Thermal Deformation

- By Use of grades with higher TaC content
- By Use of grades with lower cobalt content
- By Using CVD coated grades - Al2O3&TiC

Tool Life

The length of time that a cutting tool can function properly before it begins to fail Taylors Tool life equation

$$VT^n = C_t$$

T is time in minutes,

Ct is constant and varies with tool and work material, tool geometry

Exponent n determines the slope of the tool life curve and depends primarily on the tool material

V is cutting speed in m/min

Some of the more common criteria for judging the end point of tool life are

1. Width of wear land i.e. occurrence of a certain width of wear land.
2. Depth of crater wear i.e occurrence of a certain depth of crater wear.
3. Increase of cutting force, or power consumption, by a certain amount.
4. Increase of radial force on the tool by a certain amount.
5. Increase of feed force by a certain amount.
6. Sudden change in finish and dimension of work piece

V. CONCLUSION

If above minimizing technique is followed, we can achieve higher tool life.

REFERENCES

[1]. Tsao Chung-Chen, Hocheng Hong, Comparison of the tool life of tungsten carbides coated by multi-layer for End mills using the Taguchi methodJournal of Materials Processing Technology 123 (2002)

[2]. Caldeirani Filho Universidad Federal de Uberlandia. A.E.Diniz, Unicamp, Influence of Cutting Conditions on Tool Life, Tool Wear and Surface Finish in the Face Milling Process, Universidad Estadual de Campinas, 13083-970 Campinas, SP, Brazil, Journal of the Brazilian Society of Mechanical Sciences, J.Braz.Soc. Mech. Sci. Vol.24 no.1 Rio de Janeiro Mar.

[3]. MC Shaw- Theory of Metal Cutting

[4]. Catalogs of cutting tool manufacturing industries like Kennametal, Sandvik, Iscar, Guhring, etc.

[5]. Ashish Bhateja, Jyoti Bhardwaj, Maninder Sing and Sandeep kumar pal, Gulzar institute of Engineering and technology, Punjab, Optimisation of Different performance parameters, International