A Study on The Failure Mechanisms of Various Milling Inserts

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Abstract
Machining is a method that stands out among the production techniques to give the desired final shape to metal parts and to ensure perfect connections with each other at their points of use. The most important factor determining the process quality of machining, which is frequently used as a finishing process in production, is the quality of cutting tools. The tools with a limited service life due to factors such as wear and fracture, it creates a significant amount of expenditure. In addition, it is necessary to examine the problems that occur in the inserts due to reasons such as any failure affects the inserts also affects the pieces. Failure mechanisms that occur in inserts should be examined in order to determine tool life, to prevent any problems that may arise in the machined piece and to reduce the additional cost. In the literature, there are generally studies on the failure analysis of a certain factor on a piece. In the present study, the general failures that may be encountered on the inserts during the milling process, the mechanisms that cause failure and the recommendations to prevent this failure were mentioned. Milling inserts that examined in the study were obtained from Bor Cutting Tools Machine Industry Trade Ltd. Co. Examinations on the inserts were made using a Scanning Electron Microscope (SEM). In general in this study were observed different modes of cutting tool failure including plastic deformation, rake face wear, flank wear, chipping, abrasion and breakage.

1. Introduction

In the production of metallic parts, machining is the most widely used manufacturing method to give the final shape [1]. In recent years, with the developments in the industry, the machining sector was also developed. Production quantities have been increased with the improvement of cutting tools and machine tools and development of high speed production techniques, and as a result, the machining sector has gained importance [2]. As a result of the development of technology day by day, the industry also develops and the competition between manufacturers increases. For this reason, it is getting harder for manufacturers to maintain their positions in the sector and retain their customers. Manufacturers need to keep up with innovations and keep their costs under control. Cutting tools are an important expense item in the machining sector. Due to errors in machining parameters or incorrect tool selection, wear occurs on the inserts and breakage occurs due to the progress of these wear. Failures to the inserts are a big problem for manufacturers both due to the tool cost and the poor quality of the workpiece [1-3]. For this reason, it is very important to examine the wear on the inserts for an efficient machining and lower cost. The main purpose in machining processes is that the cutting tool can remove chips at the desired properties with high performance and maximum tool life. Different machining applications require different tool materials. The ideal cutting tool material should have all of the following properties: [4-5]

- resists wear and thermal shock,
- impact resistant,
- harder than the work it is cutting,
- high temperature stability,
- chemically inert to the work material and cutting fluid.

The most important factor affecting the tool life is a failure that occurs on the inserts. Failures occur such as thermal and mechanical fatigue, fracture, wear and plastic deformation in the insert during machining and make the tool unusable. Since failures occurs on cutting tools for various reasons during machining, the inserts loses its cutting feature. Deformations occur on the work-piece surface due to changes caused by failure in the insert surface and the progress of failure causes fractures in the insert and cutting tool. Many failure mechanisms can occur at the inserts. In order to increase the service life of the tools and to maintain the product quality, it is necessary to analysis the failures that occur on the inserts [2-3, 6-7]. For this purpose, there are many failure analysis studies on the inserts used in machining and milling in the literature [8-14]. In the studies carried out, the failure mechanism of a certain factor or an insert type was examined. In this study, it is aimed to support the literature by examining the failures on different inserts. Although the milling is a traditional method, it is still a machining process that is frequently used in the industry. For this reason, the tools used in milling were examined in this study. The tools obtained from Bor Cutting Tools Machine Industry Trade Ltd. Co. and failure analysis were made using a Scanning Electron Microscope. Different types of failure such as plastic deformation, rake and flank wear, chipping, abrasion and fracture were observed at the examined inserts. For the purpose of to prevent the tool wear and to extend the tool life in a fundamental way, an in-depth understanding of the inserts failure mechanisms is firstly required [14]. The failure mechanisms that cause these wears and cracks have been evaluated in compatible with the literature and the wear characteristics have been indicated. Suggestions have been made in order to prevent failures and extend the service life, and it is aimed to contribute to the users and the literature.

2. Experimental Procedure

Due to the large number and variety of failures encountered on cutting tools, the most common failure mechanisms are discussed here. In this study, inserts with various failure mechanisms that have completed their service life are used in the milling process by Bor Cutting Tools Machine Industry Trade Ltd. Co. The whole cutting tools have an ISO designation of SPKN150608. Si_3N_4-based ceramic, PCBN, Al_2O_3-based ceramic, Al_2O_3+TiC coated carbide, and fine-grained grain cemented carbide inserts were used for failure analysis in the study. All inserts were used in a Computer Numerically Controlled (CNC) machining center with a maximum spindle rotational speed of 10,000 rpm and a 15 kW drive motor. Image analysis of the surfaces of cutting inserts with Jeol JSM-5600 Scanning Electron Microscope (SEM) at different magnifications has been made.

3. Failure Analysis of Milling Inserts

There are many studies on failures of cutting tool used in milling [1-3, 6, 8-14]. The difference of this study is that the worn inserts were obtained and analyzed directly from the sector before the inserts were not prepared for study. Figure 1-5 shows SEM images of the failure mechanisms of the inserts used in the machining of different parts that have been used in various milling processes and have completed their service life. Most of the mentioned abrasions were observed because the failure mechanisms were more than one and interacted with each other in all examined inserts.

In Figure 1, flank and crater wear were observed on the surfaces of the tip, PCBN tool after milling. Edge and flank wear are both normal and slow types of tool wear. If the abrasiveness of the workpiece is high, such as with some cast-iron, this wear types will be accelerated [5]. Crater wear occurs behind the cutting edge and usually occurs in the machining of steels. Cratering is often observed in the machining chipping of steels and occurs behind the cutting edge. If the crater was grown large enough to come into contact with the cutting edge, the tool will immediately fail [5, 16].

Generally, the end of tool life is determined by excessive wear of the tool flank and race at conventional cutting speed. Typical tool wear on the rake and flank face using Al_2O_3-based ceramic tool is shown in Figure 2 (a) and (b), respectively. This wear pattern creates wear zones on the side and end flanks of the insert because the surface of the machined workpiece is abrasive [17]. This wear is actually caused by the very high cutting temperature at the rake face [15-16].

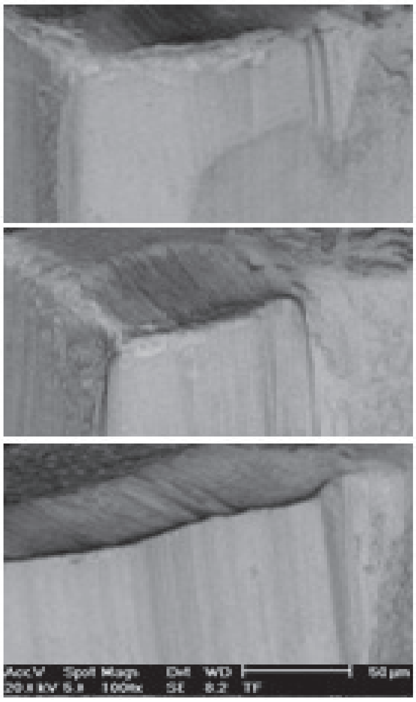

Figure 1. Wear patterns of PCBN tools in continuous milling

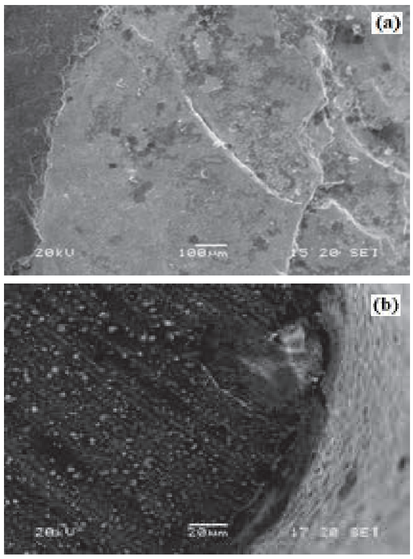

Figure 2. SEM images of worn faces of Al_2O_3-based ceramic tool

The wear mechanism that occurs on the inserts has been determined to be plastic deformation type wear, which is generally the result of a combination of high pressure and temperature [18]. Figure 3 shows abrasion and plastic deformation formation after regional melting at the cutting tip. It is thought that the cause of the wear here is high temperature and pressure. Heat build-up is the main factor causing deformation of a tool or insert. It is difficult to detect deformation without the use of a microscope, but using of a microscope is also very harmful to the machining process. Reducing the cutting speed or using a heat-resistant tool will help to prevent this deformation [5, 16].

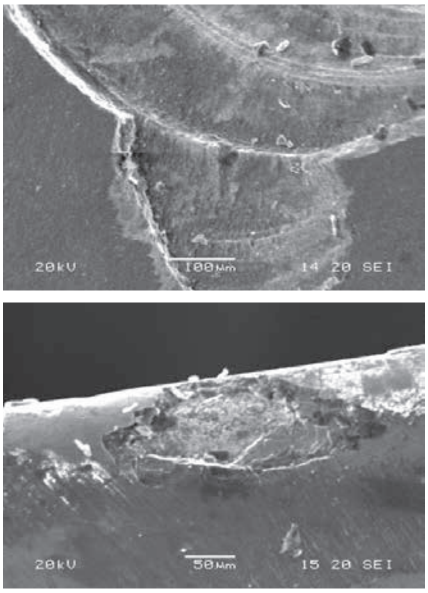

Figure 3. SEM images of worn faces of fine-grained grain cemented carbide inserts

Chipping on tool edge using Al_2O_3+TiC coated carbide tool is shown in Figure 4. Chipping is an unpredictable form of tool defect. Sometimes it starts when a high point on one side breaks. A stronger carbide grade, different edge preparation or change of clearance angle can eliminate chipping [15-16].

In Figure 5, failure mechanisms occurring in the insert are seen as breakage of the insert and built-up edge. The thermal and mechanical shocks are important factors in tool wear morphology. Fracture in tools is usually caused by the combination of the effects of thermal and mechanical stresses in an intermittent cutting process. Thermal cracking can be caused the inserts are subjected to rapid cooling and heating cycles and it can also be caused by interrupted cutting and improper application of cutting fluids [19-20].

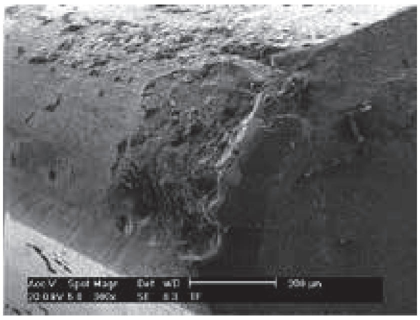

Figure 4. SEM images of worn faces of Al_2O_3+TiC coated carbide tool

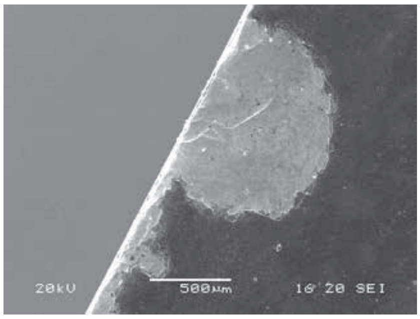

Figure 5. SEM images of worn faces of Si_3N_4-based ceramic inserts

4. Conclusion

All cutting inserts are prone to deterioration quickly, so they have a limited working life. It is not correct to use the blunt inserts with worn surfaces until they break. This is a safety hazard that causes scrap formation, affects tools, parts and therefore production costs and expenses, and also reduces productivity. For this reason, the causes of failure to the insert surfaces in machining should be known and the service life of the tips should be extended by taking the necessary precautions. For these purposes, the inserts used in the milling process, which are frequently preferred in the industry, were examined in this study. In general in this study were observed different modes of cutting tool failure including:

- edge wear and flank wear
- cratering wear
- chipping
- plastic deformation
- mechanical and thermal shocks
- breakage

Changing the hardness of the workpiece material from one point to another within the part, the variation in the cutting tool material, geometry and preparation style, tool holder and workpiece connection and other factors, vibrations caused by the workpiece surface characteristics, chemical effect of the coolant used, speed of the cutting tool directly affect the life.

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