

Investigation on Type of Wear on PVD Coated Inserts Used on Up and Down Milling

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Abstract—In this study, the wear propagation on up milling and down milling which has been used for CNC machine tools were studied. Tool wear affects the tools life, cutting forces and the surface roughness. This research focuses on cutting tools wears under the effect of different cutting parameters. The AISI 304 stainless steel work pieces and H490 ANKX 120508 PNTR - IC830 with PVD coated inserts were used to explore the type of the tools wear. Up milling, down milling and slot milling tests were carried using cutting speeds of 55, 30 and 80 m/min with feed rates of 0.05, 0.08 and 0.11 mm /rev. The cutting inserts (after 42 experiments) were examined by scanning electron microscope (SEM) and optical microscope. The results showed that mostly flank wear has been seen by 83% for all type of the milling.

Keywords— Tool wear, PVD coating, up milling, down milling.

I. INTRODUCTION

PRODUCTION methods used in modern days, can be categorized in two main groups called machining (chip removal process) and chipless forming systems.

Throughout the process of producing machine equipment, in very rare occasions it is possible to obtain the required dimensional tolerances and shape sensitivity using chipless forming system. On the other hand it can be achieved the required dimensional tolerances, surface smoothness and shape completeness via a chip removal process. The cutting motion, an effective element in the machining process, occurs by plastic deformation in front of the cutting tools of the workpiece by changing the layer that is deformed into a chip. Rough and finish cutting can be identified by the sharpness of the cutting edge, the coating type, the hardness of the workpiece, the amount of the tool wear and also by the tool life in comparison with the other processing factors.

To reduce the tool wearing throughout machine equipment production, researchers are about to analyze the effects of the factors of cutting speed, progressing motion, cutting depth and cutting width on different types of the wearing. Several studies regarding the wearing of machine equipment with respect to the cutting speed [1-3], cutting depth and cutting width have been previously studied. This study verifies the wearing effects

of the H490 ANKX 120508PNTR-IC830 PVD using AISI 304 cold stainless steel rods.

Milling cutters are cutting tools used in milling machines to make milling operations and machine tools. Three cutting types are used in milling. The first one slot milling and it is widely used. Slot milling is a type of a milling designed to face opposing edges that creates end mills. The main property of face mills is that the cutting edges of face mills are always located along its sides. Thus cutting edges cut in the front and around the cutting edges of the cutter. The surfaces which is obtained from them are upright to the axis of the rotation. The cutting edges in the front part of the surface have a similar effect to the sawing process. Second cutting type is called down milling on which the cutting direction of the cutter and feed direction of the workpiece are in the same way. The thickness of the chip in the same direction milling is the highest while the cutter is sinking in the workpiece. Third one, in opposite direction milling, which is called up milling, the cutting direction of the cutter is being directed in the opposite direction of the progressing direction of the workpiece. The milling process slides and scrapes the surface of the workpiece before the chip gets produced.

The most obligatory specifications in cutting tools consists of the following features; high pressing and bending resistance, sharpness and abrasion resistance, endurance against wear in high temperature, high thermal conductivity, resistance against impact and cheapness of the material. To comply the mentioned specifications the surface of the cutting tool is coated. The formation of the hard coating layer occurs by the rising of the hard metal from gas phase, where its process is as follows:

I) Physical methods: (PVD physical Vapor-Deposition, cathode plasma method)

II) Chemical methods: (CVD Chemical-Vapor-Deposition method)

III) Physical-chemical methods: Electrolysis smelting method, ion-plasma coating method.

II. EXPERIMENTAL DETAILS

The main parameters used in milling process are as follows: cutting speed, progressing motion, cutting depth and cutting width. This paper has used a variety of these parameters in different combinations to calculate the tool wear.

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In this work, several experiments were conducted by doing classical up milling, modern cutting tool of down milling using different cutting speeds, feed rates on a CNC vertical machining center.

The cutting toolset used in this work is coated by the physical vapor deposition and hard ceramic coating method. It is possible to observe several superiorities of PVD methods over alternative techniques. For example PVD works in low temperature therefore the base metal doesn't face the danger of overheating. PVD doesn't have unwanted directional deposition and as a result it has homogeneity of the coating thickness and furthermore PVD doesn't lead to the environmental pollution.

A. Tool and workpiece materials

The setup of the experiment consists of a 40x40 mm square profile cross section with AISI 304 cold rolled stainless steel. The technical specifications from certificate of the equipment AISI 304 is given in Table 1.

TABLE I
AISI 304 THE CERTIFICATE INFORMATION FOR STAINLESS STEEL

%C	%Mn	%Si	%P	%S	%Cr	%Ni	%Cu	%Al	%Nb	%Ti	%N
0.0350	1.500	0.440	0.0250	0.0360	18.17	8.340	0.378	0.150	0.148	0.0000	
%Tensile strength		%Tensile strength		%Elongation		%Area reduction		Hardness HB			
832.0		734.0		41.0		71.0		212.8			

In Figure 1, the inserts which has two cutting edges and coated with PVD for cutting stainless steel has been shown.

The experiments success is based on determining the value ranges of the parameter (i.e. cutting speed V_c , feed rate f). In order to avoid unnecessary repetitions and determine the effects of the parameters more precisely a design of experiment (DOE) approach has been used. Instead of using 81 experiments for 3 parameters, with 3 values for each parameter, and 3 repetitions for each value, 42 experiments has been conducted using DOE approach. 42 experiments have been done with different combinations of the three different milling methods; down milling, up direction, and slot milling. The parameters used are cutting speed (V_c) where 30, 55, 80 m/min values were used and the three different feed rate (f_z) parameter are 0.05, 0.08, and 0.11 mm/rev.

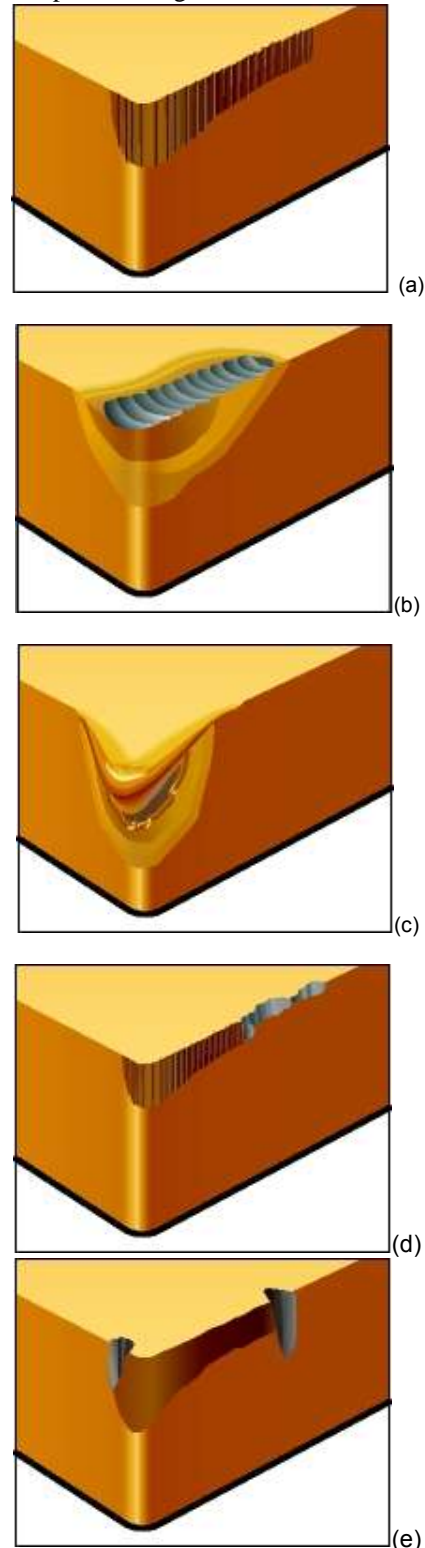


Fig. 1: Cutting tool with 4 different cutting edge for stainless steel machining

During the chip removal process, high temperature occurs under the different working conditions due to high friction on the surfaces of the workpiece/tool as well as rigid mechanical tension. Approximately 80% of the heat is extracted with the chips, 10% remains on the workpiece and 10% of the heat remains in the toolset. This is a high percentile [4].

In a chip removal process, the three surfaces of the cutting

tool, front edge, side edge (flank), upper surfaces are in contact with the workpiece. In these surfaces wearing areas grows with increasing cutting speed and the tool loses its original form. Chip surface or upper surface (crater) wear, three cavity surfaces wearing, mechanical damages, dent wearing or mechanical refraction wearing can occur. Various wear types are depicted in Fig 2.



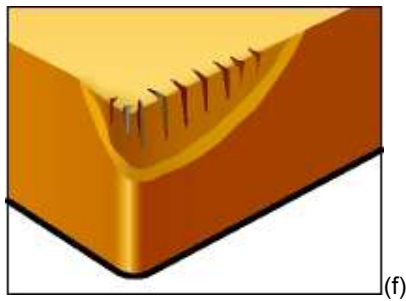
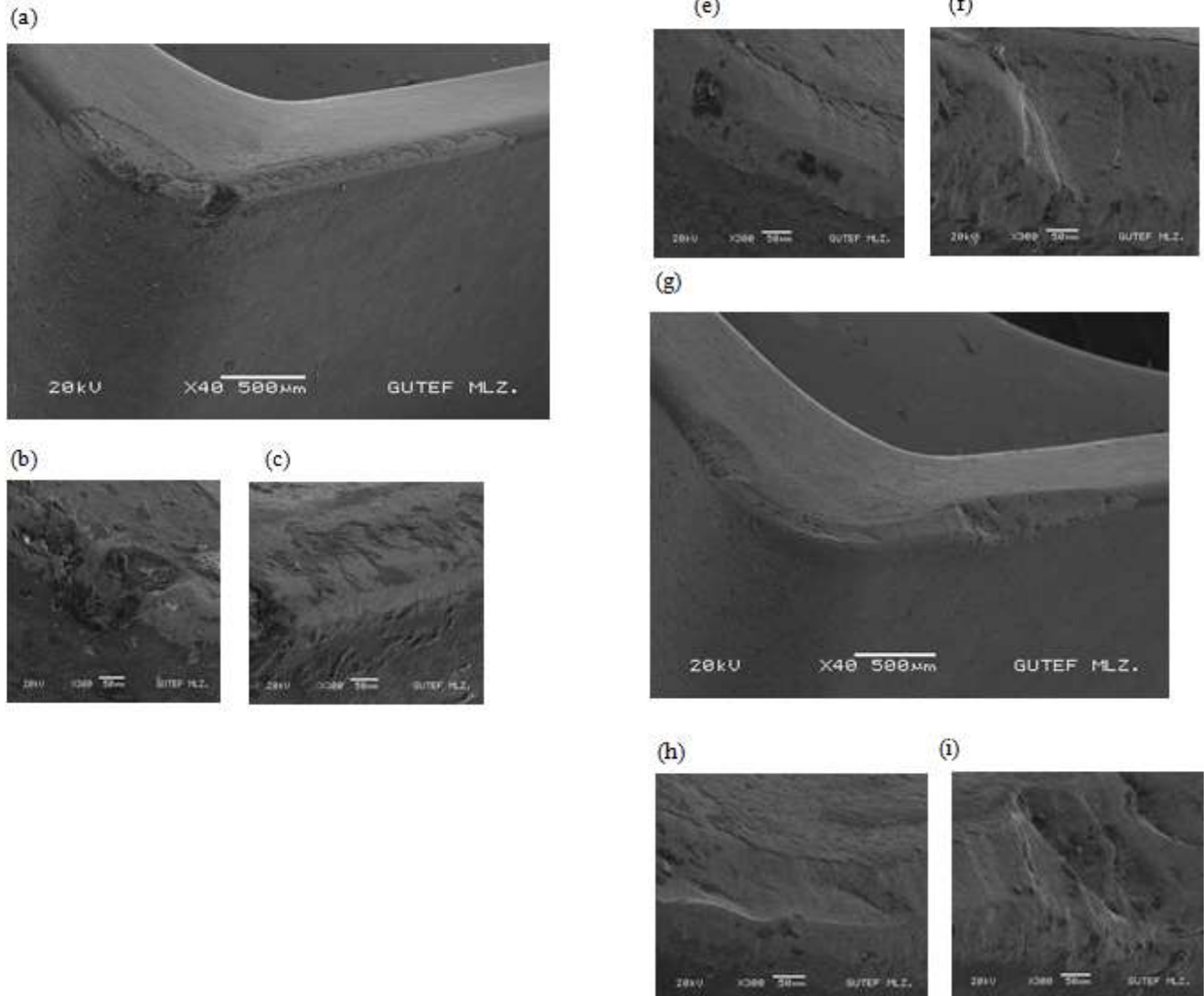


Fig. 2: Tools wearing types (a) Flank wear, (b) Crater, (c) Plastic deformation, (d) Denting outside the cutting zone, (e) Dent wearing and (f) Thermal cracks [5]

Cutting edge wearing examinations were made by SEM microscope. Snapshots of 40X and 300X magnitude were made for every existing cutting edge. Figure 3 shows a sample of SEM snapshot and the type of experienced wearing.



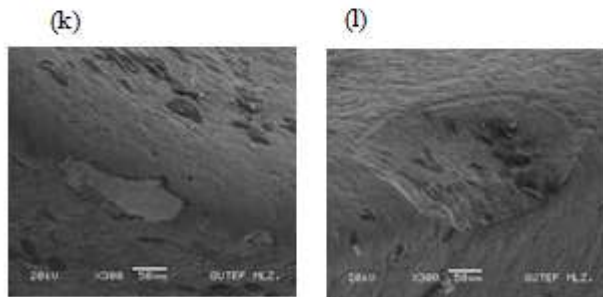
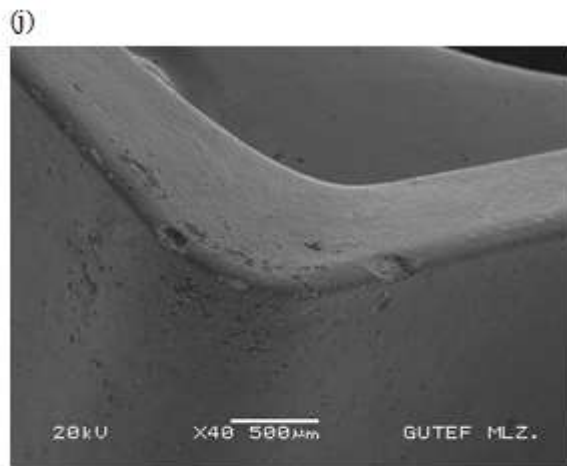


Fig. 3: Examination of edge wearing: (a), (b), (c) edge fracture, flank wear, (d), (e), (f) dent wearing, abrasive wearing, tiny fracture at edge, (g), (h), (i) flank wear, dent, chip hammering, (j), (k) and (l) fracture, dent fracture.

Scanning electron microscope (SEM) was used in making sensitive calculations and obtaining snapshots. Additionally, in this work, optical microscope was used to examine the wearing effect and compare them with SEM microscope results. To investigate edge wearing types, the SEM take 42 snapshots from different samples. For every snapshot, the surface area of the edge was captured at 20 Kv, x40, 500 µm magnitudes and the wearing of the right and left edge types were examined at the magnitude of 20 Kv, x300, 50 µm. In certain snapshots, the SEM provided black and white pictures which disabled to examine the wearing types. In such cases, optical microscope was used to provide detailed examination.

The analyses of the snapshots were grouped according to slot milling, down milling, and up milling.

For slot milling the following can be said:

1. Slot (face) milling usually shows flank wearing. Slot milling makes more vibration with respect to other milling types which results in higher amounts of flank surface wearing.
2. Slot milling generally portrays fractures in low cutting speed.

3. If the cutting speed is stable, as feed rate decreases, the fracture rate increases.

4. Out of 18 slot milling experiments of different feed rate and cutting speeds the following wearing is seen (Fig 4):

Flank (Side surface) wearing: 100%

Dent Wearing: 17%

Fracture: 17%
Edge fracture: 6%.

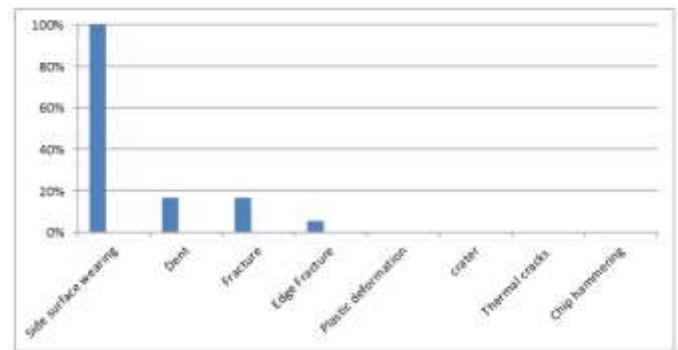


Fig. 4: The wearing type of the 18 slot milling experiments at different feed rates and cutting speeds.

For up and down milling the following can be said:

1. As expected, when cutting speed increases, the flank wear increases. In low cutting speed rates, the flank wear decreases.

2. High feed rates and cutting speeds increases fracture rate.

3. High feed rates cause dent wearing.

4. Out of 12 experiments, the following has been observed (Fig 5):

Flank (Side surface) wearing: 75%

Dent: 17%

Fracture: 17%

Edge fracture: 25%

Plastic Deformation: 8%

Crater: 8%

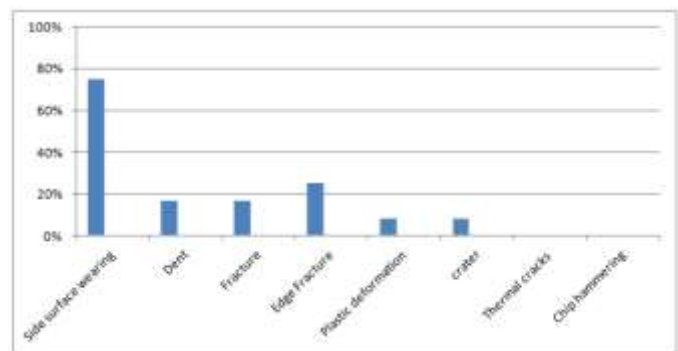


Fig. 5: The wearing type of the 12 down milling experiments at different progress and cutting speeds.

Finally, for up milling the following results were obtained:

1. At high feed rates, fractures occur more often at edges.

2. At high cutting speed, dent wearing is observed.

3. At high cutting speed and high feed rate, chip hammering can be seen.

4. From 12 experiments on up milling the following was observed (Fig 6):

Flank (Side surface) wearing: 83%

Dent: 58%

Fracture: 17%

Edge fracture: 33%

Chip hammering: 25%

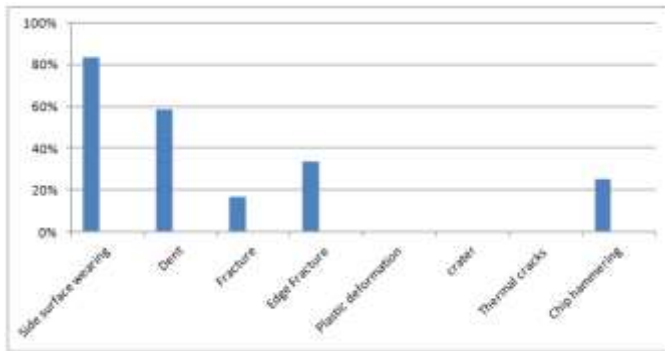


Fig. 6: The wearing type of the 12 up milling experiments at different progress and cutting speeds.

III. CONCLUSION

The present study shows that:

- For slot milling, flank (Side surface) wearing (100%), dent Wearing (17%), fracture (17%) and edge fracture (6%)
- For down milling, flank wear (75%), dent (17%), fracture (17%), edge fracture (25%), plastic deformation (8%), crater (8%)
- For up milling, flank wear (83%), dent (58%), fracture (17%) and edge fracture (33%), Chip hammering (25%) tools wearing were observed.

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