*ASIATRIB 2002International Conference*
*JEJU ISLAND, KOREA*

# Evaluation of the Wear Resistance of PVD Coatings on Drills by Using a Slurry Jet Impact Test

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In this paper, we propose a slurry jet (water containing 1 μm alumina particles) impact test in order to quickly evaluate the wear properties of physical vapor deposited (PVD) coatings on commercial cutting tools. Linear wear was obtained for both coating and substrate material, and the penetration through the coating into the substrate was signified by a sharp increase in slope of the wear versus time curve. The PVD coatings deposited on the tools showed the same wear rates as those on reference plate specimens produced by the same coating methods. We conclude that our proposed evaluation technique for coatings is considerably useful as a screening test when evaluating coated tools like twist drills, taps, end mills, gear hobs, etc.

**Keywords** : Coated tool, PVD coating, Wear resistance, Evaluation, Slurry jet impact test

## 1. INTRODUCTION

Today, homogeneous and multilayered coatings are increasingly being used to improve the wear resistance of tools for metal cutting and forming [1].

Generally, the wear properties of coatings are evaluated by using coated plate specimens instead of commercial tools. Versatile and reliable techniques for evaluation of coated tools are necessary for the development and tribological assessment of new coatings for tool applications.

In this paper, we propose a new type of slurry jet test, i.e. a solid particle impact test, aimed to quickly evaluate the wear properties of single layered and multilayered PVD coated tools.

Erosive wear rates were obtained and compared between coated twist drills, end mills, and reference plate specimens, and the ranking of the wear resistance among the investigated coatings was discussed.

## 2. EXPERIMENTAL

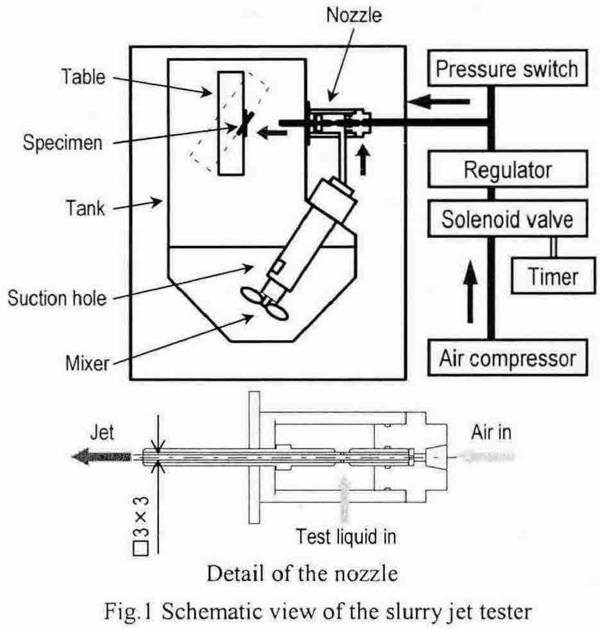
### 2.1 Test apparatus and procedure

Figure 1 shows a schematic view of the test apparatus. The details are described elsewhere [2]. The flowing stream of water containing solid particles sucked from the tank is mixed with compressed air in the nozzle, and eventually a slurry jet is ejected at high velocity. The cross-section of the nozzle is a square 3 x 3 mm$^2$. The jet velocity is regulated by the pressure of the compressed air, but could, unfortunately, not be measured. For the pressure of 0.5MPa used in this experiment, the maximum velocity was estimated to around 100 m/s at the exit of the nozzle. The impingement angle of the jet relative to the test surface was set to 90 degrees. The specimen was mounted at 10 mm distance from the end of the nozzle. The test liquid was tap water containing angular alumina particles with an average diameter of 1.0 μm, as erodent. The hardness of the alumina particles ranged from HV 1800 to 2000 [3]. The concentration of the alumina particles was 3 wt.% in the tank, and the slurry was kept at room temperature.

The wear loss of the coatings after the tests was too small to be resolved by weighing. Instead, the geometry of the erosion crater was measured with a stylus profilometer at three positions along the centerline of the square scar.

### 2.2 Specimens

The specimens were commercial drills and end mills with a diameter of 12 mm. The coating materials and their hardness, together with the substrate materials are listed in Table 1. The TiN coating was a monolayer, while the others had a multilayered structure. The total thickness of the coatings was a few μm.



Detail of the nozzle

Fig.1 Schematic view of the slurry jet tester

Table 1 Details of drill and end mill

| Coating | Coating structure | Hardness, HV | Substrate |
|---|---|---|---|
| TiN-A | Homogenous | 2400 | HSS |
| TiN-B | Homogenous | 2400 | Cobalt HSS |
| TiNCN | Multi layer | 2700 | High Grade Powder HSS |
| CrN | Multi layer | 1100~2000 | HSS |
| TiAlN | Multi layer | 2600 | Tungsten Carbide |

**3. TEST RESULT AND DISCUSSION**

The slurry jet was impacted at three areas of each drill, i.e. the edge, the coated bar near the root and an uncoated area (substrate material). An example of the wear scar generated on a coated drill is shown in Fig. 2. The square scar with of about 3 x 3 $mm^2$ was almost the same as the shape of the nozzle.

The geometry of the wear crater bottom was measured at each test interval. The distance between the original and worn surface at the deepest position was measured and designated as the wear depth. Figure 3 shows the wear depth variation with test duration. It is seen that the TiN coating have much higher wear resistance than the substrate material (HSS). The wear depth increased linearly at a moderate slope until the coating was penetrated after about 14 min. Thereafter it increased significantly. Consequently, the slope of the initial part of the wear curve is defined as the coating wear rate in this study.

Five tests were carried out at the area of root and edge of the TiN coated drills. Figure 4 shows the wear rates of these five parallel tests. The mean value and standard deviation of the five tests are summarized in Table 2. The test was found to be highly reproducible. In addition, the TiN coated plate specimens (6 x 6 $mm^2$), which were coated by the same methods as the commercial drills, were tested. Their mean wear rate is also shown in Table 2. The TiN coating shows the same wear rate on the commercial drill as on the plate.

There are strong deviations in wear rate among the investigated coatings, as seen in Fig. 5. The wear resistance was found to increase in the order CrN, TiCN, TiN, TiAlN. However, the wear resistance of the coatings does not simply correlate to the coating hardness. Further studies are necessary to clarify the correlation between the wear resistance of the coatings and the material properties.

**4. CONCLUSIONS**

(1) By using a slurry jet impact test, fast and highly reproducible evaluation of wear properties of PVD coated drills can be made.
(2) The PVD coatings deposited on the drills showed the same wear resistance as those on the plate specimens used as reference samples.
(3) For the coatings included in this study, the TiAlN proved to have the highest wear resistance, whereas the CrN was the worst.

This study was supported by a grant-in-aid administered by the Ministry of Education of Japan (No.13650149)

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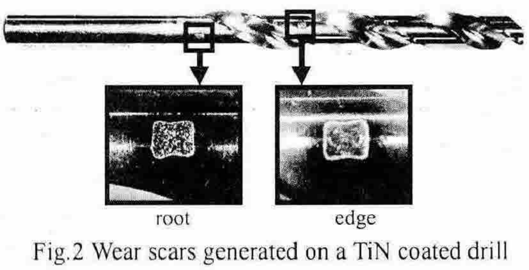

root edge

Fig.2 Wear scars generated on a TiN coated drill

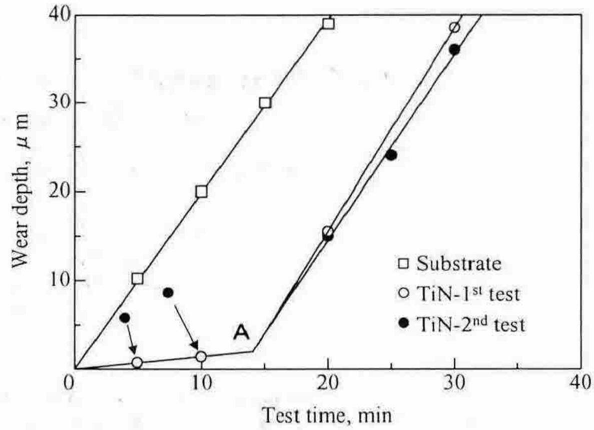


Fig.3 Wear depth vs. time for TiN and substrate

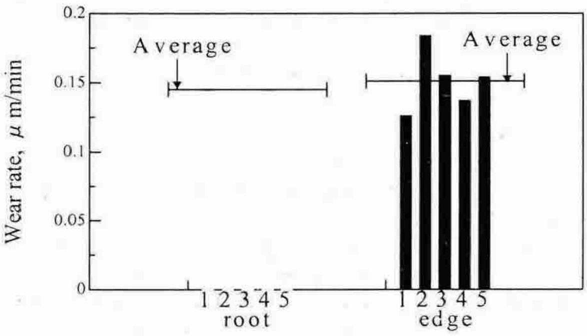


Fig.4 Wear rates for root and edge (TiN)

Table 2 Wear of TiN coating on drill and plate

| | Wear rate of TiN coating, μm/min | | |
|---|---|---|---|
| | drill | | plate specimen |
| | root | edge | |
| Ave. | 0.145 | 0.151 | 0.150 |
| S.D | 0.005 | 0.022 | 0.002 |

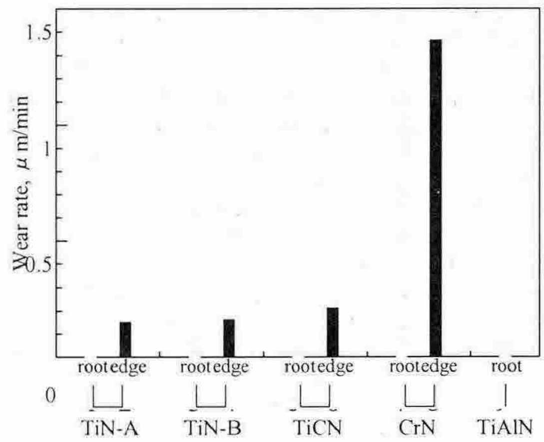


Fig.5 Wear rates of investigated coatings