Wear evaluation of flank in burins of high speed steel modified with titanium ions

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Abstract. This report shows the results obtained researching the flank wear resistance performed by the high-speed steel (HSS) burins without any surface treatment (reference substrate) and others with surface treatment based on Titanium ions. The flank wear was carried out by means of an industrial process by chip removal with repetitive tests of dry finished turning of AISI/SAE 1045 steel bars. The useful service life of the burins was evaluated according to ISO 3685:1993, and it was found that the burins treated with Titanium ions showed an increase in the flank wear resistance with respect to the ones used as reference.

1. Introduction
The manufacturing industry generally uses one-point cutting tools and machine-tools in its production processes, which rapidly deteriorate under severe operating conditions, causing millions of losses that can account for up to 25% of production costs [1], so the application of coatings on the surface of cutting tools has had a constant development during the last decades, optimizing production without significantly increasing costs and especially improving surface properties such as wearing resistance, lower coefficient of friction, resistance to oxidation, among others [2].

According to the above, an alternative technique of surface modification of metallic materials capable of achieving unique physicochemical properties, which by traditional metallurgical methods cannot be obtained, is the three-dimensional ion implantation (3DII) of metal species [3-7].

In the present investigation, by means of a process of manufacture by chip removal of turning of dry finishing [8,9], according to ISO 3685: 1993 [10] is analysed the behaviour of the useful half-life in service of the burin of HSS steel not modified superficial (reference) with respect to superficially treated with Ti ions.

2. Experimental
The flank wearing tests was realized using Impact Tools on HSS burins of 3/8” square side for 4” long (see Table 1).

The surface of the steel burins was modified superficially with ions of Ti during 4 and 8 minutes by electric hybrid pulsed high voltage and electric arc to low pressures in the reactor JUPITER (Joint Universal Plasma and Ion Technologies Experimental Reactor) [11]. The burins before the surface treatment were subjected to a sputtering process (generated with a pulsed electric discharge of 5kV) with argon gas for 15 minutes.
The flank wearing tests were carried out according to ISO Standard N° 3685:1993 [10] and the cutting parameters that define the criterion of the flank wearing of HSS Steel burins [12], are stated in the Table 2. The material selected to machining was bars of Carbon steel type AISI/SAE 1045 (CASH CK45) [8,9].

Table 2. Cutting parameters used in the machining repetitive tests.

| Variable                | Variable type | Measure                                      |
|-------------------------|---------------|----------------------------------------------|
| Cutting speed           | Independent   | 20m/min on average                           |
| Advance                 | Independent   | 0.1mm/rev                                    |
| Depth                   | Independent   | 1mm                                          |
| Mechanized time         | Independent   | Intervals of 2 minutes up to determining that the wearing is lightly a minor to 0.300mm (criterion of uniform wearing according to ISO Standard 3685:1993) |
| Material of the tool    | Independent   | Burin of steel standard HSS not well-established and implanted with ions of Ti and N |
| Wearing of the tool     | Dependent     | Flank wearing measured in millimetres        |
| Material to turning     | Independent   | Steel AISI/SAE 1045                          |

Once the type of burin, the material and size of specimen to be machined, the surface treatment and the cutting parameters were selected, repetitive tests of orthogonal cutting in dry were made on lathe every 2 minutes using reference burins and every 8 minutes with metallic Titanium species modified burins.

3. Results and discussion

Figure 1 shows the burins before and after the process of superficial modification observing that those implanted with ions of Titanium got silvered violet coloration, due to the alloy formed by the metallic species into the atmosphere during the 3DII discharge process and the interaction the material components of the material of the substratum.

![Figure 1](image-url)

**Figure 1.** HSS Burin, (a) reference (no superficial modification and (b) modified with Titanium ions.

The results show in the Table 3 and 4, of the flank wearing of burins not modified and modified superficially with Titanium ions during 4 minutes, were obtained making a maximum of seven (7) passes, whereas the results with Titanium ions during 8 minutes were achieved with a maximum of
twelve (12) passes, with machining time each pass of four times bigger than the time established in the burins used as reference and equally to the established in the modified ones with Titanium during 4 minutes. The number of burin passes during the mechanized of the bar of AISI/SAE 1045 steel is determined by the instant in which the cutting tool came to the limit of the criterion \( \text{VB}_B = 0.300 \text{ mm} \) that determines the end of the useful life in service according to the Standard ISO3685:1993 [8,10,12,14].

Table 3. Measures registered in the flank wearing test of reference burins (not modified superficially).

| Time (min) | Wearing (mm) | Average wearing (mm) |
|------------|--------------|----------------------|
|            | Burin 1     | Burin 2   | Burin 3     | Burin 1 | Burin 2 | Burin 3 |
| 2          | 0.088       | 0.089     | 0.088       | 0.088   |
| 4          | 0.098       | 0.108     | 0.109       | 0.105   |
| 6          | 0.130       | 0.126     | 0.135       | 0.130   |
| 8          | 0.149       | 0.149     | 0.147       | 0.148   |
| 10         | 0.178       | 0.186     | 0.183       | 0.182   |
| 12         | 0.210       | 0.225     | 0.220       | 0.218   |
| 14         | 0.271       | 0.277     | 0.274       | 0.274   |

Table 4. Measures registered of the flank wearing tests of burins modified superficially with Titanium ions during 4 and 8 minutes.

| Turning Time (min) | Wearing (mm) Burin Ti 4min | Average wearing (mm) | Wearing (mm) Burin Ti 8min | Average wearing (mm) |
|--------------------|----------------------------|----------------------|----------------------------|----------------------|
|                    | Burin 1 | Burin 2 | Burin 3 | Burin 1 | Burin 2 | Burin 3 | Burin 1 | Burin 2 | Burin 3 | Burin 1 | Burin 2 | Burin 3 |
| 8                  | 0.193   | 0.194  | 0.195  | 0.194  | 0.110  | 0.108  | 0.121  | 0.113  |
| 16                 | 0.228   | 0.229  | 0.230  | 0.229  | 0.133  | 0.127  | 0.143  | 0.134  |
| 24                 | 0.239   | 0.240  | 0.241  | 0.240  | 0.145  | 0.138  | 0.157  | 0.147  |
| 32                 | 0.265   | 0.268  | 0.271  | 0.268  | 0.152  | 0.158  | 0.186  | 0.165  |
| 40                 | 0.292   | 0.295  | 0.289  | 0.292  | 0.162  | 0.169  | 0.198  | 0.176  |
| 48                 | 0.300   | 0.296  | 0.292  | 0.296  | 0.171  | 0.175  | 0.209  | 0.185  |
| 56                 | 0.296   | 0.298  | 0.300  | 0.298  | 0.300  | 0.188  | 0.218  | 0.196  |
| 64                 | -       | -      | -      | 0.190  | 0.197  | 0.227  | 0.205  |
| 72                 | -       | -      | -      | 0.209  | 0.204  | 0.241  | 0.218  |
| 80                 | -       | -      | -      | 0.215  | 0.220  | 0.269  | 0.235  |
| 88                 | -       | -      | -      | 0.233  | 0.239  | 0.278  | 0.250  |
| 96                 | -       | -      | -      | 0.250  | 0.255  | 0.304  | 0.270  |

In the Figure 2 appears the measures of the flank wearing average depending on the time of mechanized, and is observed that the flank wearing average of the burins treated superficially with Titanium ions during 8 minutes show the best performance in relation to the flank wearing of the burins used as reference. The superficially modified ones with Ti ions during 4 minutes, had an increase of the useful life service of approximately 585.70% and 71.43%, respectively, so the flank wearing burins with Ti ions during 8 minutes achieved an approximate reduction of 28.47% according to the criterion of wear \( \text{VB}_B = 0.300 \text{ mm} \) [8,10,12,13], defined by the number of passes in relation with the flank not superficially modified. The results show in the Figure 2 were obtained mechanizing a steel bar AISI/SAE 1045 of diameter 50.8mm×200mm, and making mediations with a Mitutoyo
Digital Caliper with an accuracy of 0.001mm, and they are the graphical representation of the Tables 3 and 4.

The flank wearing average of the burins used as reference showed an intensive growth as the time of turning increases. According to the total time of turning it was an increase of the useful life in service of 300% in the flank of the burins superficially modified with Titanium ions during 4 minutes with regard to the burins of reference. Nevertheless, according to the criterion of wearing about the number of passes, the flank wearing of the burins not modified registered an approximate reduction of 8.76% with regard to the flank of the burin modified with Ti ions 4 minutes, so the flank wearing with Ti ions 4 minutes was major. In spite of that the machined time established for a pass was four times more than the assigned to the burins not superficially treated.

![Flank wear average](image)

**Figure 2.** Flank wearing average with regard to turning time of reference and modified superficially with Titanium ions during 4 and 8 minutes burins.

The Figure 2 shows that the resistance of the flank wearing of the modified superficially burins with Titanium ions during 8 minutes improved significantly in comparison with the flank wearing burins with Titanium ions 4 minutes and the reference ones, which is why it becomes the most optimum and efficient surface treatment in the dry finishing turning process of AISI/SAE 1045 steel.

4. Conclusion
The repetitive tests on bars of Carbon steel type AISI/SAE 1045 getting in dry finished with machining on lathe, demonstrated that the flank wearing of high speed steel (HSS) burins superficially modified with Titanium ions during 8 minutes improved significantly the service useful life in comparison with the flanks of the burins treated with Titanium ions during 4 minutes and the ones used as reference (not modified), demonstrating that the covering with Titanium is a protection mechanism that might be implemented in the flank of the burins used in the manufacturing industry.

Acknowledgement
The authors express their gratitude to the Group of Investigation in “Física y Tecnología del Plasma y Corrosión (FITEK)” of the “Universidad Industrial de Santander”, to the Laboratory of Machines and Tools of the “Universidad Francisco de Paula Santander” and to the Laboratory of Materials Resistance of the “Universidad EAFIT”.

4
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