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## Durability of cutting inserts coated with ion-plated AlTiN thin films

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**Abstract.** It is known that during the cutting processes, due to the high contact pressures, to the high temperatures, to the relative velocities and shocks between the contact surfaces tool-part can lead to a wear more or less pronounced of the metal carbide cutting inserts. Are known numerous coating processes regarding the increasing the durability of the used cutting inserts, namely by deposition of different materials, having protection role for the cutting inserts locating and clearance surfaces, methods as: vapor chemical deposition at low pressure, pulverization, cathodic arc ion plating, vacuum thermal evaporation and condensation from the vapor phase. Researches carried out by authors in this paper, have followed the deposition of aluminum and titanium materials (AlTiN) in thin layers, on surface of some metal carbide cutting inserts profiled. The depositions of AlTiN materials are new coatings which consists in deposition of the compound solid of AlTiN in the form of vapor in thin layers on different tools or/and the cutting inserts. In the purpose of increasing the cutting inserts durability, they used deposition method by cathodic arc ion plating in vacuum. The authors chose this method due to its advantages, which can be enumerate: the relatively low costs of the equipment, the simplicity in operation, the possibility to be used also to realize researches and industrial installations. As a result of using this method was found a considerable increase of the durability for the metal carbide cutting inserts coated with AlTiN materials, used in the cutting process compared to cutting inserts which were not coated.

### 1. Introduction

During exploitation of cutting tools, as a result of pressure on the contact surface, of the temperature and relative velocities tool-part and semi-finished-part, active surfaces of cutting tools are subject to wear. This one consists in deterioration the edge of cutting tool during the processing process, deterioration which leads to the fall of processing accuracy and respectively of the surface quality. After [1] achieving to some high quality parts, establishing of some cutting conditions which leads to the increase of processing productivity as well as the rational and efficient use of cutting tools impose the knowledge of their behaviour at wear. Whatever the type and their destination, the cutting tools used in normal regimes limits it wears out only on the settlement face or simultaneously both the settlement face, as well as on the clearance face.

Wear it occurs preponderantly only on one of the active surfaces of cutting tools, or on both surfaces, in the following conditions: wear only on the settlement face occurs in generally in the case of cutting with low speed and low thickness of the splinter, because it increase the specifically



mechanical work of friction forces on the settlement face; wear only on the clearance face occurs in generally, for high cutting speed and large splinter thickness because the mechanical work of friction forces on the clearance face is higher; wear on the settlement face and clearance face occurs in medium cutting conditions and is the most common case.

A new modality to increase the durability of cutting tools is represented by the surface coatings with ceramic materials based on titanium compounds, such as: titanium carbide (TiC) and titanium nitride (TiN); titanium-aluminum nitride (AlTiN), titanium carbon-nitride (TiCN). Depositions of thin layers are applied on cutting tools in order to improve the desired properties of the surface, such as corrosion resistance, wear resistance, hardness, or friction. The research problems regarding the production of coatings are one of the most important surface engineering development directions, ensuring the production of coatings with superior properties in the field of applications to the mechanical characteristics and wear resistance [2, 3]. For that surfaces of the cutting tools, which are the most exposed to wear, to be used at maximum capacity these it can harden by several methods, of which are mentioned the coatings processes: physical vapor phase deposition (PVD) and chemical vapor phase deposition (CVD). The coating realized by physical vapor phase deposition or chemical vapor phase deposition, have gained special attention because of their unique physical and chemical properties, for example, extremely high hardness (40-80 GPa), corrosion resistance, excellent resistance to oxidation at high temperatures, as well as high abrasion and erosion resistance [4, 5].

## 2. Method

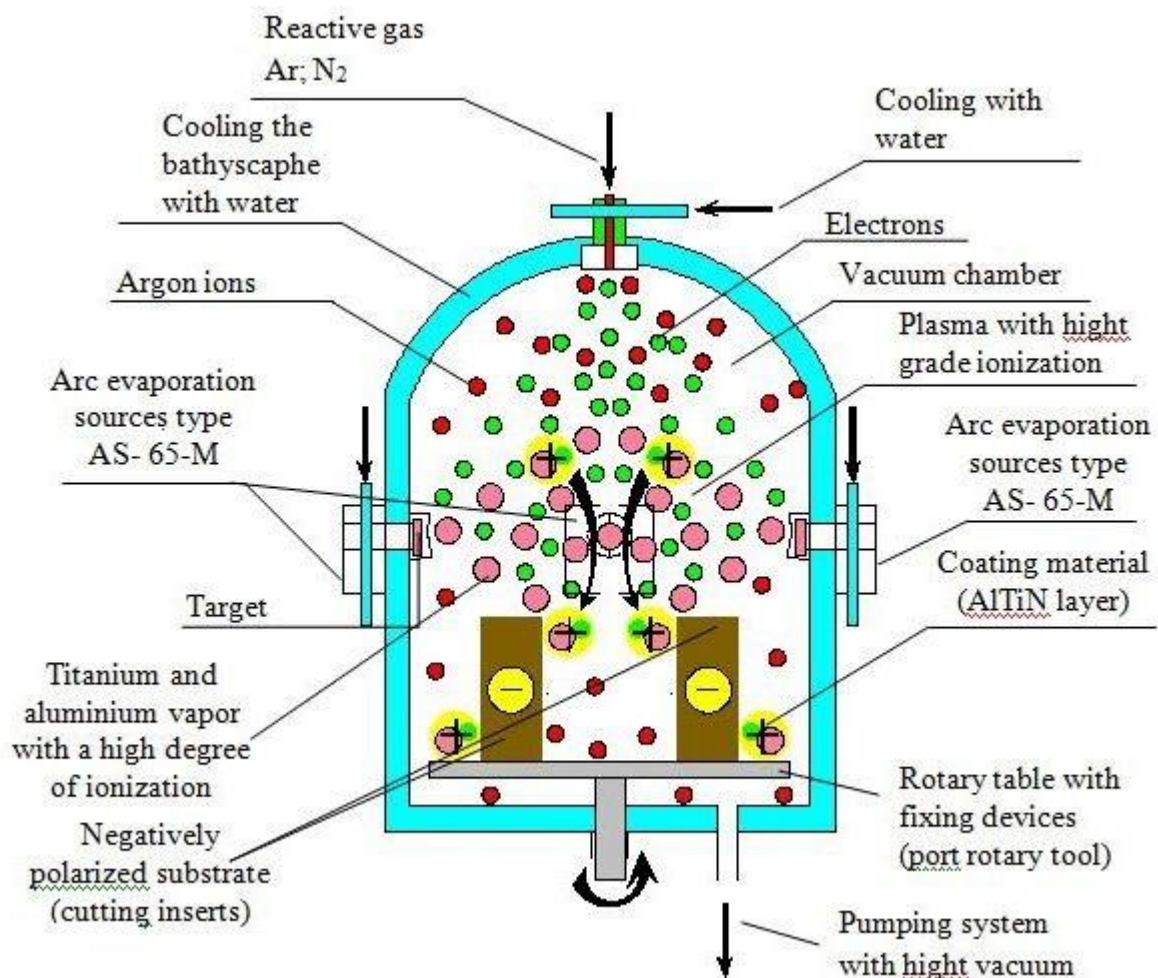
In this paper the authors have proposed the deposition on some metal carbide cutting inserts of some thin layers of AlTiN by cathodic arc ion plating method, in order to increase the durability of the cutting inserts and increasing the wear resistance of these. The cathodic arc ion plating method after [6] is the process of deposition of thin layers in which the substrate is subjected to bombardment with ions of a working gas, before deposition and, with ions of material of deposition and of the working gas, during deposition. For AlTiN layers deposition on the cutting inserts was used an equipment type Dreva 400 shown in figure 1 who allowed their introduction together with their fixing device, inside the vacuum enclosure (at  $1 \cdot 10^{-3}$ - $5 \cdot 10^{-2}$  mbar).

The deposition of the AlTiN layer takes place inside the enclosure in which it apply suction for the cutting inserts to be covered (100 pcs.), the rotary table of the machine being performed with the help of device so that, the deposition take place only on the surface which will be in direct contact with the vapor of AlTiN ions of inert gas and the reactant gas. The material to be deposited on the substrate (work piece to be covered - the cutting insert) being in solid state is brought in vapour state as a result of its heating, up to evaporation of the target (AlTiN) and recondensation on the substrate when its temperature is lower than the vapors. The enclosure is cylindrical one, having double walls cooled with water and three arc evaporation sources type AS 65 M mounted along the bathyscaphe walls, used to generate the AlTiN vapors. In the enclosure shaft is mounted a rotary port-tool support equipped with the special devices designed for the settlement of the cutting inserts. The symmetrical positioning to the axis of the cylindrical enclosure makes as the inserts subject to the coating, located in batch, to be in identical deposition conditions for ensure a uniform thickness of the deposition.

Cleaning of the cutting inserts before deposition is carried out also inside the vacuum chamber by spraying with a controlled stream of argon. The AlTiN particles resulting from the evaporation process of the target, on their way to the substrate (the cutting inserts), collide with reagent gas ions (nitrogen) and with the electrons of a glow discharge plasma. Thus, the material particles positively ionized are accelerated in cathodic dark space of the substrate and hitting it with increase energy performs the deposition of some layers with a adherence and structure improved on it.

The AlTiN coating process involves a succession of operations. First, cleaning the plates for 20 min in a tank of benzene to remove grease. Fixing of the cutting inserts on supports in their locations on the machine rotary table. After this, the enclosure is closed and vacuumed for 15-30 minutes, up to  $1,1 \cdot 10^{-2}$  mbar. At the same time the Hollow cathod is heated for 20 minutes at  $402^{\circ}\text{C}$  up to  $1,2 \cdot 10^{-2}$  mbar. Then, take place Bias voltage for 10 minutes at  $425^{\circ}\text{C}$  up to  $9,6 \cdot 10^{-3}$  mbar. Inside of the

bathyscaphe enclosure there is an ionization, using argon and nitrogen, for 20 minutes. The coating process begins after removing the covers of the arc evaporation sources for 20 minutes, at a temperature of 350-700°C. This is followed by cooling in two steps, first for 15 minutes at 180°C and the second for 20 minutes at 150°C. To remove the inserts now coated with AlTiN, the bathyscaphe will be repressurized for 20 minutes and its cap will be raised for extraction.



**Figure 1.** Scheme of the installation used in the application of the cathodic arc ion plating method [7].

### 3. Results

In order to perform their experimental researches the authors used cutting inserts unprofiled type SPUN 120312. The metal cutting inserts were used to achieve by turning chamfers inside the pieces type roller shown in figure 2, the cutting inserts both coated with AlTiN and uncoated being shown in figure 3, respectively figure 4, and in figure 5 and 6 are shown the cutting inserts after the turning operation, having their wear areas marked.

During the use of these metal carbide inserts type SPUN 120312 in turning process of the roller it was determined their durability, both in case of those uncoated as well as in case of those coated with titanium, at the same time establishing and the number of the machined parts with these cutting inserts, till their wear and loss of quality cutting.

The cutting process by turning was carried out in the same conditions for each case of using the cutting inserts both coated with AlTiN and uncoated. Conditions in which was carried out the cutting process by turning are given in table 1.

**Table 1.** Conditions in which the turning operation took place.

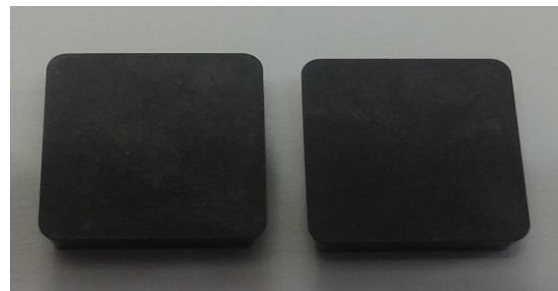
| Cutting depth<br>$t$ [mm] | Cutting speed<br>$v$ [m/min] | RPM<br>$n$ [rot/min] | The working advance<br>$f$ [mm/rot] | The base time<br>$t_b$ [sec] | The volume of chips displaced<br>$v$ [mm <sup>3</sup> /min] |
|---------------------------|------------------------------|----------------------|-------------------------------------|------------------------------|---|
| 0.3                       | 60                           | 1500                 | 0.3                                 | 0.5''                        | 185.17  |



**Figure 2.** Roller.



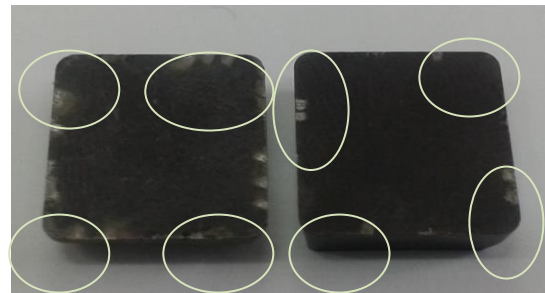
**Figure 3.** Inserts type SPUN 120312 with coated AlTiN.



**Figure 4.** Inserts type SPUN 120312 with uncoated AlTiN.



**Figure 5.** Inserts type SPUN 120312 uncoated with AlTiN and used.



**Figure 6.** Inserts type SPUN 120312 coated with AlTiN and used.

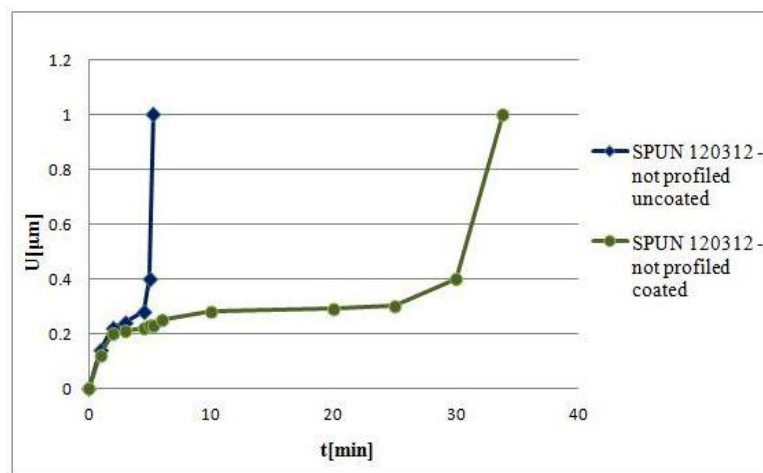
The values obtained are shown in table 2, respectively table 3, showing a remarkable growth to durability of the cutting inserts undergo the process of thin layer coating with titanium and aluminum by a physical vapor deposition process, for these types of cutting inserts used, in relation to any non-processed by titanium and aluminum deposition. Also in table 4 is shown the total values for durability



of the cutting inserts used. The graphical representations on how is the variation in time of the cutting inserts wear, as well as the volume of machined parts, during normal operating time of these, are shown in figure 7 and 8.

**Table 2.** The obtained time with these cutting inserts during turning operationst

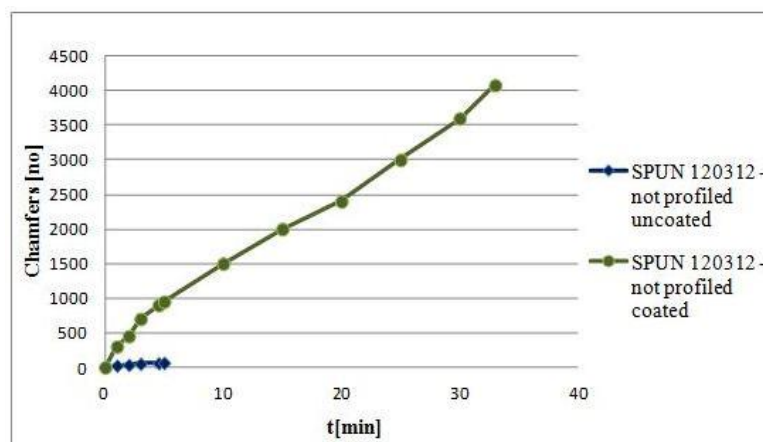
| INSERT TYPE | DURABILITY (min) |       |        |       |        |       |        |       |        |       |
|-------------|------------------|-------|--------|-------|--------|-------|--------|-------|--------|-------|
|             | Edge 1           |       | Edge 2 |       | Edge 3 |       | Edge 4 |       | TOTAL  |       |
|             | C                | U     | C      | U     | C      | U     | C      | U     | C      | U     |
| SPUN 120312 | 33.4'            | 0'43" | 33'    | 0'57" | 33.57' | 0'52" | 33'8"  | 0'55" | 33.84' | 0'51" |



**Figure 7.** Diagram with variation in time of the wear of the type cutting inserts SPUN 120312 – not profiled uncoated and coated with AlTiN.

**Table 3.** Pieces number processed with these cutting inserts obtained by turning operation.

| INSERT TYPE | DURABILITY (pieces) |    |        |    |        |    |        |    |       |    |
|-------------|---------------------|----|--------|----|--------|----|--------|----|-------|----|
|             | Edge 1              |    | Edge 2 |    | Edge 3 |    | Edge 4 |    | TOTAL |    |
|             | C                   | U  | C      | U  | C      | U  | C      | U  | C     | U  |
| SPUN 120312 | 1010                | 52 | 1025   | 69 | 1015   | 63 | 1010   | 67 | 4060  | 63 |



**Figure 8.** Diagram with the volume of the manufactured parts with the type cutting inserts SPUN 120312 – not profiled uncoated and coated with AlTiN.

**Table 4** The durability total values of the cutting inserts used.

| NR.<br>CRT. | THE TYPE OF INSERTS         |                        | NR.<br>TESTED<br>INSERTS | DURABILITY<br>TESTED<br>[min] | NR.<br>CHAMFERS<br>MADE | SAMPLE<br>TYPE |
|-------------|-----------------------------|------------------------|--------------------------|-------------------------------|-------------------------|----------------|
| 1           | SPUN 120312<br>not profiled | Uncoated<br>with AlTiN | 2                        | 0'51"                         | 63<br>chamfers          | roller         |
| 2           | SPUN 120312<br>not profiled | Coated<br>with AlTiN   | 2                        | 33.84'                        | 4060<br>chamfers        | roller         |

#### 4. Conclusions

Using in the process of turning of pieces type roller the inserts type SPUN 120312 not profiled, following their coating with thin layer of AlTiN by a physical vapor deposition method, to an increase more than 10 times their durability, with them can be processed more than 10 times pieces until the qualities are lost through cutting wear of the tool.

Regarding the volume of processed parts it is noted a direct proportionality with increasing the time as how the inserts keep their qualities of cutting. The results obtained opens new opportunities for continuing the studies in this domain, future researches following: diversification of the qualitative types of cutting inserts coated with thin layers of AlTiN through a PVD process and the study of their behavior in the processes of turning; realization of coatings and with other types of layers: Ti-Cr, Ti-Cr-Al and the analyze of their influence on the hardness increase and implicitly, the durability of the cutting tools; determination of thickness of deposited layers and determining their optimum values (depending on the layer structure), which allow achieving the highest values of durability.

#### References

- [1] Szalók I 2013 Analysis of drilling surface microgeometry 2<sup>nd</sup> Regional Conference *Mechatronics in Practice and Education-MECHEDU* pp 111
- [2] Dobrzanski L A, Lukaszewicz K, Zarychta A and Cunha L 2005 Corrosion resistance of multilayer coatings deposited by PVD techniques onto the brass substrate *Journal of Materials Processing Technology* **164-165** pp 816-821
- [3] Lukaszewicz K and Dobrzanski L A 2008 Structure and mechanical properties of gradient coatings deposited by PVD technology on to X40CrMoV5-1 steel substrate *Journal of Materials Science* **43** pp 3400-3407
- [4] Veprek S, Mannling H D, Karvankova P and Prochazka J 2006 The issue of the reproducibility of deposition of superhard nanocomposites with hardness of  $\geq 50$  GPa *Surface and Coatings Technology* **201** pp 6064-6070
- [5] Zou C W, Wang H J, Li M, Yu F J, Liu S C, Guo L P and Fu D J 2010 Characterization and properties of TiN-containing amorphous Ti-Si-N nanocomposite coatings prepared by arc assisted middle frequency magnetron sputtering *Vacuum* **84** pp 817-822
- [6] Mateescu G 1998 *Straturi subțiri depuse în vid Tehnologii avansate* (București: Dorotea)
- [7] Bădănac A, Lupescu O, Manole V and Rusu O T 2014 Researches to improving durability of the cutting inserts coated with titanium thin layers *Academic Journal of Manufacturing Engineering* **12** pp 6-11