Equipment for vacuum arc deposition of hard and superhard coatings on tungsten carbide tools

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Equipment for vacuum arc deposition of hard and superhard coatings on tungsten carbide tools: *Vacuum arc deposition is a high-tech process forming hard and superhard coatings which was made considerable relevant by machining industry progress. Proper equipment for realization of this process is shown in this study. Different carousel gears for sample's transportation which are in straight relation with process productivity are main accent. Properties of deposited layers are investigated.*
Key words: *tungsten carbide, HSM, WC/Co, hard metal, PVD, TiN, TiCN, AlTiN, AlTiSiN, nanocomposite coatings, VAD, EAD*

INTRODUCTION

In many modern instrumental and equipment productions high cutting speed and feed rate at relatively low depth are used e. g. production of moulds, dies. This machining method is known as high speed machining (HSM) and is expedient for hard metal WC/Co-based cutting tools use. These tools have a great hardness which is stable at very high temperature. In recent years new tungsten carbide alloys were synthesized which owns remarkable fracture toughness as well. Famous manufacturers of tools for HSM are Guhring, Sandvik, Kennametal, etc. Despite their qualities, WC/Co-based tools will acquire much better performance after deposition of suitable coating on their surface. Currently, practically all manufactured hard metal tolls, used in the industry, are coated. Since these coatings are generally adhesive, some varieties of the physical vapor deposition (PVD) method are often used. Type of the coating is mainly determined by the type of the coated tool (kind of machining) and type of the material machined by the tool.

TiN is conventional coating that has a long history. Although, it is behind many other coatings regarding the characteristics already, it is still asked by the customers. However, it has relatively high thermal resistance, low friction coefficient and excellent adhesion. TiC_xN_{1-x} has a higher hardness, but lower thermal resistance. $(Al_{1-x}Ti_x)N$ is relatively new and topical coating that has a remarkable hardness and high thermal resistance. It should be noted that the hardness of these coatings is somewhat due to internal stress and diminish over the time [6]. TiN also has a very attractive golden colour (stoichiometric deposited) and often used for the outer layer by deposition of hard and superhard coatings only for commercial reasons.

Nanocomposite coatings nc-$(Al_{1-x}Ti_x)N$/a-Si_3N_4 and nc-$(Al_{1-x}Cr_x)N$/a-Si_3N_4 are among state of the art superhard coatings. Particularly, they are suitable for deposition on hard metal tools because of their high formation temperature (usually above 500˚C). Lowering the formation temperature causes obtaining a regular solid solution with worse performance similar to standard $(Al_{1-x}Ti_x)N$, respectively $(Cr_{1-x}Ti_x)N$ coatings. Unlike many steels, hard alloys allow unimpeded treatment at such high temperatures. Besides, unlike other coatings, the nanocomposites can be easily removed with appropriate stripers without harming the hard metal, which allows re-covering after appropriate tool re-grinding [5]. The mentioned nanocomposites retain their work performance to very high temperature (above 1000˚C) and possess high oxidation and chemical resistance. Last, not least, they have a little thermal conductivity. Thereby, they protect the tool from the heat that is created durring the machining.

DESCRIPTION OF THE EQUIPMENT FOR VACUUM ARC DEPOSITION

Two vacuum arc deposition (VAD, EAD) plants, one made by the Central Laboratory of Applied Physics (CLAP) and other one, π80+ of company Platit, are used for coating formation. Both systems allow achievement of high initial vacuum, inlet flow of several working gases simultaneously. They are supplied with cathodes of Ti, Cr, Zr, AlSi, AlTi and allow samples cleaning by Ar and Ti etching immediately before the coating deposition. More their details are presented in Table. 1.

Table 1. Used VAD systems

characteristic / VAD system	chamber's volume, m^3	working volume, m^3	initial vacuum, mbar	gas lines, pcs.	evaporators, pcs.	cathode current, A	bias voltage, V	initial temperature, C°
CLAP made	$492,6.10^{-3}$	$223,4.10^{-3}$	$1,1.10^{-5}$	3	4	50÷160	20-1200	350
π80+	$79,0.10^{-3}$	$28,3.10^{-3}$	$2,0.10^{-6}$	4	2	60÷200	25÷1000	550

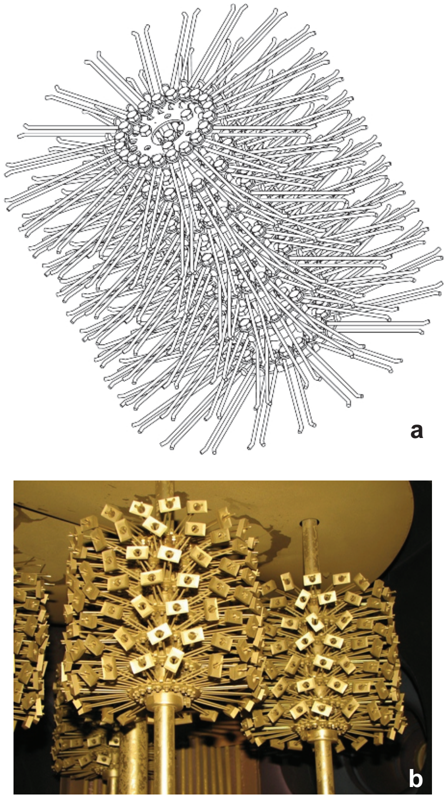

Fig. 1. Two-fold carousel movement of hard metal inserts: general look at the holder (a) and working disposition in the chamber (b).

Since VAD chambers are usually cylindrical, almost always carousels for sample's transportation are applied. Accordingly, they may have one-, two- and three-fold rotation (application of more axes of rotation greatly complicates the construction and therefore, four-fold rotation is rarely used). It is important to mention, that the type of movement not only affects the deposition thickness and its distribution (uniformity) but also the structure of the coating [4, 5]. This may be crucial for the parameters of certain types of coatings.

When batches are relatively small (free samples for costumer suasion, completion of contracts – the final cycles and so on), it is necessary resort to a simpler scheme of transportation, i. e. two-fold rotation. This allows the achievement of the required coating thickness at a time shorter than this one needed with three-fold rotation. It is necessary to place the samples in the appropriate position, ensuring thicker stratification on the important work surfaces (although the bias voltage contributes uniform distribution of coating thickness, VAD remains line-of-sight process). Easy manufactured holders for two-fold rotation were made (fig. 1).

In the case of large batches three-fold rotation is usually applied. In order to avoid overload of the leading actuator, often a ratch is used. Thus, just one of the triaxial satellites is rotated at any moment. Similar construction was realized (fig. 2).

The processing of large quantities of different samples causes the need for rapid design and the manufacture of suitable carousel gears. The modern software for computer aided design (CAD) provides great opportunities in this area. However, the entire solution of this task demands developing a specific algorithm which could allow obtaining the final generated model of the carousel gear by setting the initial conditions. The creation of such algorithm is at the beginning, but one can already see good practical results (fig. 3). Moreover, it is possible knowing the parameters of the carousel (geometry, ratios, loading factor, etc.) to provide the necessary speed of the leading actuator at any time of the technological process to obtain a multilayer coating with a predefined thickness of individual underlayers.

Sometimes, the variety of contracts or their content is huge. This requires the use of modular adaptable constructions, which allow an arrangement of many different samples in the working chamber - realization of so-called mixed batch. Accordingly, it is useful to make productive diagrams for the used carousels (fig. 4). Upon orders receiving, samples are separated into several basic groups according to the diagram. The ratios between the amount of the ordered samples from any group and the samples of the same group produced in one working cycle, are developed. The sum of these relations is rounded to the upper integer and gives the required number of processing cycles necessary for production of the all ordered samples. With enough adaptability of the carousels, this result is completely applicable for preliminary calculations

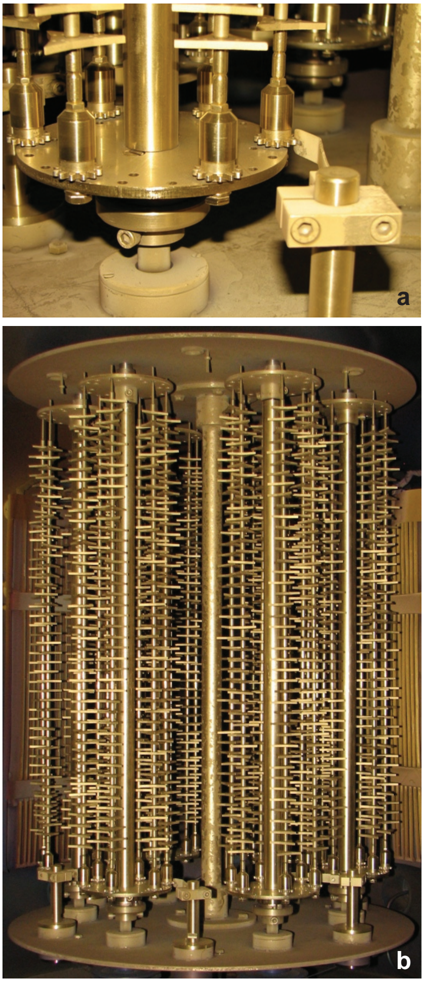

Fig. 2. Three-fold carousel movement of hard metal inserts: general look at the ratch (a) and working disposition in the chamber (b).

APPLICATION OF THE EQUIPMENT FOR VACUUM ARC DEPOSITION

Through the use of vacuum systems equipped with high-performance carousel gears, it is possible to process large amounts of hard metal inserts (cutting plates). For example, the carousel presented in fig. 2 allows processing of several thousands to about a ten thousand of them per a working cycle (depending on their geometrical dimensions). This one and similar gears were used at CLAP-BAS for coating more than 300 000 inserts.

Drills, mills, taps, reamers and similar elongated cylindrical tools are processed by carousels, having a construction, similar to this one presented in fig. 3. Special sleeves are used, in which the tools are poked and which are attached to the carousel's nests. These sleeves, except providing firm fixture of the tools, protect their shanks from the processed coating as well. Although the end stratification is very thin, generally it is not allowed to cover the shank of the tool or at least the area where it connects with a chuck.

According to the customer requests, different coatings, suitable for tungsten carbide are applied [1, 5]. All of them are a gradient multilayer. Most of the underlayers are designed for smooth transition between the main layers and have a negligible thickness. Original technological recipes of company Platit and developed in CLAP-BAS are executed either.

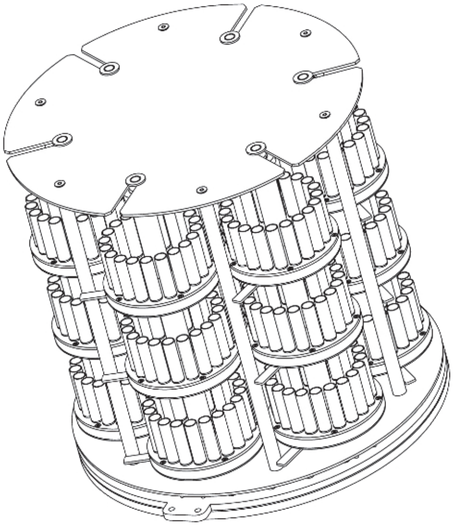

Fig. 3. Generated three-fold carousel gear for processing of hard metal tools.

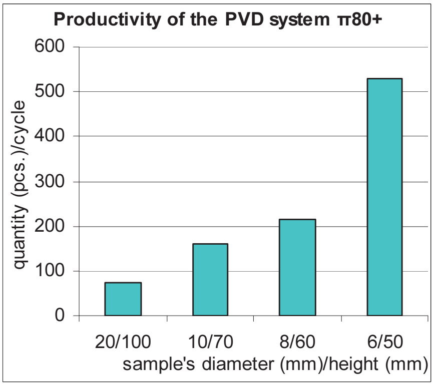

Fig. 4. Productive diagram of the vacuum system π80+.

In some of the processing cycles, samples-witnesses were placed and then investigated. They were cleaned and prepared following the same procedure as the rest samples of the batch.

Mainly, the mechanical characteristics were found out. The thickness of the coatings was measured by a LEITZ Incident-light Microscope Interferometer in monochromatic light (λ=560 nm) and has a good agreement with that set in the technological process by the recipe setting-up. The wear intensity was obtained on a test stand made in the Technical University of Sofia - branch Plovdiv [2]. The rest characteristics were investigated by a Compact Platform CPX (MHT/NHT) CSM Instruments. All of the results are presented in Table 2. They have a good coincidence with these published in the technical manuals and catalogues, as well as in the scientific works [3].

Practical performance of the coated tools can be evaluated by customers' surveys. They are not presented here due to lack of accurate methods during their implementation. On the other hand, the increased request for VAD offered by CLAP-BAS is indirect evidence of the good qualities of the deposited coatings.

CONCLUSIONS

Practical use of the described equipment for VAD allows to make the following conclusions:

1. It is possible to process huge amounts of hard metal inserts with not too complex gears.

2. Deposited coatings have characteristics which are similar to the published in the scientific literature.

Table 1. Mechanical characteristics of the mainly processed coatings

characte-ristic / coating	thickness, μm	hardness, GPa	tensile modulus, GPa	adhesion Lc1/Lc2, N	friction co-efficient, -	wear in-tensity, mm^3/Nm
TiN	1÷3	28	365	25/over 30	0,42	$4,8.10^{-6}$
TiCN	1÷3	42	460			
(AlTi)N	1÷3	37	385			
nc-(AlTi)N/a-Si_3N_4	1÷3	40	428	22/over 30	0,53	
nc-(AlCr)N/a-Si_3N_4	1÷3	39	588	19/over 30	0,39	$4,4.10^{-6}$

3. Modern CAD products allow a rapid synthesis of the carousel gears for vacuum systems.

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