RESEARCHES TO IMPROVING TOOL LIFE OF THE CUTTING INSERTS COATED WITH TITANIUM THIN LAYERS

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ABSTRACT: It is known that the cutting tools wear more or less accentuated in cutting processes may occur, due to the unevenness of the cutting depth, to the machining parameters variation, as well as due to the existence or nonexistence of the coolant oiling. The cutting tools lives being influenced by all these factors in dominant and negative mode, one can impose actions and decisions to reduce the wear processes of the tools or/and of the cutting inserts. For increasing the durability of the cutting inserts, there are known numerous researches concerning their coating with material (ions) by vacuum deposition, using methods as thermal evaporation, ionic plating, pulverization or chemical vapor deposition. The authors propose to improve the cutting tools lives using the deposition method by ionic plating in vacuum (PVD) with thin titanium layers, following the cutting tools behavior in operation treated in this way.
KEY WORDS: carbide cutting inserts, tool life, titanium thin layers, ionic plating, machining test.

1 INTRODUCTION

During the cutting process, the cutting tool wears out due to the high contact pressures, to the high temperatures, to the relative high velocities and shocks between the contact surfaces tool - workpiece, but also due to the mechanical and thermal stresses which appear on the tool active faces, having as effect the cutting capacity loss and the processing quality diminishing. This is a continuous and evolutionary process, leading to a gradually diminishing of the quality parameters performance for the cutting tools, when wears out simultaneously both the side flank and tool face (Dulău & Şoaită, 2007; Mateescu, 1998). Taking into account these aspects, in order to increase the durability of the cutting tools or of the metal carbide inserts, respectively, in view of their reconditioning after wear processes, one can impose measures of preventive maintenance, respectively corrective maintenance (Sărăriu, 2014).

In this direction, the deposition of some materials such are aluminum, tungsten, titanium, chromium etc. may constitute a method of maintenance that provides the achievement of the pursued objectives, the method being of current interest in the researches at the global level (Popa et al., 2010; Serro et al., 2009), and one can be interested also in the results obtained in the case of different technical applications such as: improving wear resistance, developing and using some layers with optical properties and/or outstanding electrical, nano composite layers with protective role or bio-layers used in medicine etc. In the last decade, the general trend consisted mainly in the development and deposition of some materials in the form of multifunction thin layers, having to simultaneously respond to several requirements imposed by the conditions in which they are used (Purdea, 2014).

The coating layers can act as a chemical and thermal barrier between the tool and the workpiece, increasing the tool wear resistance, improving the chemical inertia of the cutting material, reducing the volume of the cutting edge deposition, decreasing the friction between tool and chips, contributing in this way to the cutting forces reduction.

The thin layers deposition using the vacuum as environment of developing the deposition process had a big ascension in the last period. The first coatings used at industrial scale in order to increase the wear resistance of tools were made, after (Dulău & Şoaită, 2007), of thin layers of titanium nitride, mainly used as tribological coatings for cutting tools, but also as resistant layers at corrosion and erosion.

Currently, there are several methods of applying these layers, their general classification grouping them (Sărăriu, 2014; Mateescu, 1998) in: chemical vapor deposition processes (CVD) and, respectively, physical vapor deposition processes (PVD) (Sărăriu, 2014; Mateescu, 1998), ionic plating in vacuum being part of the second category.

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2 METHOD AND EQUIPMENT USED

In order to increase the durability of the cutting tools, for increasing the wear resistance of the inserts used for machining of the bearing rings and rollers, the authors proposed the deposition on these cutting inserts of some thin layers of titanium, by the PVD method (ion plating method), following the behavior improvement in the exploitation of the tools thus treated. The ion plating method is the process of deposition of thin layers in which the substrate is subjected to bombardment with ions of a work gas, before deposition and, with ions of material of deposition and of the work gas, during deposition (Mateescu, 1998).

This method was used due to its advantages comparing with other known and possible methods to be applied, advantages between which one can enumerate: the relatively low costs of the equipment, the simplicity in operation, the possibility to be used also to realize research and industrial installations. For the deposition of titanium layer, it was used the equipment DREVA 400, presented in figure 1, which includes: a rotary table, a vacuum chamber, supports of supply (air, water, gas), components for completing the installation and the electrical equipments.

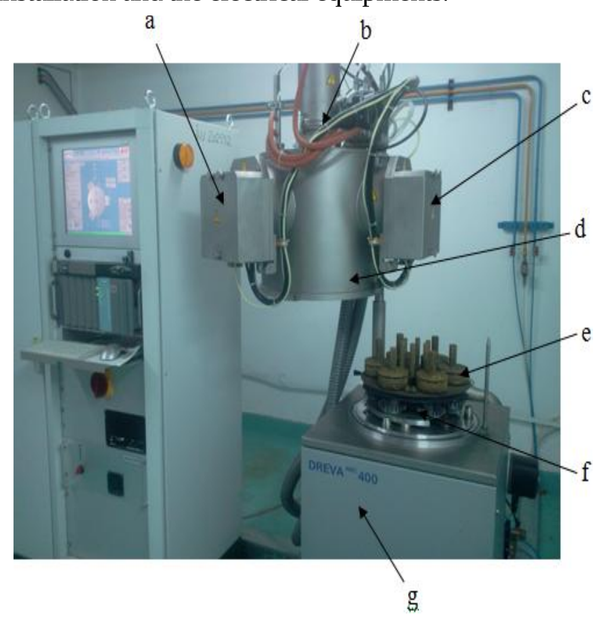


Figure 1. General view of the equipment DREVA 400
a. The support arc evaporation source AS 65 M;
b. Hollow cathode plasma;
c. The support arc evaporation source;
d. Bathyscaphe;
e. Device;
f. Rotary table;
g. Support ensemble for rotary table for vacuum chamber

The deposition of the titanium layer takes place inside the recipient in which a certain vacuum is generated, where the material that must be deposited on the substrate (work piece to be covered, meaning the cutting insert), being in solid state, is brought in vapor state as a result of its heating, up to evaporation of the target (Ti) and re-condensation on the substrate, when its temperature is lower than that of the vapors.

The principle scheme of the installation is presented in figure 2.

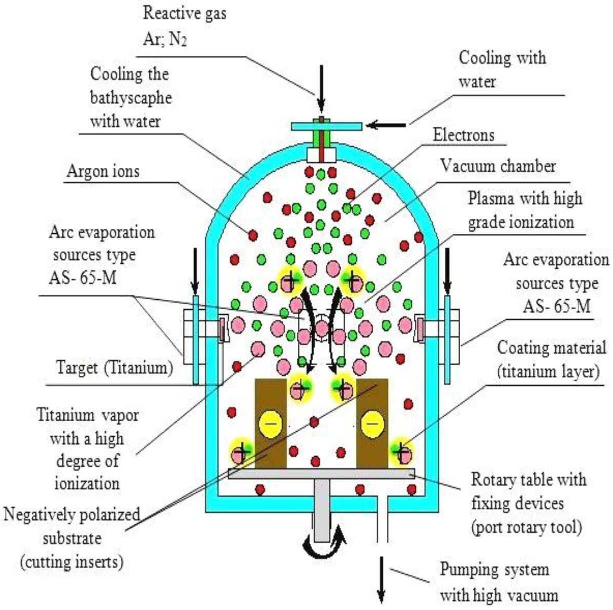


Figure 2. The principle general scheme of the installation used in the application of the ionic plating method

The recipient 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 metal titanium vapors. In the recipient shaft, there is mounted a rotary port-tool support (figure 2) equipped with the special devices designed for the settlement of the cutting inserts.

The symmetrical positioning of the cylindrical recipient to the axis makes as the inserts subject to the coating, located in batch, to be in identical deposition conditions for ensuring a uniform thickness of the deposition. Cleaning of the cutting inserts before the titanium deposition is carried out also inside the vacuum chamber, by spraying with a controlled stream of argon. Titanium 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 positive ionized and excited partially are accelerated in cathodic dark space of the substrate and, hitting it with increased energy, performs the deposition on it.

3 RESEARCHES AND OBTAINED RESULTS

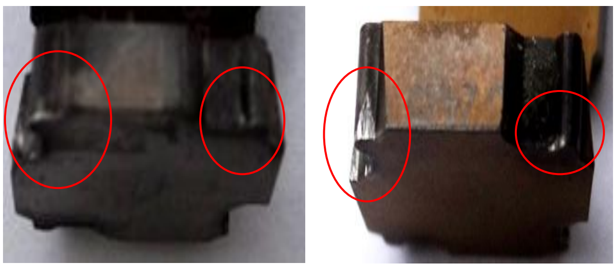
For the experimental researches, four types of carbide cutting inserts were used:

- type SPUN 120412-A, used for turning two channels inside the outer ring (figure 3) of a bearing ball; the profile shape inserts (cutting inserts), made by wire electrical discharge machining on the equipment ULTRA CUT F1, is evidenced in figure 4 and is identical in both cases: for the titanated cutting insert (figure 4.a) and, respectively, for the cutting inserts without titanium deposition (figure 4.b), areas of wear after the turning operation carried out on equipment SHM 120 are indicated, in both cases, in figure 5.

Figure 3.Outer ring of the ball bearing

a B

Figure 4. Insert SPUN 120412-A
a. Without titanium deposition;
b. Coated

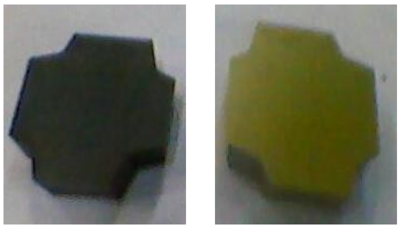


a b

Figure 5. Insert SPUN 120412-A
a. Without titanium deposition and used;
b. Titanated and used

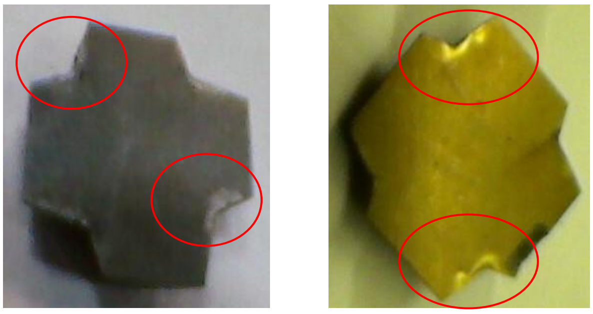
- type SPUN 120312-A, used in turning interior radius and chamfers of the car engine roll from figure 6, operation performed on equipment KTSP – 80A; cutting inserts shaped by wire electrical discharge machining on equipment ULTRA CUT F1, both titanated and titanium uncoated, are highlighted by figure 7 and in figure 8 there are shown the cutting inserts after the turning operation, having their wear areas marked.

Figure 6.Car engine roller



a b

Figure 7.Pill SPUN 120312-A
a. Without titanium deposition;
b. Titanated



a b

Figure 8.Pill SPUN 120312-A
a. Without titanium deposition and used;
b. Titanated and used

- cutting inserts type SPUN 120412-B, uncoated and coated with titanium, used for turning two channels to the outside of the outer ring (figure 9) of a cylindrical roller bearing, highlighted in figure 10.a, respectively in figure 10.b, show areas of wear of the inserts after the turning operation.

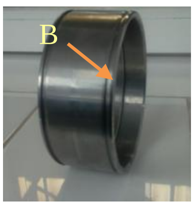


Figure 9. Outer ring of the cylindrical bearing

a b

Figure 10. Insert SPUN 120412-B; a. Uncoated and used;
b. Coated and used

- type SPUN 120312-B, used in turning of exterior radius and chamfers of the car engine roll from figure 11, operation performed on equipment KTSP – 80A; cutting inserts shaped by wire electrical discharge machining on equipment ULTRA CUT F1, both uncoated and coated with titanium, are highlighted by figure 12 and in figure 13 the cutting inserts after the turning operation, having their wear areas marked are shown.

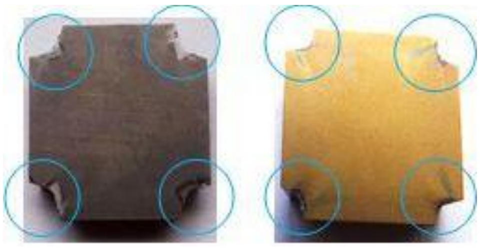
Figure 11. Car engine roll

a **b**

Figure 12. Insert SPUN 120312-B

a. Without titanium deposition;

b. Titanated



a. **b.**

Figure 13. Insert SPUN 120312-B

a. Without titanium deposition and used;

b. Titanated and used

Table.1 Specific conditions of the turning process of all four cutting inserts uncoated and coated with Ti

Cutting inserts type	Depth t [mm]	Speed v [m/min]	Spindle speed ω [rpm]	Feed f [mm/rot]
SPUN 120412-A	3	110	360	0.15
SPUN 120312-A	0.46	80	1132	0.3
SPUN 120412-B	2.6	140	318	0.3
SPUN 120312-B	1.1	107	1512	0.3

During the use of the four types of metallic carbide cutting inserts in the turning process of the rings and bearings roller, it was determined their tool lives, both for the uncoated with titanium and also in case of their titanium coating and the number of the machined parts without these coatings and, also, in case of their titanium coating and the number of the machined parts with these cutting inserts, till their wear and loss of cutting quality.

Measurements made allowed also elaboration of graphical representations about how the variation in time of the cutting inserts wear is, as well as the volume of machined parts, during their normal operating time, in the case of inserts type SPUN 120412-A (figure 14 and figure 15), respectively in the case of inserts type SPUN 120312-A (figure 16 and figure 17) and, also, in the case of inserts type SPUN 120412-B (figure 18 and figure 19), respectively the inserts SPUN 120312-B (figure 20 and in figure 21).

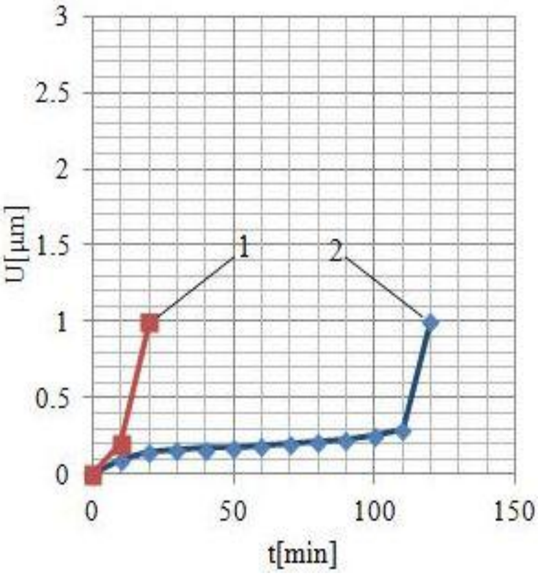


Figure 14.Variation in time of the wear with the cutting inserts type SPUN 120412-A at outer rings of an radial ball bearing

1- profiled uncoated with titanium;

2- profiled coated with titanium.

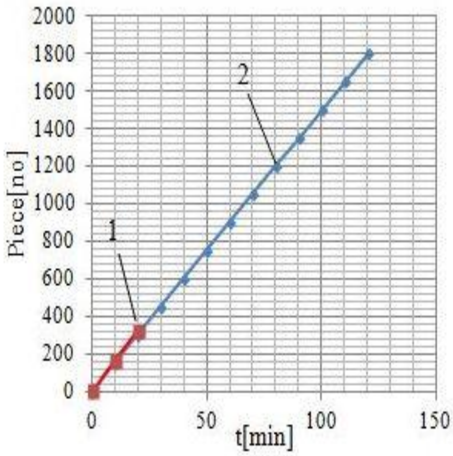


Figure 15. Variation in time of the volume of processed parts with the cutting inserts type SPUN 120412-A at outer rings of an radial ball bearing

1- profiled uncoated with titanium;

2- profiled coated with titanium.

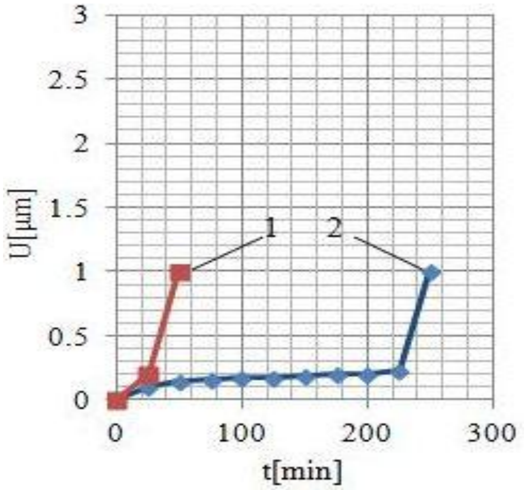


Figure 16. Variation in time of the wear of the cutting inserts type SPUN 120312-A at cutting of car engine roller: 1- uncoated with titanium; 2- coated with titanium

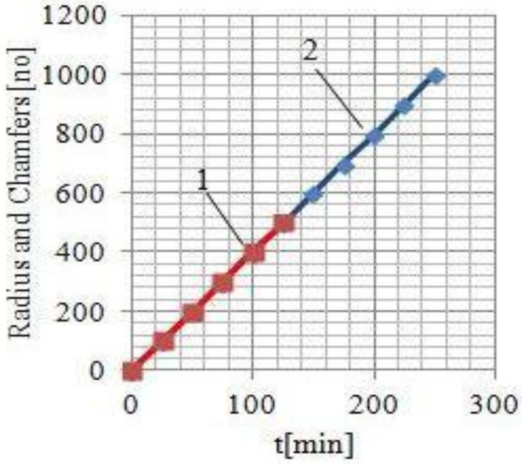


Figure 17. Variation in time of volume of processed parts machined with the inserts type SPUN 120312-B at cutting of car engine roller: 1- uncoated with titanium; 2- coated with titanium

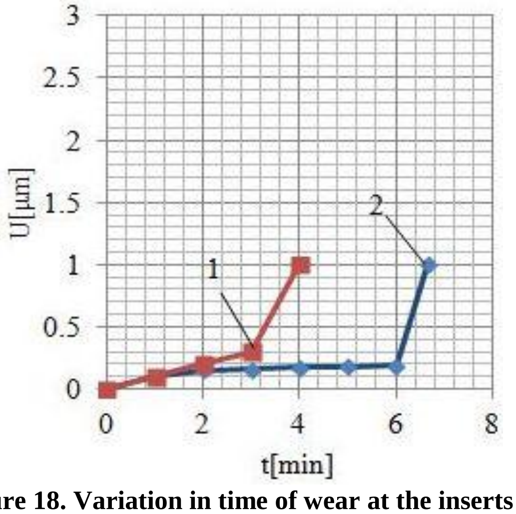


Figure 18. Variation in time of wear at the inserts type SPUN 120412-B at cutting of outer rings of a cylindrical roller bearing:

1- uncoated with titanium; 2- coated with titanium

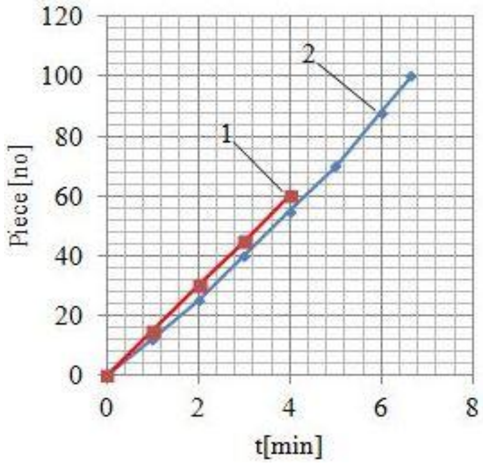


Figure 19. Variation in time of the volume of processed parts at use of the inserts type SPUN 120412-B at cutting of outer rings of a cylindrical roller bearing:

1- uncoated with titanium; 2- coated with titanium

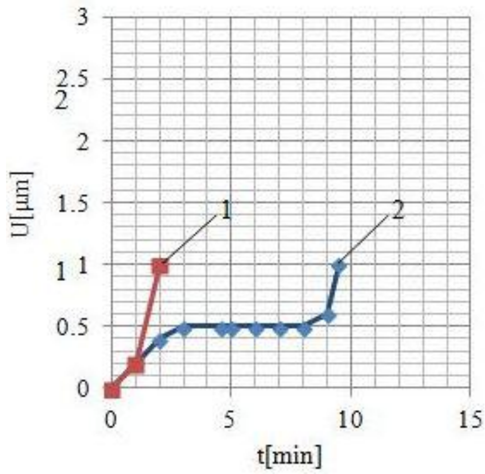


Figure 20. Variation in time of the wear at the inserts type SPUN 120312-B at cutting of car engine roller:

1- uncoated with titanium; 2- coated with titanium

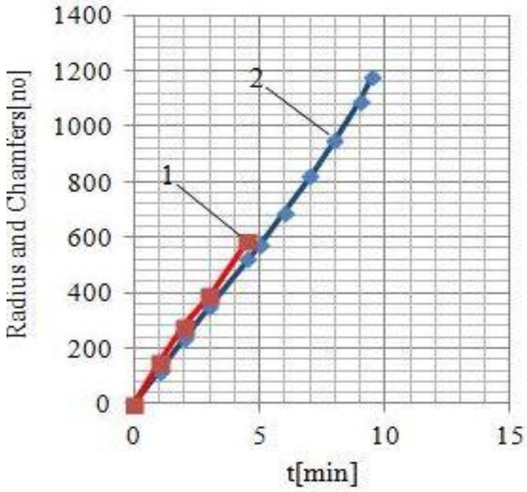


Figure 21. Variation in time of volume of machined parts at the use of inserts type SPUN 120312-B at cutting of the car engine roller:

1- uncoated with titanium; 2- coated with titanium

Values obtained by machining are shown in table 2, they showing a sustainability remarkable growth of the metallic inserts undergo the process of thin Ti coating by a PVD process, for all four types of cutting inserts used, in relation to those non-affected by titanium deposition.

Table 2. The durability of the carbide cutting inserts used

The type of insert		Nr. tested insert	Durab. tested [min]	Nr. Samples made	Samples type
SPUN 120412-A	U	1	21'33"	320 channels (160 rings)	Outer ring of a ball bearing
SPUN 120412-A	C	1	121'33"	1820 channels (910 rings)	Outer ring of a ball bearing
SPUN 120312-A	U	1	120'	500 Radii and chamfers	Car engine roll
SPUN 120312-A	C	1	240'	1000 radii and chamfers	Car engine roll
SPUN 120412-B	U	1	4'	320 channels (160 rings)	Outer ring of a ball bearing
SPUN 120412-B	C	1	6'40"	1820 channels (910 rings)	Outer ring of a ball bearing
SPUN 120312-B	U	1	4'53"	500 radius and chamfers	Car engine roll
SPUN 120312-B	C	1	9'47"	1000 radius and chamfers	Car engine roll

4 CONCLUSIONS AND FUTURE RESEARCHES

Following the analysis of the obtained results presented before, the titanium deposition in thin layers leads to an improvement about 1.5-2 times of the used cutting inserts life, in the cutting process of outer bearing rings and rollers, compared to the case of those metal carbides cutting inserts uncoated with titanium.

This fact largely confirms indicated results from literature. Use in the process of turning the outer rings of bearings of the cutting inserts type SPUN 120412-A and type SPUN 120412-B led, following their coating with a thin layer of Ti by PVD method, to an increase of almost 6 times of their tool life; with them could be processed 6 times many pieces until the cutting qualities are lost through wear of the cutting tool. In the case of the use of the cutting insert type SPUN 120312-A and type SPUN 120312-B, durability of the covered one has doubled towards to the uncoated one with a layer of Ti. Increase of the durability is lower however than in the first situation possible, due to a larger surface of contact between cutting insert and roller surface of the workpiece in this second case, this when the number of pieces manufactured is double.

There is a logical growth, directly proportional to the working piece volume, possible to be processed with those cutting inserts, simultaneously with the increase of durability, fact that justifies the increase of the processing productivity by highlighting the cutting inserts average time for proper functioning.

The positive obtained results open new opportunities to continue the researches in the field of deposition of thin layers, were resistant, following in the future: determining the layer depth or the successive layers depth deposited, its optimal values established so that they can reach some high values for the durability, determination of thickness of deposited layers and determining their optimum thickness (depending on the layer structure), study of their behavior in the processes of turning, the possibility to use some other filler materials not included in the performed study, using the same PVD process, as well as the cutting inserts types diversification, which will be the subject to filler material deposition and their behavior in the cutting processes.

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