APPLYING TITANIUM COATINGS ON CERAMIC SURFACES BY ROTATING BRUSHES

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Abstract

The article describes a new method of applying titanium coatings on ceramic surfaces using special tools - rotating brushes with titanium fibers. The soldering of ceramic-metal joints involves the use of expensive active solder eliminating the lack of wettability of the ceramic. More economically advantageous solution is to give a wettability to the ceramic surface, by applying a durable titanium coating and using a wider range of soldering materials. The titanium coating obtained by means of friction metallization can be used as an alternative to metallization, for example by thermal spraying methods. The metallization method using rotating brushes enables the titanium coating to be applied on flat and 3D surfaces. The article outline the structure of the tool and the method of applying the coating, as well as the results of the tests carried out.

Keywords: Friction metallization, metallization of ceramics, titanium coating, cup brushes, soldering ceramics and metal

1. INTRODUCTION

Using ceramic materials in technology imposes the necessity of creating ceramic-metal joints. The basic problem of joining metal and ceramic is the difference in their physical and chemical properties and different atomic bonds which resulting low wettability of ceramic surfaces by large part of liquid metals [1,2]. Titan is one of the few elements that reacts with nitrogen, oxygen or aluminum, which are components of ceramic materials [3,4].

In case of the process of joining ceramic with metal, the ceramic material remains solid and the joined metal is melted [5. The metallic coating obtained by the friction method allows to occur a connection between the ceramic substrate and the metallic coating with keeping solid state of both materials [5,6].

The most popular methods of applying titanium coatings on ceramic surfaces are thermal spraying (flame), detonation spraying, arc or plasma spraying [7]. These technologies are extremely time-consuming and costly, an additional problem is the heating of processed parts up to 150 °C and high noise levels during the process. Regular thickness of titanium coating on curved surfaces is difficult or impossible to obtain by using these technologies. There are also special active solders that allow making ceramic-metal joints without additional coatings, but they are not widely available and their prices are high. Ceramic-metal joints are also realized by means different methods where the energy for joining are delivered in way of friction or in a different mechanical manner [10-15].

In the proposed method, a rotating brush with titanium fibers was used as the coating application tool. The tool can be mounted in a standard CNC machine tool holder and the workpiece can be attached by using standard tool holders, such as vices or dedicated fasteners depending on the shape of the workpiece. The friction technology of titanium coatings does not require the use of vacuum chambers and additional machine tool modifications.

2. PREPARATION OF TITANIUM COATING ON CERAMICS

There are more and more brush tools on the market for metalworking tools. An example of this is the Xebec rotary tools [16]. Tools are equipped with ceramic fibers to improve surface roughness and deburring [17]. Unfortunately, all of the offered tools are used to remove the top layer of material. In the proposed method, the titanium fibers of the rotating brush are rubbed into a ceramic substrate.

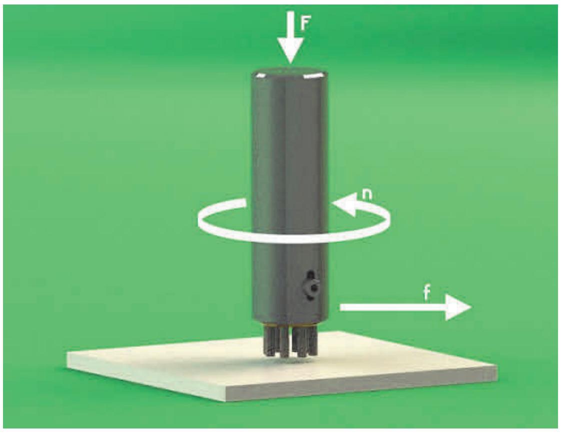

Figure 1 The principle of the rotary brush tool with titanium fibers (own case study)

The titanium coating is obtained by rotating friction with the front of the brush along with the transmission of a straight-line translational movement to increase the machining surface (**Figure 1**).

During the tests, two versions of the tools Prototype 1 and Prototype 2 were made. The Prototype 1 tool has a similar structure to the ceramic tools used for material removal. Prototype 1 (**Figure 2**) consists of a compensating holder mounted to the CNC machine spindle. The tool body with the insert with titanium fibers (Grade 2) is mounted in the compensating holder. The first version of the tool used eight fiber packages located circumferentially on the face of the insert, the thickness of a single fiber was 0.3 mm, and its length was 40 mm. A spring was used in the compensating holder, which allowed to achieve a pressure force of approx. 9N.

Figure 2 Prototype 1 tool with compensating handle mounted in the CNC machine spindle (own case study)

Figure 3 Prototype 2 tool with compensating handle mounted in the CNC machine spindle (own case study)

After the first tests, it was found that the fibers are not rigid enough and it was decided to make another tool. After analyzing the conclusions of the research, the Prototype 2 tool (**Figure 3**) was designed and made, differing in its design from the predecessor. Prototype 2 does not have an additional compensating grip, which provides a constant clamping force and allows for easier adaptation of the fibers to the work surface, including flat surfaces and 3D surfaces. In similar friction metallization tests using a titanium rod tool [3], the ceramic substrate was sometimes destroyed due to insufficient elasticity of the tool with respect to the substrate material. The function of the compensating grip has been taken over by the spring inside the body. In addition, a spring was used to obtain a pressing force of up to about 88 N. **Figure 4** shows the half-section view of the Prototype 2 tool, in the body 1 similarly to the Prototype 1 version there is a pressure spring 2 and an insert 5 with eight titanium fiber packages 6. The tool body has two channels 3 that enable the insert to be secured with screws 4. The thickness of a single fiber increased to 0.4 mm, and the fiber length was reduced to 10 mm.

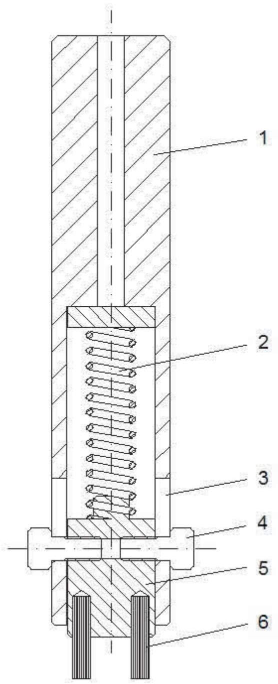

Figure 4 Prototype 2 tool (own case study)

The changes made in this way allowed to obtain a tool with a more compact construction and to obtain fibers with higher stiffness. In both Prototype 1 and Prototype 2, titanium fiber bundles were glued into the insert with an epoxy resin. The substrate material was discs with diameters from 70 to 80 mm made of AlN and Al_2O_3 ceramics. Ceramic discs have been glued to metal bases enabling easier mounting on the machine.

3. SELECTION OF MACHINING PARAMETERS

The friction metallization process was performed on the Cincinnati Arrow 500 milling center. For each of the tests, the samples were mounted in a three-jaw chuck mounted on the CNC machine table (**Figure 5**). The research focused on determination of optimal machining parameters such as: spindle speed, tool clamping force and tool feed speed on the ceramic substrate.

Figure 5 The Prototype 2 tool during working on the Cincinnati Arrow 500 center (own case study)

In the first part of the tests made with the Prototype 1 tool, the rotational speed of the tool was changed from 1000 rpm to 6000 rpm, the tool pressure was constant and was about 9 N, the feed speed was selected so that a constant feed rate could be obtained at tool rotation of 0.01 mm/rev. The best results were obtained after using the spindle speed of 6000 rpm (**Figure 6a** stitch no. 1). In the further part of the research, using the Prototype 1 tool, the feed rate was changed to 0.016 mm/rev which resulted in a longer time of rubbing and improved the effect (**Figure 6b** stitch no. 3).

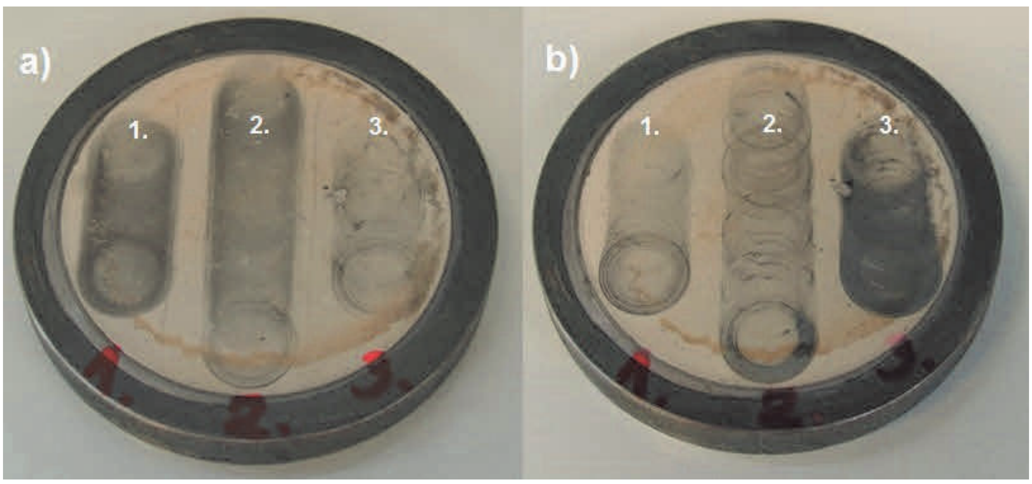

Figure 6 Samples made with Prototype 1 tool, a) change of tool speed, b) change of tool feed speed (own case study)

In the next part of the tests made with the Prototype 2 tool, tested parameter was the tool pressure. During the tests the clamping force was changed in the range from approx. 88 N to approx. 28 N while maintaining the rotational speed of the tool of 6000 rpm and a constant feed per revolution of 0.016 mm/rev (**Figure 7**).

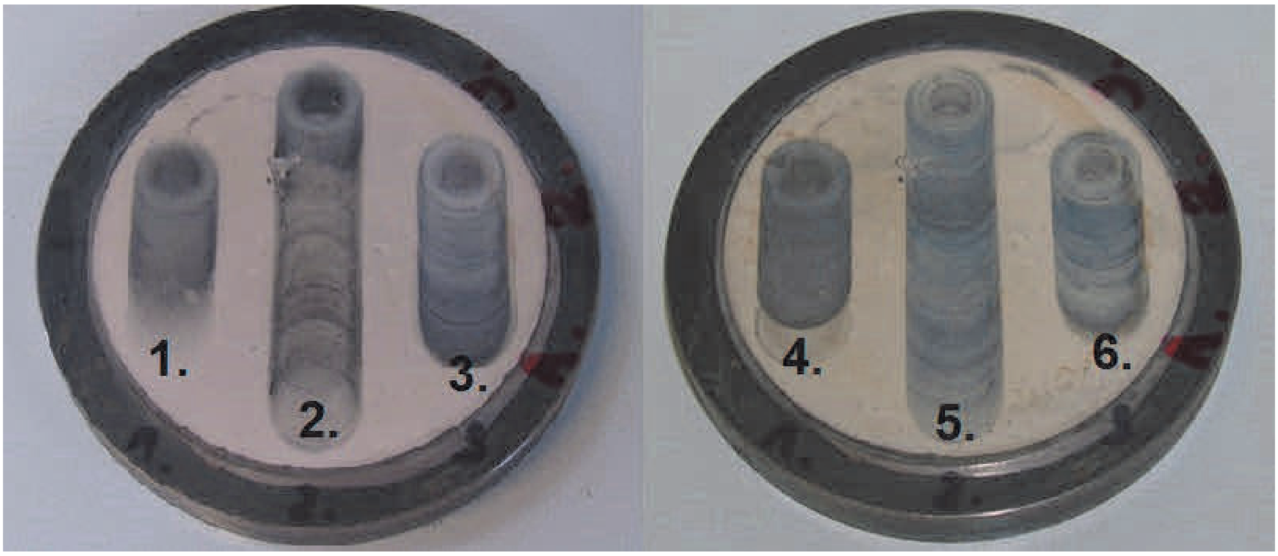

Figure 7 Samples made with Prototype 2 tool, stitch no. 1 pressure force 88 N, stitch no. 2 pressure force 73 N, stitch no. 3 pressure force 53 N, stitch no. 4 pressure force 48 N, stitch no. 5 pressure force 38 N, stitch no. 6 pressure force 28 N (own case study)

In the test with the change of the clamping force parameter, the best effect was observed for the clamping force value of approx. 48 N. In the case of a higher pressure force, the effect deteriorated, which was caused by the excessive spreading of the fibers from side to side and the lack of proper rubbing of the fibers into the substrate. In the case of a lower value of downforce, there was a coating on the samples. The resulting coating was a titanium fiber dust that rubbed against the substrate leaving a weaker layer of titanium on the ceramic.

After the tests, it was found that the most optimal parameters for the Prototype 1 tool is the use of a rotational speed of the tool of 6000 rpm, a value of 50 N clamping force, and the value of the tool feed rate of 0.01 mm/min. **Figure 8** shows the titanium coating applied with the above-mentioned machining parameters.

Figure 8 Titanium coating made with the following parameters: 6000 rpm; 50 N; 0.01 mm/min (own case study)

Studies were also carried out using a shield in an argon atmosphere. Similar tests [4] showed the possibility of making a coating of pure titanium and coating TiO and TiN for the substrate made of AlN ceramics. In the further part of the research, it is planned to increase the rotational speed of the tool, lower the feed speed, measure the coating thickness, analyze the coating phase on the AlN and Al_2O_3 ceramics, perform soldering tests and solder picking tests.

CONCLUSION

The proposed method can be an alternative when making titanium coatings on ceramic surfaces. The use of high rotational speeds of the tool (≈6000 rpm) allows the creation of a titanium coating by providing sufficient kinetic energy, and the use of low feed speeds ensures longer time of rubbing the titanium fibers into the sample allowing for a more uniform coating. The value of the clamping force depends on the length and thickness of the fibers. A single fiber must have adequate stiffness. It is possible to obtain coatings consisting of TiO, TiN or pure titanium depending on the atmosphere used during the process.

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