

DEVELOPMENT OF HIGH RESOURCE PLASMA SPRAYING EQUIPMENT AND PROSPECTS OF ITS USAGE IN FOOD INDUSTRY

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Summary. The article contains the results of creating and testing the high resource electric-arc plasmotron, designed for spraying the protecting coating. It also deals with the prospects of its usage in food industry.

Key words: plasma spraying, electric-arc plasmotron, work resource, hollow cathode, particulates, food industry.

INTRODUCTION

In contemporary engineering various sources of highly concentrated power flow are used. The significant place among them is taken by plasma heat sources that are used in different types of material processing: plasma arc-welding and metal arc-cutting, plasma spraying of coatings, plasma and mechanical processing. For recent decades a significant importance has been reached by plasma spraying and plasma surfacing that are used for producing new parts with wear-, heat-, corrosion-resistant coatings and other types of coatings, as well as for renovation of worn-out and reject parts [1, 2].

Traditionally, in practical work argon, up to 25% hydrogen-filled argon, nitrogen, hydrogen and nitrogen mixtures, sometimes neutral gases mixtures, containing helium have been used as plasma-supporting environment while plasma spraying of parts. High price and deficiency of neutral plasma-supporting gases constricted the sphere of usage of powder material plasma processing. These reasons caused the usage of air and air and fire carbureted hydrogen gas mixture as plasma-supporting gas.

Efficiency and technical practicability of usage of gas-air mixture led, on one side, to increase of plasmotron capability, on the other side, it caused dramatic decrease of its operation life. Besides, the spraying plasmotrons are characterized with inadequate dimensions of the zones of plasma flow and heated particles interaction, low performance index and spraying capability, as well as short electrons' operation life [1, 3].

Partial solution of the problems mentioned has been reached in Institute of Gas of Ukraine National Academy of Sciences (NAS) and Scientific and Production Enterprise (SPE) "TOPAS" thanks to the change of geometry of plasmotron's discharge channel

and usage of gas-air mixture as plasma-supporting gas; in Institute of Thermal Physics of SB Russian Academy of Science (RAS) and St. Petersburg State Technical University developing the plasmotron with interelectrode insert elements; in the Volodymyr Dahl East-Ukrainian National University [4, 5].

RESEACH OBJECT

The aim of the article is to develop the high-resource and high-performance electric-arc spraying plasmotron that works with air-gas mixture, and to search for the prospects of its usage in food industry.

The investigations were held in EUNU named after V.Dahl at Engineering Technologies Department and Light and Food Industry Department. The presence of thermochemical cathode in spraying plasmotron leads to restrictions in number of the working gases used, current intensity and number of starts (because of the high level of starting erosion). In this basis as well as after searching for other conditions of increasing the plasmotron operation life for processing particulates and its efficiency caused the creation of Plasmotron ПЛІ-8А. The plasmotron of indirect action has the wattage of 40 kW and is intended for surface hardening and spraying of protective coating.

While designing the plasmotron there was used the system of three-dimensional parametric projectivity COMPAS-3D. Plasmotron consists of the hollow copper cathode 1 and the anode 2 that are situated in the collector 3 and separated by the working gas supply chamber (fig.1). On the outside surface of the anode mount there are some screw holes that are used for mounting the spraying material supply unit.

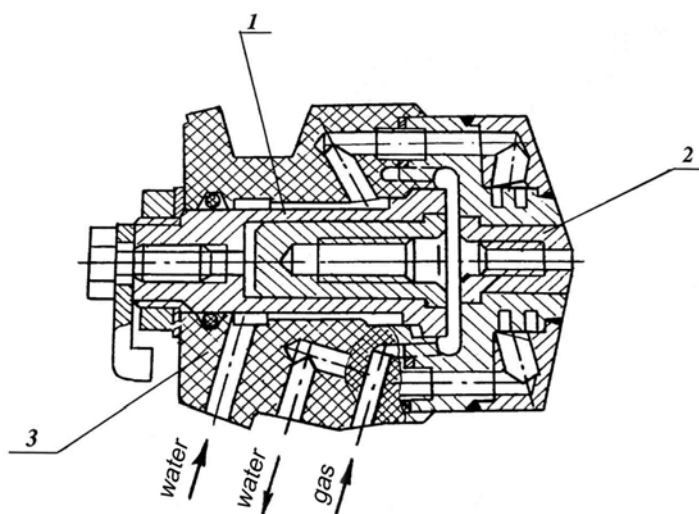


Fig. 1. Construction scheme of Plasmotron ПЛІ-8А
1 – cathode; 2 – anode; 3 – collector

For spreading cathode and anode locking-on of the arc along the discharge channel the way of arc splitting was used. It is proved that in smooth cylinder electrode channel the process of arc splitting is possible, but it is of unsteady character. That is why in electrode, of homogeneous material, there must be made the points of preferred locking-on of the arc to the electrode for providing gas-dynamic splitting.

In the plasmotron, for these reasons, a screw thread was made on the surface of cathode and anode discharge channel. Mounting arc points (cathode and anode) are split into «*n*» mounting points that leads to heat and erosion spreading along the channel and increases electrodes operation life. The splitting steadiness is supported by choosing the pitch and depth of screw line rifling.

Providing a discharge channel with a screw thread helps to enlarge the arc length and, correspondingly, the voltage (5-10%) and promotes more effective heat transfer between the arc and heated gas, that causes 15-20% increase of coefficient of thermal efficiency.

RESULTS OF EXPERIMENTAL RESEARCH

The experimental investigations of the plasmotron were held in the laboratories on the test bench (fig. 2) with the following Plasmotron parameters: working gas flow (air) $G=0,2-2,5$ gm/s, arc current rate $I=50-250$ A and pressure $P=1 \cdot 10^5$ Pa. The results of investigations proved steady, stable Plasmotrom operation.



Fig. 2. The working Plasmotrone on the test bench.

The experiments for quantifying the plasmotron current voltage characteristics were held with the hollow cathode, both with bent threads and not. The general view of the characteristics is degressive, that is explained by the bridging effect. The specialty

of current voltage characteristics of the plasmotron with the cathode that has an inside thread, is 5-10% higher arc voltage, compared to the cathode with a smooth channel. The more intensive gas and current flow is, the bigger the voltage difference is.

Also the investigations for qualifying the plasmotron heat characteristics were held. The coefficient of thermal efficiency of the plasmotron with the bent threads in a discharge channel is $\eta = 0,65-0,67$, that is approximately 10% higher than the coefficient of thermal efficiency of the plasmotron with a smooth discharge channel.

The operation-life investigations were held with the examination of cathode and anode work surface after every start and proved that the plasmotron working ability without changing the electrodes is over 70 hours that is a double working ability of commercial plasmotrons of a similar type.

The main parameters of the plasmotron, received during the experiments, are placed in Table 1.

Table 1. Technical specifications of the electric-arc spraying plasmotron

Wattage, kW	Arc current rate, A	Working gas flow, gm/s	Coefficient of thermal efficiency	Spraying productivity, kg/h	Operating life, h
40	300	0,5–2,5	0,55–0,65	3–10	70

Production validation of the electric-arc plasmotron was held while spraying a heat-resisting alloy EI-435 on aircraft engine's parts made of titanium alloy OT4-1. Plasma reconstruction was made for ring collars of the industrial unit UPU-3D.

For spraying the coating there was set the following experimental mode for spraying a heat-resisting alloy on ring-collars:

- distance between the plasmotron's nozzle exit and the surface processed 105 mm,
- flow approach angle $(90 \pm 3)^\circ$,
- rotation speed of a part 8 r/min,
- arc current rate 300 A,
- argon flow 1,04 g/s,
- time of coating application 12,5 min.

Coating thickness received is 0,8–1,2 mm on the side and was measured by gaging the part's thickness with a beam-compass before and after the coating application. Fig. 3 shows the ring collars' surface before and after applying the coating. Visual examination proved that the coating is flaw- and voidless [6].

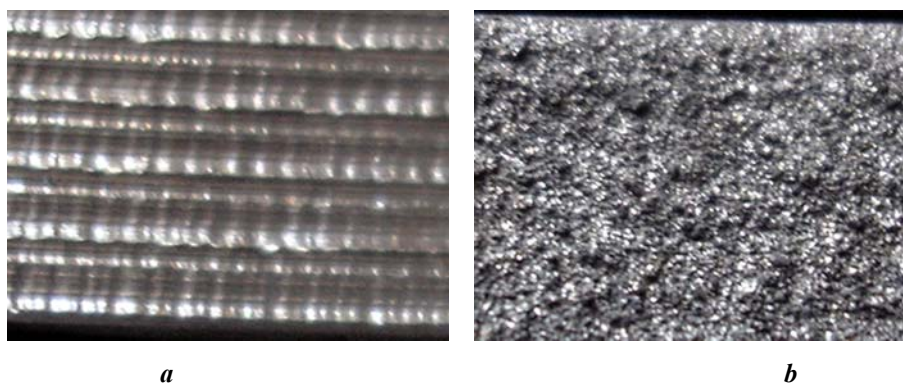


Fig. 3. Ring collars of wheel rotors of a helicopter engine:
a – the surface of a ring collar bored under the coating; *b* – restored ring collar's surface

CONCLUSION

The set of topical problems, concerning the increase of plasmotron's operating life and effectiveness while processing the particulates, have been solved. In such a way, the electric-arc plasmotron designed and the results received can be recommended for commercial usage for plasma restoring of component parts.

The prospects of follow-up studies in this direction. The problem of restoring the component parts and their spraying with wear-resistant coating is topical in food industry. That is why the follow-up development and plasma spraying usage is recommended for the following component parts: pressing-out and other screws, screws in hydraulic press, welded tanks and others (fig.4). For example, while spraying the material VN-20 on the surface of cutter's knife there appear an effect of self-sharpening, and as a result the operating life between resharpenings increases 2-5-fold.

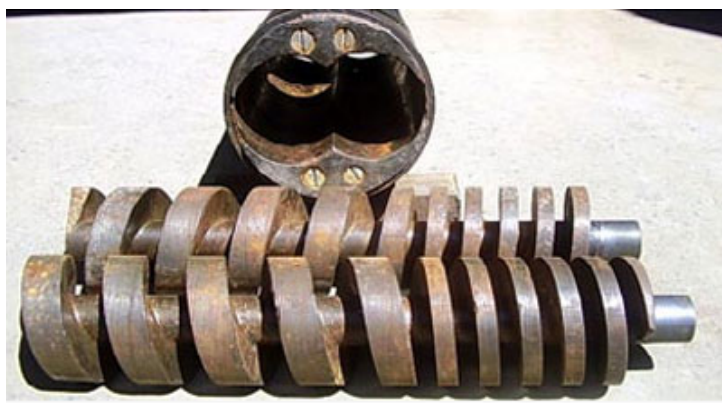


Fig. 4. Worn-out screw and sleeve ("compressor gun")

The special importance in food industry is seized by aluminum oxide coatings that can be used for increasing the wear-resistance of component parts that work in conditions of friction with soft materials – food products, rubber, fluorine plastic and other ones that are used for packing assemblies; with hard materials in friction bearings. Besides, such coverings possess heat-stealing and electroinsulating characteristics, and are used for corrosion prevention.

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РАЗРАБОТКА ВЫСОКОРЕСУРСНОГО ПЛАЗМЕННОГО ОБОРУДОВАНИЯ ДЛЯ НАПЫЛЕНИЯ И ПЕРСПЕКТИВЫ ЕГО ИСПОЛЬЗОВАНИЯ В ПИЩЕВОЙ ПРОМЫШЛЕННОСТИ

Гаврыш В.С., Морнева М.О.

Аннотация. В статье представлены результаты по созданию и испытанию высокоресурсного электродугового плазмотрона, предназначенного для нанесения защитных покрытий. Также показаны перспективы его использования в пищевой промышленности.

Ключевые слова: плазменное напыление, электродуговой плазмотрон, ресурс работы, полый катод, дисперсный материал, пищевая промышленность.