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AUTOMATION OF PLASMA MACHINING IN A CONTINUOUS OPERATION LINE

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Abstract

The application of plasma techniques for surface modification like cleaning, activation and etching are described in this article. Technological process of glass packaging decoration takes place on a continuously operating conveyor line. A machine tool for plasma modification with a movable vacuum chamber has been designed. Construction and structure of mechanical, pumping and electric power supply systems have been described, together with machine tool operating cycle.

Keywords: *production automation, plasma modification, plasma cleaning, plasma activation, plasma etching, low temperature plasma*

1. Application of plasma techniques for surface modification

Low pressure plasma allows for various possibilities of surface modification. Some of the applications are as follows: precise cleaning of dirty structural components, plasma activation, etching and coating of components [1], [2].

Plasma cleaning is a method of surface cleaning which proved to be effective, economic and safe for the natural environment. Plasma cleaning is six times more effective than traditional cleaning methods, and cleaned surface is ready for subsequent operations with no significant loss of material. Electrons are accelerated to very high velocities by oscillating electromagnetic field and excite atoms and gas molecules, which results in plasma generation. Ultraviolet radiation emitted during plasma generation very effectively breaks bonds of most organic compounds which contaminate the surface. The surface is physically cleaned using ion bombardment, and, depending on gas type, by chemical reactions. Contaminations are transformed into gaseous phase and sucked off.

Plasma cleaning has been used for:

- removal of lubricants, oils, oxides,
- pretreatment before bonding, soldering or gluing,

- pretreatment of components before lacquering [3].

Plasma activation can be used in case of surface modification of new packaging materials. Material surface is machined by plasma, using oxygen, for example. Radical points are created, ensuring good adhesiveness (which is necessary before overprinting, lacquering, gluing of components).

In the process of material structuring, creating good adhesiveness of associated materials when producing packaging materials, surface etching of such material can be useful. The surface is etched using a reactive process gas. The material is removed, converted into gaseous phase and sucked off. It may increase the area and wetting characteristic.

Plasma modification of a surface may take place on different organic materials, giving them hydrophobic, hydrophilic characteristic, resistance to external mechanical impacts. Shaping of the profile of textural surface properties of organic materials is not excluded. Moreover, plasma technology can be used to create barrier coatings, resistant to external mechanical impacts, including hydrophobic and hydrophilic coatings [1], [2], [4].

2. Industrial application

The need for automated plasma treatment of bottles before their decoration resulted from insufficient quality of the process which has been realized in existing production lines in the leading company operating in Poland. Up till now, corona plasma cleaning using individually set gas burners has been used. The results of such cleaning have been unsatisfactory because of local (partial) burns of the cleaned surfaces and variations of surface adhesion.

A conveying line shown in drawing 2 is used in the automatic line for bottle decoration presented in drawing 1. Components, which are being machined, move continuously, which results from the technological process related to repeated application of paints and lacquers, and ultraviolet curing of the surface. Cleaning and activation of surface using low temperature plasma, which ‘flows around’ the component being cleaned in the vacuum chamber, have been proposed.

It required practical verification of proposed plasma method on specially built test stand, and designing a mechanical assembly consisting of a moving vacuum chamber, which was sequentially closing a batch of components being machined, and, after plasma treatment, was returning to initial position. Such solution has not been used on the market of vacuum devices for plasma cleaning, so it has been a subject of patent application [5].

3. Machine tool construction and design

Machine tool (drawing 3) consists of a stand with guides, on which a slide 1 is placed with a vacuum chamber 2. A system of aluminium sections item® has been used to build a movable assembly. Slide 1, driven by a servo-motor 4, moves along the guides of the stand 5. Vacuum chamber has been divided into two parts, which are closed by pneumatic actuators 3. On the front of two parts of the chamber a silicone seal is placed, in which holes have been cut for spindles which fasten components to be machined (drawing 4). Because of seal durability, when the chamber is closed, spindles are centered with V-blocks elastically fastened to both sides of the chambers.

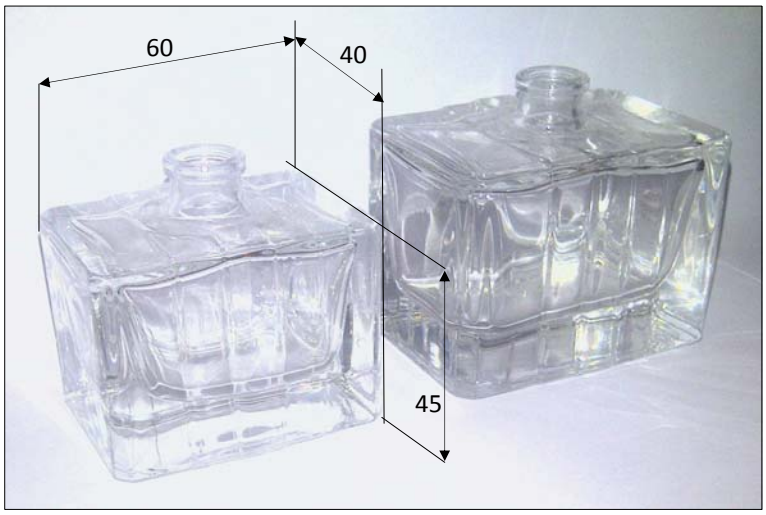

Fig. 1. Glass packagings for machining – plasma cleaning

Fig . 2. Continuously operated line

The vacuum chamber dimensions are as follows: 1900 x 160 x 160mm. The vacuum chamber has been made as a welded structure of 1.4306 stainless steel. The slide with the vacuum chamber moves along the conveyor line, on which the cleaned elements are fastened (bottles) with a constant pitch of 100mm. The conveyor line moves with a uniform speed of 4m/min. Vacuum is created by a pump assembly, consisting of an initial rotary pump and a Root WA501 pump made by PfeiferVacuum. The pumps make it possible to achieve the vacuum of 10^{-3}mbar. Fast pumping away of the chamber is necessary, so an additional ballast tank 8 is used, of 0,5m^3 capacity. The pump assembly is connected to the vacuum chamber with a flexible hose 12. Pressure inside the chamber is measured with a TPR Pirani gauge. Pure argon or a mixture of argon and oxygen in a ratio of 9:1 as technological gas can be supplied to the vacuum chamber. Gas flow rate is set with a mass controller Bronkhorst (18…900sccm). The control of the mechanical drive system and pump assembly is realized by a PLC with vacuum valves 9, 10, 11. Dora Power System 16 is used as a power supply for the plasma generator. It constitutes an autonomic current source, in which

the distribution of power is independent of load impedance [6], [7]. Current stabilizing takes place in the processing system without any feedback. To fulfill these conditions, a resonant circuit of power conversion with a resonant circuit quality factor stabilizing is used in DPS power supply. Energy supply is controlled discretely thanks to group modulation of generator signal which controls a bridge which keys a resonant frequency. Positive and negative poles are connected to electrodes 18 placed opposite to each other in both parts of the vacuum chamber 2 – drawing 4. Structural presentation of the machine tool with a pump system is shown in drawings 5 and 6.

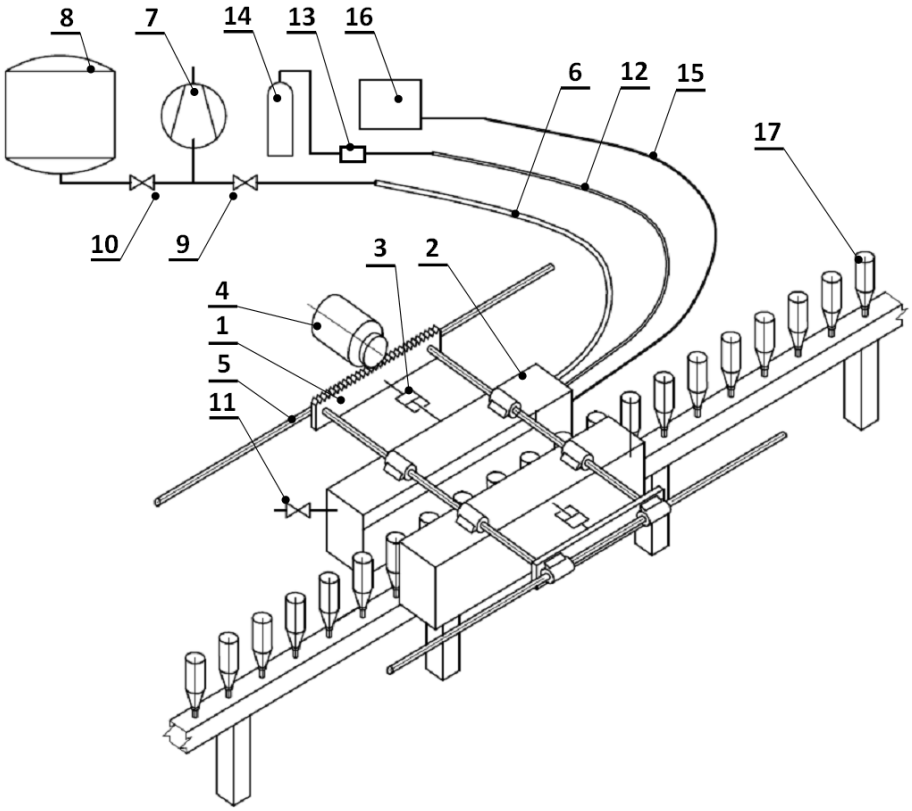

Fig. 3. The diagram of the machine tool for plasma cleaning of the elements in continuously operated line, (description in the article)

4. Working cycle – the process of plasma cleaning and activation

The system operates in the following way: elements which are to be machined are moved on a conveyor 17, continuous movement, at a uniform speed, and vacuum chamber 2 is opened and placed in a terminal position of the stand guides 5. Next, the vacuum chamber is moved – accelerated motion – until movement speed is equal to the line speed, and the chamber is closed. There are 19 elements fastened to the spindles in the chamber. Now, the vacuum chamber 2 with elements to be cleaned moves with a speed which is equal to the speed of the conveyor line. After closing the vacuum chamber the valve 9 is opened, so the chamber is connected with the ballast tank. Pressures are equalized to the level of approximately 450mbar within about 2,5sec.

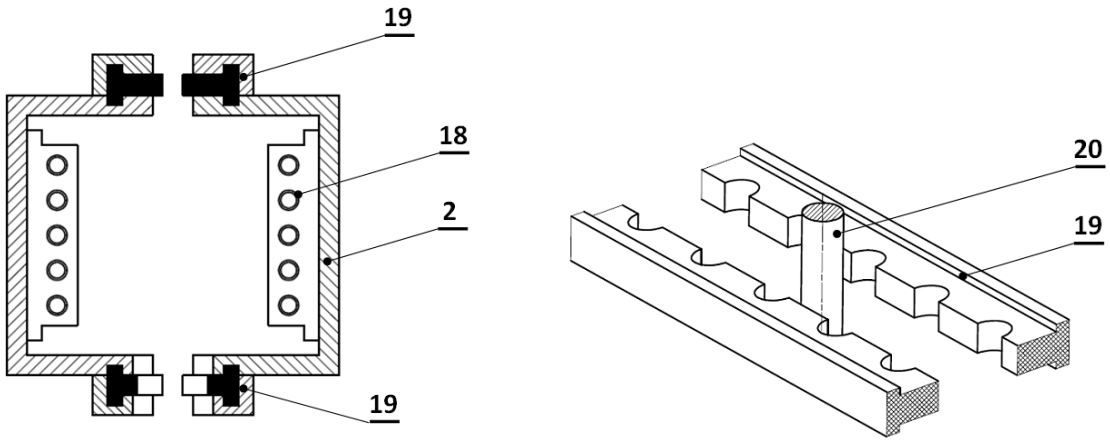

Fig. 4. Arrangement of electrodes and sealing of the chamber and spindles

Then the valve cuts off the ballast tank and further pumping is performed only by the pumps. After reaching the vacuum level of 100mbar, DPS power supply is switched on and plasma is initiated. Optimum time of the cleaning process is 3 seconds, and has been set on the grounds of test results. So, it is advantageous to continue vacuum pumping with simultaneous metering of the technological gas. After that time the power supply is switched off. Then vacuum pumping is switched from the vacuum chamber 2 to the ballast tank 8 by closing the valve 9 and opening the valve 10, after opening the valve 11 the air gets into the vacuum chamber. Operating time of the vacuum valves is 0,2 sec. and the time of filling with air is 2,5sec. After the air got into the chamber it is possible to open the chamber and slow down, then the chamber goes back to the initial position. Return movement time is 3 sec. Then the working cycle is repeated.

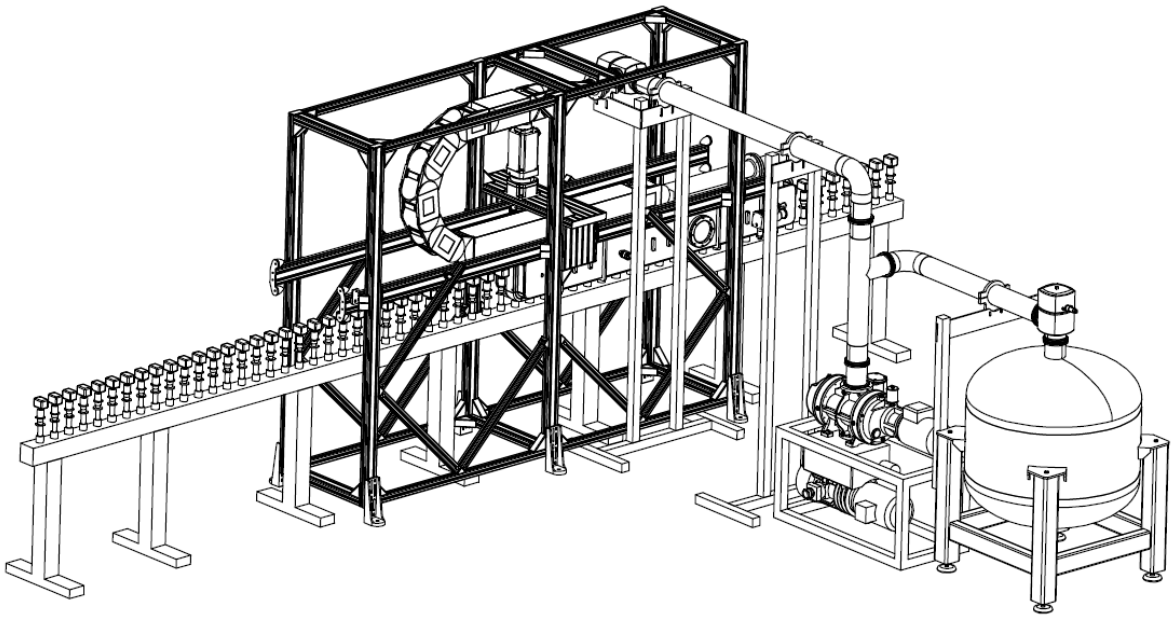

Fig. 5. The designed machine tool for surface plasma modification in continuously operated line

5. Conclusions

The machine tool has been designed and made, for modifying the surface of the elements on the continuously operating conveyor line. Machine tool has been introduced in the industrial plant in the region. Economical purposefulness of the introduction is based on the high quality of the product and the possibility of application of this technology in other production lines in the plant. It is possible to employ this solution in the production lines in the industry of glass packagings and plastic packagings, in food and pharmaceutical industries .

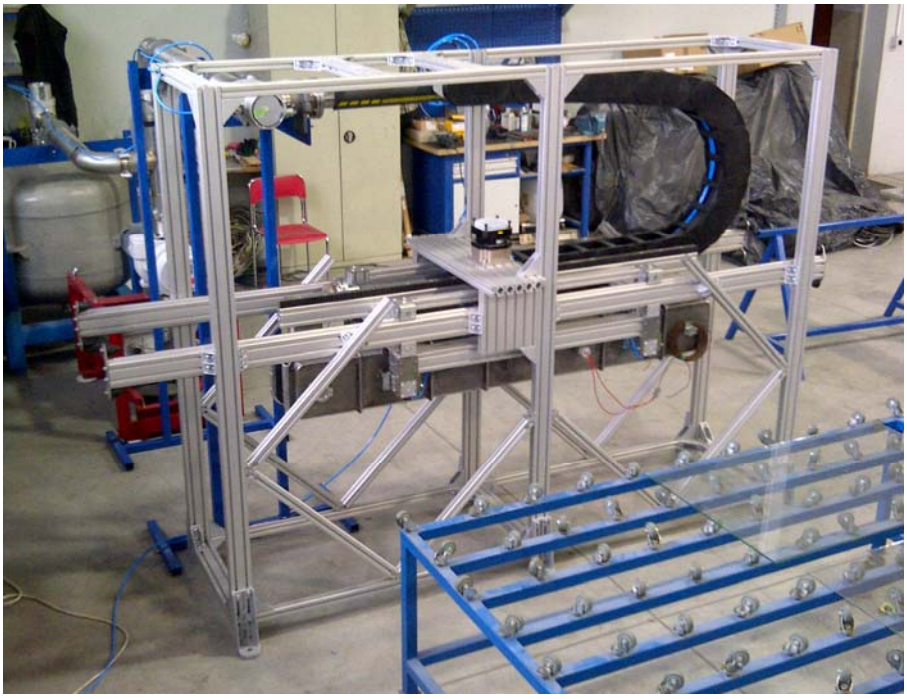

Fig. 6. Machine tool for surface plasma modification in continuously operated line

References

[1] Szałatkiewicz J.: *Wytwarzanie plazmy i jej zastosowania*, Pomiary Automatyka Robotyka, 3/2010.
[2] *Plasma Technology Process Diversity + Sustainability*, German Federal Ministry of Education and Research (Bundesministerium für Bildung und Forschung – BMBF), 2001.
[3] *Plasma technology*, Published by: Diener electronic GmbH + Co. KG, 2007. www.diener.de
[4] Kaczmarek D., Domaradzki J., Prociów E., Wojcieszak D., Mazur. M., Sieradzka K., Adamiak B., Domanowski P.: *Powłoki wielofunkcyjne dla transparentnej elektroniki,* III Sympozjum : Fotowoltaika i Transparentna Elektronika - perspektywy rozwoju, Oficyna Wydawnicza Politechniki Wrocławskiej, 2012.
[5] Domanowski P.: *Układ i komora próżniowa do obróbki plazmowej elementów na linii o ruchu ciągłym*, Zgłoszenie patentowe nr P 399750, Urząd Patentowy RP, 2012.
[6] Dora J.: *Zasilacz rezonansowy*. Patent PL nr 313150, Urząd Patentowy RP, 1996.
[7] Halarewicz J., Domanowski P., Dora J., Wawrzak A., Karwowski K., Pinio P., Wiatrowski A., Posadowski W. M.: *Próżniowe otrzymywanie cienkich warstw na wielkogabarytowych, szklanych podłożach. Część 2 – linia przemysłowa,* Elektronika - Konstrukcje, 4/ 2012.