Stanisław KOZIOŁ, Andrzej MAJCHER,
Krzysztof MATECKI, Tomasz SAMBORSKI
Institute for Sustainable Technologies – National Research Institute, Radom

A MECHANICAL SYSTEM FOR FORCE DELIVERY TO A HIGH VACUUM CHAMBER

Keywords

Vacuum chambers, pulse sintering, high vacuum.

Abstract

This paper presents problems connected with the realisation of complex movements of performance elements applied in vacuum chambers. Exemplary solution of a loading system applied in a device for pulse sintering of special materials in high vacuum conditions is presented.

Introduction

Carrying out technological processes and research in high vacuum conditions often requires the application of different mechanical systems carrying out particular movement often accompanied by significant resistance. The main problems that the designers of such solutions have to face concern the development of mechanical system realising the adopted kinematics and the dynamics of movement in a vacuum environment and the creation of a drive system intended for its realisation.

In high vacuum conditions, the work of mechanical systems is accompanied by the increased resistance of movement connected with a higher friction rate [1, 2]. In every application resistance can not be diminished through the application of lubricants. In many processes (e.g. layers deposition by means of

PVD method [1, 2]), it is impermissible to apply materials inside a vacuum device which can emit elements disturbing its course. One practical solution to this problem is the application of appropriate materials for friction pairs (slideways, screw gears, bearing machinery etc.). These are Teflon, stainless steal, cast iron and copper. The lack of lubricants requires the necessity to apply, e.g., power transmission systems of greater force.

Similar problems occur in the process of developing appropriate power transmission systems. Only in few types of applications can propulsion motors be used in the immediate proximity of the mechanisms, i.e. inside the vacuum chamber, e.g. in devices for electron beam welding, where the positioning systems of joining metals work together with their power transmission systems in the vacuum. In the majority of cases this favourable solution cannot be applied due to several reasons:

– Many processes are accompanied by the emission of a significant amount of heat, as a result of which the temperature inside the device reaches values of the order of 1000ºC.
– Aggressive substances that can negatively affect the operation of power transmissions may be emitted or may accompany the process.
– Power transmissions, similar to the previously mentioned lubricants, may constitute the source of a potential pollution.

A solution eliminating all of the above inconveniences is placing the power transmission system beyond the vacuum area, i.e. outside the chamber. It poses another problem for the constructors to solve: ensuring the air-tightness of the transition of elements coupling the performance mechanism with power (force) transmission system through the chamber wall.

In practice, we deal with the following types of the coupling elements' movements: rotary (unidirectional or oscillatory), reciprocating or pendulous movements requiring the application of particular types of seals [1]. The seals have, in the application of a high vacuum, to meet many requirements characteristic for this domain of technique. They have to be characterised with high effectiveness, limiting to the minimum the leaks of atmosphere to the inside of the chamber in difficult working conditions connected to the occurrence of dry friction, the impact of gases and process pollution, ionisation radiation and high temperature.

The aim of the presented work was the design and construction of a special experimental mechanical system for force delivery to the high vacuum chamber intended for carrying out the electrical pulse process of powder sintering. One of the more difficult tasks to be realised within the work was developing and constructing of a hydraulic and mechanical system of press moulding inside the vacuum chamber in substantial and variable conditions, during unit pressure, high sintering temperatures, high vacuum and the use of high-voltage sintering technique [3, 4].

1. Press with vacuum chamber intended for the realisation of PPS technology

The device is intended for the manufacture of composite targets for PVD technologies by means of PPS methodology [3–6]. When setting about designing the device the following assumptions were adopted:

- the process is carried out in vacuum at pressure of 10-0÷10-4 Pa,
- force was exerted on sintered powder from 1 to 100 kN,
- the accuracy of force delivering of the punch pressure was 0.5 kN,
- the accuracy of punch position measurement was 2 µm,
- the voltage of a breakdown between punches and chamber elements were not to be lower than 15 kV,
- the maximum amplitude of damped sinusoidal current following through sintered piece was up to 150 kA,
- the frequency of damped sinusoidal current flowing through sintered charge was up to10 Hz,
- The temperature in the synthesis zone was up to 2000ºC.

On the basis of such formulated assumptions, a prototype device was manufactured whose performing mechanical part consists of two basic sets a vacuum chamber with a sintering and hydraulic press process meant for the realisation of the intended load presented in Fig. 1. A special prototype impulse-plasma device was designed, manufactured and put into application in the Institute for Sustainable Technologies – National Research Institute (ITeE – PIB).

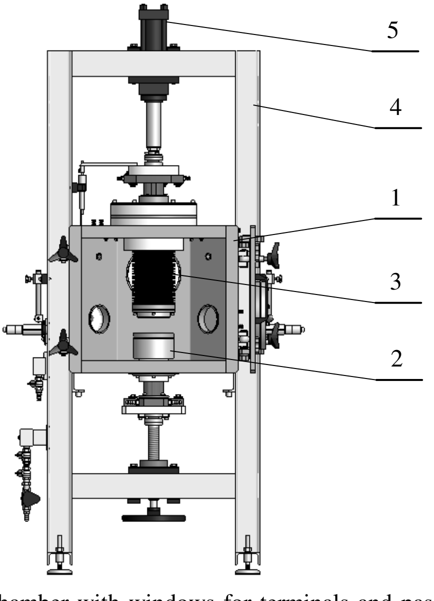

Fig. 1. Frame and door of the chamber with windows for terminals and passes of technological equipment manufactured as steel plate-welded constructions: 1 – vacuum chamber, 2 – bottom punch set, 3 – upper punch set, 4 – frame of hydraulic press, 5 – servo-motor

Vacuum chamber was a stainless sheet welded construction [7]. Its frontal wall constituted a widely opened door intended for the assembling and setting up its inside equipment and charge loading. In the door and the side walls, there were several windows and peep-holes intended for the observation of the process course occurring inside the chamber and for taking measurements of its parameters. In the back wall, a special terminal of pump system was installed, through which air is pumped out in order to obtain a vacuum.

In the upper wall and in the bottom of the chamber two of the most important sets of hydraulic and mechanic devices have been installed:

- a movable upper punch driven by a hydraulic servo-motor closing the mould with sintered stock and exerting controlled pressure,
- an adjustable bottom punch positioned by means of a screw mechanism constituting the bottom surface of a working set.

The hydraulic press consists of a steel welded frame in which the vacuum chamber has been placed. In the upper beam, a servomotor of the hydraulic system has been mounted connected with the upper punch. In the bottom beam, a screw mechanism of the bottom punch has been installed. The press has been equipped with a hydraulic unit with a proportional controller, enabling the realisation of time dependent courses of force exerted by the servomotor, where the time dependent reference is stored in the controlling computer.

The task of the performing set of the device is the positioning and closing of the mould with sintered powder, exerting a controlled pressure and delivering the current impulses to the charge. Particular requirements that have to be fulfilled by the set is the electrical isolation of the circuit created by electrodes and the sintered sample required in the sputtering conditions of conductive material's elements, as well as the air-tightness of the vacuum system despite the transmission of considerable shifts, loadings and currents into the chamber, the application of moveable terminals of cooling systems and the high temperature of work.

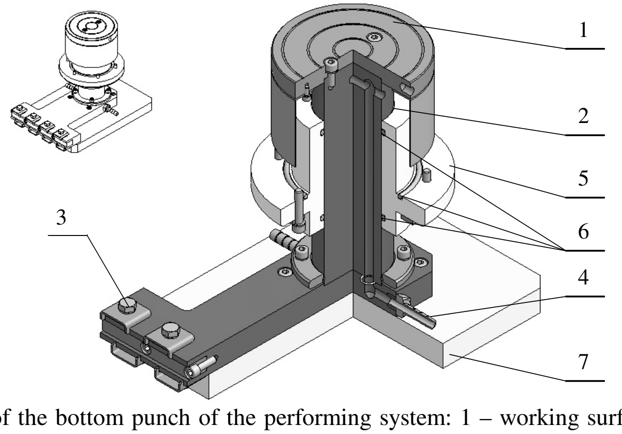

Fig. 2. The set of the bottom punch of the performing system: 1 – working surface of the punch (table), 2 – copper electrode, 3 – high-current terminal, 4 – cooling system, 5 – electrode sleeve, 6 – vacuum seal, 7 – isolation plate

The set of the bottom punch (Fig. 2) plays the role of a table with a regulated height on whose working surface a mould with the sintered material is placed. The steel plate of the table is attached to a copper electrode equipped with a water-cooling system and a high-current electric terminal. The main place of the emission of large quantities of heat is the sintered charge; therefore, there is a necessity of an intensive cooling of the table and the electrode. The roll part of the electrode is slide-seated and sealed in a sleeve made of an isolation material, tightly mounted in the bottom of the vacuum chamber. The set is, through the isolation plate, based on the screw mechanism, which is used for relevant setting of the table's height. The table's plate has been equipped with a shield in the shape of a tube preventing the sputtering of conductive materials on the sleeve surface and the creation of electric bridges between the electrode and the mass of the device.

The upper punch set (Fig. 3) plays the role of an active performing set closing the mould and providing the pressing power to the sintered powder. The transfer of often required line movement with significant pitch required the application of a seal in the form of a steel siphon bellows, characterised by a considerable higher durability and reliability than sliding seals [8]. The sleeve leading the electrode was, due to the same reason, manufactured of steel and mounted in the upper wall of the chamber by means of isolation separators created in a way to prevent the creation of electric bridges on their surface.

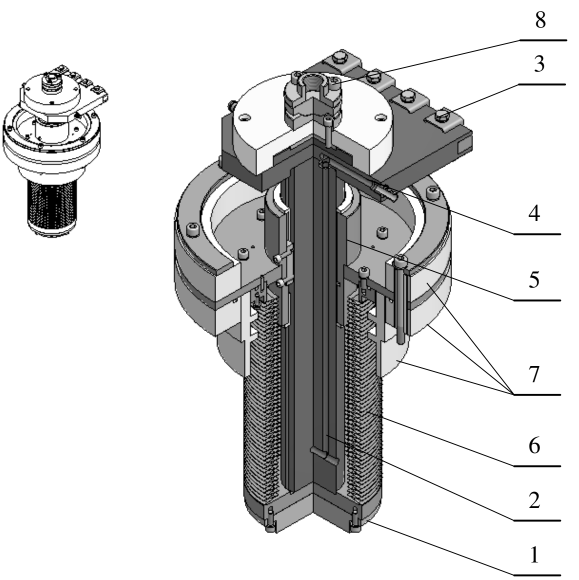

Fig. 3. The set of the upper punch of the performing system: 1 – working strap of the punch, 2 – copper electrode, 3 – high current terminal, 4 – cooling system, 5 – sleeve leading the electrodes, 6 – steel sealing bellow, 7 – isolators, 8 – servo-motor terminal

The electrode, similar to the bottom one, is water-cooled and electrically connected with the feed system. The set is, through the isolation separator, connected with the hydraulic servomotor exerting the intended load on the system.

Conclusions

The hydraulic press with vacuum chamber for pulse-plasma sintering has been manufactured in the Prototype Department of ITeE-PIB and, together with a special feed and controlling system, put in operation in the Faculty of Materials Engineering at Warsaw University of Technology. The conducted trails of the sintering of composite materials revealed the correct operation of the applied technical solutions in the mechanical-hydraulic performance system. The presented construction is an original solution in which the properties of the applied materials and elements were used accurately; therefore, the intended electric, kinematic and functional parameters of the device were achieved.

The developed sets can also be applied in other vacuum devices requiring performance systems working in high vacuum, safeguard loads, high-voltage and high-current conditions.

Acknowledgements

Scientific work financed by the Ministry of Science and Higher Education and carried out within the Multi-Year Programme "Development of innovativeness systems of manufacturing and maintenance 2004–2008".

References

1. Burakowski T., Wierzchoń T.: Inżynieria powierzchni metali - podstawy, urządzenia, technologie. WNT, Warsaw, 1995 (in Polish).
2. Roberts W.H.: Surface engineering and heat treatment. P.H. Morton, 1991.
3. Oleszak D., Jaroszewicz J., Rosiński M., Michalski A.: Structure of NiAl-TiC composite fabricated by mechanical milling and pulse electric discharge sintering. Rudy i Metale Nieżelazne, 2002, 9, 432.
4. Michalski A., Świderska A.: Nanocrystalline intermetallic Al-Ti phases sintered by a pulse electric discharge. Proc. of 14th Intern. Symp. on Plasma Chemistry. Academy of Sciences of the Czech Republic, Praha, 1999, 4, 2247.
5. Oleszak D., Michalski A., Majewski T.: Fabrication, structure and consolidat D.ion of NiAl-Al2O3 mechanically alloyed nanocomposite powders. Acta Physica Polonica, 2002, A 102, 187.

6. Michalski A., Krasnowski M., Rosiński M., Siemiaszko D.: Nanocrystalline (FeAl-TiC) composite sintered by a pulse electric discharge. Proc. of 15 th Intern. Symp. on Plasma Chemistry, CNRS University of Orleans, 2001, 2885.
7. Kozioł S., Samborski T., Brudnias R., Smolik J., Walkowicz J.: Nowoczesne konstrukcje komór próżniowych dla technologii PVD. Problemy Eksploatacji, 2004, 3 (in Polish).
8. Metal Bellows Manual. Witzemann GmbH, Pforzheim, 2000.

Reviewer:
Bogusław GRZESIK

Mechaniczny układ zadawania siły do urządzeń wysokiej próźni

Słowa kluczowe

Komory próżniowe, spiekanie impulsowe, wysoka próżnia.

Streszczenie

W artykule przedstawiono problematykę związaną z realizacją złożonych ruchów elementów wykonawczych stosowanych w komorach próżniowych. Zaprezentowano przykładowe rozwiązanie układu obciążania zastosowanego w urządzeniu do impulsowego spiekania specjalnych materiałów w warunkach wysokiej próżni.