A TECHNOLOGICAL APPROACH TO THE DEVELOPMENT OF EQUIPMENT AND THE PROCESS OF DETONATION-GAS COATING APPLICATION

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Abstract: The matter of construction and technological solutions' technological interdependency is discussed during the development of equipment and the process of detonation-gas coating application whose revealing and using is the constituent part of the problem of providing for material-science results of detonation-gas powder application.

1. INTRODUCTION

Detonation-gas powder application (DGPA) is one of the ways of gas-thermal coating application (GTCA). GTCA process and the system of detonation-gas powder application (SDGPA) were developed and patented in 1952 – 1955 by the American inventors R. Purman, G. Surgent and H. Lumpray. The essence of the process (fig. 1) lies in impulse heating and acceleration of the applied powder material's particles by means of high-speed and high-temperature flow of detonation products (FDP) created with the specified cyclicity in the one-side open stem of the SDGPA as a result of working gases mixture's combustion [1-4].

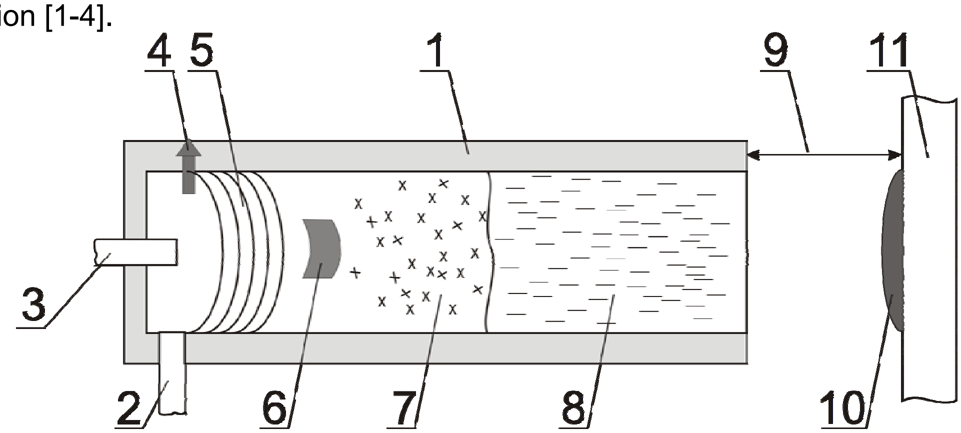

Fig.1. The scheme of detonation-gas coating application
1– thermally controlled stem; 2 – system of batching and applying the working gases; 3 – system of batching and applying the powder material, 4 – system of combustion triggering, 5 – gases combustion zone; 6 – detonation wave; 7 – zone of the powder material location within the stem (powder cloud); 8 – zone of heating and accelerating the FDP powder cloud; 9 – spraying distance; 10 – applied coating; 11– sprayed detail

Among the technological advantages of DGPA over other ways of GTCA there are: a wide range of applied powder materials like metals, ceramics, polymers and their compound compositions; a range of physico-chemical functionality of the systems "powder material – detonation products (DP)", "coating – sprayed detail's surface (undercoat); a possibility to

apply coatings on various construction materials, such as metals, ceramics, glass, graphite, polymers, tissues; the mechanism of the coating's structurability.
The complexity of DGPA process's qualitative performance for solving different material science problems is conditioned by the diversity and interdependency of its construction and technological solutions [5-7].

2. A TECHNOLOGICAL APPROACH TO THE DEVELOPMENT OF EQUIPMENT AND THE PROCESS OF DGPA

We shall discuss the requirements to producing the standard SDGPA construction including the following knots and systems: a stem, a system of batching and applying the working gases, a system of batching and applying the powder material, a system of combustion triggering, a system of temperature control, a manipulator and a control system.
Among the known stem constructions there are the ones with round, square, rectangular, oval and other shapes of cross-section; the ones with constant and length-variable area (changing sharply or smoothly) and shape of cross-section; the ones with different longitudinal section shape such as straight, curved, ramifying, straight with both open ends, loop- and U-shaped ones, multi-chamber, ring-shape, spiral, multi-section ones; those with horizontal, vertical and inclined location; those with gas-proof walls and various roughness of the inner surface [2, 3, 8-11].
The expediency of choosing the correspondent stem structure is connected both with using the technological technique of a single spot coating application such as that of a square or round shape and with the range of its physico-technical properties including the energetic indices.
The basic criteria of the technological choice of a certain stem structure include the following:

- material science criteria affecting the physico-chemical properties of the sprayed coating (the composition of working gases influences the choice of the stem part length within the gases combustion zone because of the different pre-detonation dynamics of their combustion, and the stem part length within the FDP powder cloud heating and acceleration zone should be optimal to provide heating, acceleration and performance of the sprayed powder material particles' chemical interaction with DP during their joint flow);
- heat, velocity and dynamic indices of the regimes of combustion and the working gases mixture's detonation depending on the stem structure, engineering and technological solutions concerning the ways to apply and trigger the working gases mixture, the technological parameters of this mixture (composition, volume, pressure, temperature, application regime and preparation technique);
- gas-dynamic and physical properties of the sprayed powder material, such as the windage, dimensions, weight, viscosity, heat conductivity, etc. affecting the choice of a stem structure's physico-technical properties and its structure parameters;
- possibility to locate the powder cloud between the area of the detonation wave's occurrence and the stem open end at using the technique of working gases mixture triggering at the stem closed end, which provides for the powder cloud's flow towards the undercoat. If the powder particles within the stem are located between the source of combustion triggering and the area of the detonation wave's occurrence, there is the multidirection of the particles flow at the account of cubic expansion of combustion products and the part of DP moving within the stem from the detonation occurrence area towards the combustion products front, which makes the popping-back effect;

- using the technique of working gases mixture triggering from the stem open end aimed at increasing the coefficient of this mixture's usage and SDGPA energy capacity, which also influences both the choice of the powder cloud's location within the stem and the behaviour of the powder material particles within FDP;
- the technique of applying the powder material into the stem or to the zone between the stem open end and the undercoat whose task is to efficiently move the material from the powder feeder into the necessary stem or FDP zone (local position of the powder cloud in the process of DGPA finally has a significant effect on the physico-chemical properties of the applied coating and its structure formation);
- the technique of applying the working gases into the stem, for example, the evenness of filling the stem with the gas mixture affects the heat, velocity and dynamical properties of their combustion and detonation regimes;
- providing for the stem's working chamber (working chambers) thermoregulation, for example, stem heating over the inflaming temperature of the gas mixture results in unauthorized triggering of this mixture during its application to the stem;
- construction-technological combination of the DGPA technique with other techniques of GTCA, for example, the improvement of energy properties of the sprayed powder material is achieved by means of combining DGPA with the electropulse powder spraying;
- the dynamic properties and the parameters of powder particles interaction with FDP within the zone of the powder cloud heating and accelerating; they are defined by the construction parameters of the stem, chemico-energetic data of FDP and physico-chemical properties of the powder particles;
- tasks and the technique of the two-phase powder particles flow formation with DP at flowing out of the SDGPA stem depending on the chosen ways of the coating application and structuring;
- the necessary range of the qualitative regimes of applying homogeneous or compound powder compositions whose choice also depends on material science tasks of coating and the technological ways of coatings application, for example, layer-by-layer coating application from different powder compositions;
- technico-economical DGPA tasks and technico-economical SDGPA parameters, for example, functionality, productivity, number of shots per second (rate of shots), efficacy of using the powder material and working gases, energy capacity, concerning the volumous properties of the applied coating and its material-science application.

The system of batching and applying SDGPA working gases is based on the following technological criteria:

- ✓ the principle of batching and applying the working gases into the SDGPA stem (using the valveless or valve systems, as well as their combined usage);
- ✓ providing for the protection against non-fire-rated and explosive sources of the working gases components' supply;
- ✓ minimizing the amount of working gases, their combustion products and DP getting into the gas pipeline, including those with the powder particles, which, for example, affects the rate of shots of SDGPA, as in this case it is technologically possible to decrease the period between the cycles of working gases mixture supply into the stem;
- ✓ the impulse structure and characteristics, reproducibility and controllability of working gases supply parameters, which provides for the possibility to optimize the part of the coatings application cycle process occurring in the SDGPA stem, as well as its control;
- ✓ ways of working gases preparation;
- ✓ SDGPA knots service, for example, working gas supply to the powder feeder for transporting a single batch of the powder into the SDGPA stem, and the service for the

DGPA technological techniques, for example, creating the technological gas environment within the coating application zone;

- ✓ using the gas-dynamic components of the process.

The valveless system of gas supply, for example, performed using fire resisting devices, and the valve system of gas supply made using the check valves provide for the necessary protection of the gas supply sources, stability, reproducibility and the high flow capacity of gas supply. The low persistence and flow capacity of such systems provide for the possibility of achieving the SDGPA rate of shots up to 50 shots per second. In case of using such schemes of gases batching, there is a drawback of the system of the working gases batching and supplying which lies in the incomplete range of using the possible ways to control the parameters of the working gases supplying which is necessary for performing various technological techniques of coatings application. For example, in case of using the technological technique of changing the system's rate of shots during the coating application, the system's rate of shots change can be achieved only at the account of controlling the gas supply sources' pressure, which leads both to the change of the combustion regime and of the working gases detonation, and to the change of the powder cloud's location in the stem. In this case, changing the conditions of reproducing the interaction results within the stem of the powder material and DP finally has a negative effect on the coating quality.

The valve system of gas supply performed using the valves which are controlled by means of the outer drive, for example, the mechanical or electromagnetic ones, allows to perform a wider set of DGPA technological techniques qualitatively, including changing the rate of shots during the coatings application, while providing for reproducing the conditions and parameters of the interaction between the powder cloud and DP within the SDGPA stem. In case of using such valves, the choice of the valves possessing the maximum flow capacity, stable operation regime at bigger pressure, low pneumatic resistance, minimum period of power control is expedient [12]. Improving the technical indices of these valves provides for the possibility to optimize the conditions of the initial gas suspension formation and flow within the SDGPA stem, as well as to improve the energy capacity and rate of shots of the process.

The protection of non-fire-rated and explosive sources of gas components supply is necessary in case of the correspondent emergency situations occurrence during SDGPA operation; this is treated at the account of engineering-technological techniques such as using fire resistance devices and flame traps. The engineering and technological task of solving this problem also includes minimizing the pneumo-resistance of the system of batching and supplying the working gases during the gases supply to the stem, which provides the possibility to improve the SDGPA rate of shots and the optimization of DGPA process (the system's high rate of shot influences the quality of the applied coating by means of providing the physico-dynamic properties of its formation). For example, the location of the fire-resistant devices in the gas pipelines between the valves and the stem with lower flow capacity of the fire-resistant devices compared to that of the valves can significantly decrease the SDGPA rate of shots and the energy capacity of the process.

The tasks of the working gases preparation include the optimization and the stabilization of their supply's regimes and parameters. These problems' solution can be discussed with the help of some examples:

- in order to provide for the quality of the gas mixture components' combustion and detonation the mixture is performed within the mixing chamber;
- in order to stabilize the pressure parameters during the working gases supply in the pulse mode there are used the expansion vessels from which the gases are supplied into the SDGPA stem via the valves;

- in order to increase the gas mixture's combustion and detonation rate oxygen ionization is used.

It is expedient to use gas-dynamical components of the DGPA process for completing the technological tasks of the working gases batching and supplying system, for example, for performing the technological operation of the stem "blowing". After the two-phase flow of the powder material's and DP particles from the stem, it shows the formation of the vacuum area which is filled with the gas from the zone between the stem open end and the sprayed detail; this gas contains fine-dispersed particles of the powder material's evaporated dose. In order to prepare the stem for the next cycle of coatings application it is expedient to use the stem "blowing", which is used utterly rarely because of the technological time expense. The mechanism of compensating the detonation products' underpressure in the stem can be performed as the system of check valves installed at the stem closed end. The check valves are opened and transmit the atmospheric gas catharized of the powder material's particles into the vacuum area in case of vacuum formation and distribution within the stem, thus excluding the need for the additional time expense for its "blowing" [13].
The technological requirements to the powder material batching and supplying system based on DGPA technological techniques and peculiarities include the following:

- pulse supply of the powder material into the specified zone, which is predetermined by the pulse mode of the process;
- using the back-shock products for transporting the powder material into the SDGPA stem;
- providing for the powder feeder's protection against the back-shock;
- reproducibility of the batching parameters;
- changing the single portion of the powder material during the coating application;
- high quality of supplying the single batch of the powder material into the specified zone;
- the location of SDGPA stem within the area.

Any powder feeder may be used for the powder material pulse supply if this feeder provides for the formation of the necessary single portion of the powder material for its further transportation. The pulse supply of the powder material into the specified zone can be performed by means of different techniques, for example, by the pulse with both the gas and electromagnetic environs.
Transporting the powder material into the SDGPA stem by means of the back-shock products is possible in case of using the injection feeders for batching the powder materials with the sintering temperature higher than that of the back-shock products.
In case if the back-shock products are not used for transporting the single portion of the powder material, the powder feeder has to be protected from their gas-dynamical effect on the dosed material in order to exclude the batching parameters failure [14].
The choice of the powder material's structure is determined by the accuracy of reproducing the batching parameters at the specified cyclicity of its work.
In order to provide for the technological techniques of coatings application it is advantageous to use the powder feeder with the possibility of cyclic controlling the single portion of the powder material during its operation.
The technological problem of high quality supply of the powder material's single portion is to optimize its supply period, as well as to provide for the necessary localization and distribution of the powder material in the pulse cycle of its supply. This is predetermined by the choice of the powder material's structure, the ways of the material supply and transportation. The conditions of the powder material's inflow into the interaction zone with the working gases or FDP make the constituent factor of optimizing the parameters of their interaction with DP during the coating application.

The SDGPA stem location in the area influences the ways of its feeding with the powder material, for example, the axial or the diagonal one, as in these cases the physico-dynamical conditions of forming the powder cloud in it possess the peculiar characteristics.
The system of combustion triggering should provide for the possibility to minimize the period of detonation formation in the working gases, as well as provide for improving the energy properties of detonation products. This problem can be solved at the account of the following: increasing the power of the combustion triggering source; spatial-technical characteristics of the stem within the zones of the working gases combustion, detonation occurrence and distribution; DP additional energetic feeding, for example, plasma-forming discharge.
The technical problem of the temperature control system is to provide for the optimal temperature parameters of the corresponding knots and devices of SDGPA, working gases, powder material, undercoat and the sprayed coating. For example, the additional heating of the gas mixture components provides for increasing the detonation rate, which increases the DP flow rate, and consequently that of the powder material's particles. The high rate of the powder material's particles is a positive constituent of structure-formation and quality of the applied coatings.
The technological possibilities of the manipulator have to be sufficient to provide for the specified transitions including the spraying distance during applying the coatings on the specified number of details of the possible overall sizes. During designing the manipulator it is necessary to concern the range of the planned technological modes of the coatings application, for example, SDGPA rate of shots, influences the rate of the cylinder detail's rotation, as well as the modes of the coatings application techniques, for example, the coating shielding.
The technological application of the control system is providing the specified parameters of the coatings application process. The problems of the control system during DGPA process include: program agreement of the operation modes and controlling the working capacity of all the SDGPA knots and systems; controlling the current state of the process; controlling the working capacity of the process backup accessory systems, for example, ventilation. The efficacy and technological effectiveness of the control system depends on the possibility of individual controlling and managing each technological process of the coatings application.

3. CONCLUSIONS

The effectiveness of developing the equipment and the process of DGPA depends significantly on aggregate performance of its constructive, technological and material science components. The development of the equipment and the process of DGPA within the broad range of its construction and technological components requires a big amount of natural experiments for studying and investigating these results. Here, the efficacy of DGPA technological processes development for solving new material science tasks performed on the basis of the existing construction and technological solutions of processes decreases but for the usage of the possible potential of the components set.
It seems expedient to develop the equipment and the process of DGPA for solving the correspondent material science problems by means of the technological choice of the physico-technical and the physico-chemical set of constructive, technological and material science components of the process. Such an approach makes it possible to develop the special-purpose equipment and DGPA process of high quality, as well as to provide for the minimization of time for solving certain material science problems.

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