THE FORMATION AND TESTING OF THE TRIBOLOGICAL LAYERS SPRAYED IN THE PLASMA JET

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INTRODUCTION

The materials used for installations from the food industry, demand special requirements - as high resistance to wear, corrosion**...**

To solve some of these problems, so to increase the tribological proprieties and also to increase the reliability of installations with less expensive materials, the formation of wear resistant layers in couples of friction is proposed. The layers are made from powders containing these components in different proportions: Cr, Ni, Ti, Mn, Si, Al ... The surfaces of pieces are coated with powder through the plasma jet.

1. THE RESEARCH METHOD

The thermal spray process with plasma is based on the formation of the plasma jet in which the powders are introduced. The materials are melted, mixed and projected on the base material, thus achieving covering layers -composite type. The principle consists in passing a powder material by plasma jet - generated by an electric arc of plasma generator. Due to high temperature the powders melt and are entrained by the gas to the base material. The particles in plastic state adheres to the surface of the base material due to specific mechanisms. The impact between molten particles and the substrate leads to their solidification on the substrate forming thereby the deposition.

The quality of deposited layers through the plasma jet and the coating process depends on the physic-technological properties of sprayed materials.[1,2] The powders- ПГ-СР2, ПТ-19Н-01, ПС-12НВК-01 ПР-Н17Д7СХ, ПН85Ю15, СНГН-50 and various proportions of Al_2O_3 and Al have the particle size of 40-90 μm. The deposition was carried out at УПУ-3Д installations. The mixture of $CO_2 + C_3H_8 + C_4H_{10}$ (carbon dioxide and natural gas propane-butane) was used as a plasma former.

The protective properties of plasma coatings and the quality are determined by the physicochemical characteristics of powders and the pieces subjected to spraying; technological characteristics of the process equipment; kinematic and the type of deposition; thermal, deformation and thermochemical phenomena at the interaction of powders particles with the surface.[3,4,5]

The high adherence of the layer that forms the roof with the base material is a compulsory condition, but not decisive in the choice of material for sliding bearings. The decisive factor is the roof property to operate without grip in certain working conditions (load, slip rate, fluid viscosity and chemical activity).

The assessing of the compatibility of materials is made according to the size of critical load, at which the gripping or scuffing phenomenon is observed (tribological system vibration, stream variations) [3,6,8].

Checking for compatibility in laboratory conditions was per formed with water as lubricant.

Friction power loss was determined as the difference between the total power used by stand in working with couples (WE) and the work-load power (We, g):

$$\Delta W = W_E - W_{e,g}. \qquad (1)$$

The Power loss coefficient of friction is determined from the relationship:

$$K_{TP} = (W_E - W_{e,g}) / W_E , \qquad (2)$$

$W_{e,g}$ - the work-load power (kW), W_E - stand power (kW) to a thermal regime of a specific task set

$$P_{i\,sp} = P_i / S_p , \qquad (3)$$

P_i –bearing load on the regime i (N), S_p - working surface of the specimen (m2)

$$S_p = S - S_k ; \; S = \pi(R_e^2 - R_i^2), \qquad (4)$$

R_e – internal ray (m), R_i – external ray (m).

$$S_k = a \cdot l \cdot n , \qquad (5)$$

a- groove width for cooling (m), l- groove length for cooling (m), n -Number of grooves

Specific task of determining radial bearings:

$$P_{sp,\,rad} = P_i / S_{rad} , \qquad (6)$$

P_i –Summary of radial bearing (N), S_{rad} = d L, d - external diameter of the bush (m), L - length bush leaning on bolster(m).

In the experiments, the specific task of sliding bearings is specified depending on the actual contact surface that is formed on the surface of the bush after running under load:

$$P_{sp,\,F} = P_i \,/\, S_F \,, \tag{7}$$

S_F –actual contact surface of the bush (m^2).

Wear speed of friction couple material was determined by the expression:

$$v = \Delta U \,/ T \,, \tag{8}$$

T- time of experiments (h), $\Delta U = \Delta U_1 + \Delta U_2$, ΔU_1 – wear bushing sliding bearings or specimen (mm), ΔU_2 – sliding bearings wear (mm).

Operating time of sliding bearings to limit state is determined by the expression:

$$T_{lim} = \Delta U_{lim} \,/\, v_{med} \; (h), \tag{9}$$

ΔU_{lim} – allowable wear limit value regulated by technical documentation (mm), v_{med} –auverage speed wear of materials friction couple (mm/h).

2. THE RESULTS

The results of experiments have shown that the layer that consists of materials containing nickel with the addition of chromium, boron and other components, work well in a couple with pieces whose hardness is lowerthan the layer, Fig. 1.

The layers formed of powders ПТ-01-19Н in couple with АМС – 3 and АРВ-200-В83 material, works at minimal friction power. A stable operation was determined with rubber 7-3825С this power, at this couple the friction power increasing slower than the couple with grafitoftoroplast 7В-2А at an increased specific pressure from 0.49 MPa to 2.45 MPa (the rubber from 0.32 to 0.58 KW ; 7В-2А from 0.18 to 0.7 kW). The layer consisting of ПТ-19Н-01 powders is incompatible in couple with materials containing silicon carbide and namely СГ-Т and "СУГВАМ" material. At their functioning in couple the galling occurs at a specific pressure of 1.47 MPa at a sliding speed v = 15.7 m / s. The effect of galling occurs also at ПТ-19Н-01and "СУГВАМ" couples of friction. The increased friction power demonstrates the incompatibility of these couplers in these working conditions. Other materials as: the АМС-3, the 7-3825 rubber, АРВ-200-583, АГ-1500-583, 7В-2А at a functioning in couple with ПТ-19Н-01 demonstrate that they are compatible, but their use is desirable to a specific pressure of 1.47MPa. The functioning at such pressure allows the removal of the heat from bearings, increasing the reliability of tribological system.

The layers formed of ПГ-СР2 powders are slightly different from ПТ-19Н-01 by the chromium content: the chromium content constitutes 12-15% in ПГ-СР2 powders, and from 7.9% to 14% in ПТ-19Н-01 powder. The layer from these powders works well in couple with 7В-2А material. The friction power depending on a specific pressure for this couple of friction is minimal. At a pressure of 0.49 MPa it constitutes 0.15 -0.16 kW and at 1.96 MPa – 0.44 kW.

Research has shown that at the ПГ-СР2 couples of friction and grafitoftoroplast КВ, have approximately the same results. At light load the consumption of power at friction is lower for these selected couple than when operating with 7В-2А. But with an increasing load the power is intensified. The ПГ-СР2 couples with rubber and with АРВ-200-Б83 works stably without galling.

The ПГ-СР2 layer in couple with АМС-3 operates inadequate due to an increased consumption of power at friction. This couple of friction consumes 0.5 kW at the load of 0.49 MPa, while for the other couples the power load is 0.16 kW. For the ПГ-СР2 layers, formed in the plasma jet, the regimens with specific voltages not higher than 1.47 MPa are recommended

The layers formed of СНГН-50 powders (without melting) at the functioning in couple with established materials, have increased power consumption at friction. This is due to a high porosity and a low hardness of the layers, since the spraying was carried out without melting. The hardness increases to values of 47-57 HRC when the powders are melted. The power at friction is minimum for the couple of СНГН-50 and КВ grafitoftoroplast. At the load of 0.49 MPa this couple of friction consumes power at friction of 0.12 kW. For the mentioned layer in couple of friction with grafitoftoroplast 7В-2А material, at a specific pressure of 0.49 MPa, the friction power is 0.35 kW, so it is 3 times higher. The couples with 7В-2А and КВ material at an increasing specific pressure to 1.96 MPa work identically. At a further increasing specific pressure the power at friction increases at СНГН-50 and КВ material.

The materials containing graphite and added metals (АГ-1500-Б83 and АРВ-200-В83) at a specific pressure greater than 1.47 is not working in couple with СНГН-50. The friction power constitutes 1.32 kW for the couple of friction consisting of material АГ-1500-Б83 and СНГН-50 at a specific pressure of 2.45 Mpa, and for the couple with 7В-2А material, the friction power is 0.52 kW. For КВ and 7В-2А materials the recommended regimes at a specific pressure in couple with СНГН-50 can be increased to 2.45 MPa. The couple of friction СНГН-50 with СУГВАМ material has demonstrated a satisfactory function, although the galling starts at minimum specific pressure of 0.49 MPa, in couple with the layer formed from СГ-Т and СУГВАМ powders. The lack of galling of these couplers of friction is due to poor quality of the surface of sliding bearings. Almost all sprayed layers with hardness less than 45 HRC in couple with СУГВАМ and the lubricant water, is galling at small specific pressures.

The layers formed in the jet of plasma from ПН-85Ю15 powders, having at the base the nickel with the addition of aluminum, showed antifriction properties. The couplers formed from the ПН-85Ю15 layer and studied materials, operate quite difficult. At a minimum specific pressure, increased power consumption at friction is observed. At loads of 0.49 MPa, the friction power varies from 0.3 kW for 7В-2А material up to 0.45 kW in couple with АРВ-200-В83. Further, at the increasing of specific pressure, sharply increases the power at friction and the galling occurs (for materials of couplers of friction). The exception is the couple with АМС-3 material.

This is due to aluminum particles that cling to the working surface of the studied material and afterwards produce the galling. An analog behavior was determined at the surfaces formed in the jet of plasma, the powders representing Al_2O_3+ 10%Al and 70% AL_2O_3+30%Al.

The ПС-12НВК-01 powder material was accepted to form layers in the jet of plasma of sliding bearing surfaces, because of high antifriction properties. These capacities are due to the material components consisting of 35% wolfram carbide WC, 14% chromium and the base nickel base, 14% chromium and nickel as a basis. The low power consumption at friction of ПС-12НВК-01 layer in couple with АМС-3 antifriction material, allowed recommending this couple of friction for research at all specific pressure values. The results show that the power consumption at friction does not exceed 0.4 kW.

A practical interest presents the specific loads of 1.47 MPa with power consumption at friction of 0.2 kW, because the calculated values of specific radial loads of submersible electric pumps do not exceed these loads values. The carbide component of the ПС-12НВК-01 layer in couple with СУГВАМ material, make possible to avoid the galling at values of specific pressure from 0.49 MPa to 2.45 MPa. The ПС-12НВК-01 layer in couple with other antifriction materials, works *well only for specific small loads up to 0.98 MPa.* The galling process is observed at the functioning in couple with КВ antifriction material, at an increased specific load up to 1.96 MPa.

The adherence to the base material depends on the intermediate layer. At the roof formation of 90% Al_2O_3+ 10%Al on the basis of 12Х18Н10Т with intermediate layers ПТ-НА-01 and ПН85Ю15 a different adhesion is obtained. It is because of powders composition ПТ-НА-01 (ТУ 48-4206-156-82) that contains 4 ÷ 5 % Al, 96 % nickel and ПН85Ю15 (ТУ 14-1-3282-81) contains 12-15% Al and the rest is nickel.

The research has shown that the layers from ПС-12НВК-01 powders on the basis of 3 steel, with ПТ-НА-01 intermediate layer, have an adherence of 16.2 MPa. The distance from the coating surface to the electrode was 180 mm. The adherence of this layer to the basis of 3 steel, without intermediate layer constitutes only 10, 4 MPa.

When placing the coating without an intermediate layer, the coefficient of linear expansion differs substantially and therefore the adherence of the roof to the surface, decreases. A high adhesion was determined at the layer ПН55Т45, without intermediate layer based on titanium 3M alloy, constituting 13.5 MPa.

The СГ-Т (П) roofs with ПТ-НА-01 intermediate layer and ПГ-АН9 (without intermediate layer) based on 3 steel showed a low adherence and constitutes 7÷7, 5MPa.

ПТ-19Н-01 layer formed by plasma jet [1, 2] works well in a couple with 7-3285 rubber, АМС-3 and АРВ-200-Б83. The loss of power at friction at a specific pressure of 0.48 MPa are at rubber ÷ 2.45 - 0.32 ÷ 0.58 kW at grafitofluoroplast 7В-2А - 0,18 ÷ 0,7 kW. It is reasonable to use these couplings to a specific task not exceeding 1.5 MPa to remove the heat from the couple, increasing the reliability of tribotechnical system.

ПГ-СР2 layer contains a higher percentage of chromium (12 to 15%) than ПТ-19Н-01 (7.9 to 14%) and works very well in a couple with 7В-2А grafitofluoroplast. The loss of power at friction depending on the specific task at this couple is minimal: at 0.49 MPais 0.15 ÷ 0.16 kW and from 1.96 MPa - 0.44 kW. Around the same data are shown by couple ПГ-СР2 with КВ grafitofluoroplast. The layer СНГН-50 shows a loss of power at a relatively high friction. The reason of this phenomenon is the high porosity accompanied by a low hardness of the layer. The minimum power at friction is in couple with КВ grafitofluoroplast. At a specific task of 0.49 MPa, the power friction is

0.12 kW. The low antifriction properties were shown by nickel layer with added aluminum ПН85Ю15 (containing 15% Al). At specific tasks of 0.49 MPa, the consumption of friction power is 0.3 kW, in couple with 7B-2A grafitofluoroplast and up to 0.5 kW in couple with APB-200-68.

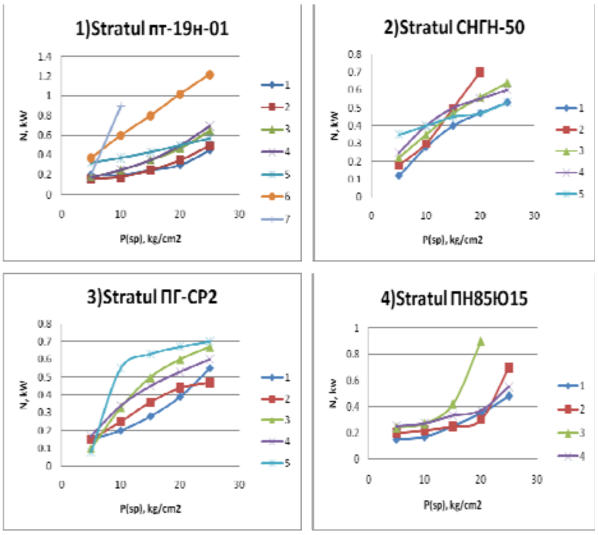

Figure 1. The Dependence of power loss to friction on specific task in couple:
1*) ПТ-19Н-01. Materials Testing: 1- AMC-3 ; 2- APB-200-Б83; 3- AГ-1500-Б83; 4- 7B-2A; 5- rubber7-3825; 6- grafitofluoroplast KB; 7- carbonfiber''СУГВАМ''. 2) СНГН-50. MaterialsTesting: 1- grafitofluoroplast KB; 2- AГ-1500-Б83 ; 3- APB-200-68 ; 4- carbonfiber ''СУГВАМ'' ; 5-grafitofluoroplast 7B-2A. 3) ПГ-CP2. Materials Testing: 1- grafitofluoroplast KB ; 2- grafitofluoroplast 7B-2A ; 3- rubber7-3825 ; 4- APB-200-Б83 ; 5- AГ-1500-Б83. 4) ПН85Ю15. MaterialsTesting: 1- graffiti fluoroplast7B-2A ; 2- graitofluoroplast KB; 3- AГ-1500-Б83 ; 4- APB-200- 68.*

3. CONCLUSIONS

The kinetics of this phenomenon depends on the physical parameters such as: speed, temperature and enthalpy of the sprayed particles. Studies have shown a significant impact on the dynamics of movement of sprayed particles, by phenomenological laws for the frontal drag coefficient, taking into account the loss of pulse of the plasma jet in acceleration of these particles and their diameter.

It has been found that the large difference between the diameters of the sprayed particles contributes to a substantial separation of particles in a spray point if falling on the surface of the piece having different speeds.

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