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Mechanical properties [Basalt-(Ni-Al)] System By Thermal Spraying Method

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Abstract:

The current research deals with the method of thermal spraying with flame by using a spray device that consists of oxygen and acetylene gas and an upper flush to put the powder to be painted as basalt rock powder was used as a base material and was supported with a binder of nickel and aluminum, different support ratios of the bonding material were used as well as transactions Various temperatures and variable spray distances for prepared samples. The tests included (hardness, adhesion strength, wear, porosity). Where it found that the best optimum conditions for the spray coating is a distance (15cm) and mixing ratio (50%) and the best thermal treatment is (1100 ° C). The test results are given greater hardness (1150HvT), and the highest strength of adhesion (13.91 MPa), and less wear all at the same optimal conditions mentioned above.

Introduction:

Cermet materials are used as a thermal barrier coating in gas turbines, jet engines, as well as marine engines [3, 2, 1]. These materials also protect the metal base from oxidation, as in the exhaust silencer [4]. It is also used in making braking discs in cars where it is made of a hard material such as silica, immersed in a phase base plastic of mostly metal or bronze ingot. In addition, Cermet materials composites are used in ceramic motors for transportation, as the benefit of all ceramic motors is demonstrated in low weight and high degrees of work that turn into high efficiencies [5]. The composite material system cermet composed with alloy metal and one of the most important of special applications of heat engineering material systems (Thermal Barrier) and involved in various fields of technology and the most important coating blades of gas turbines and temperature resistance in containers combustion in gas turbines and in the pipe of exhaust [6, 4]. Thermal spray techniques are among the important technologies with important surface protection applications that are used to protect surfaces from chemical corrosion or mechanical damage (Erosion) and return them to their original dimensions through the process of cladding with engineering materials metals, ceramic or polymeric or use Composite materials with special specifications [7]. Thermal spray coating techniques include heating the coating material to a degree of ductility or melting and then tossing at a high speed towards the base. In this regard, there are several techniques, which are flame spray, electric arc spray, plasma spray, Detonation spray, high-velocity oxy-fuel spray. The main difference between these methods, which is essential in classifying them, is the heat source needed to melt the coating material. These technologies are generally considered one of the most important means used industrially in surface cladding operations because of their high specifications that suit most industrial requirements in this regard. For example, it is possible to paint large pieces with high efficiency and precipitation rates, and their suitability to paint most types of ceramic materials, including metal. However, we find that the technology requires high accuracy and control of the parameters and conditions of the

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coating, such as the rate of material feeding, the force of the air force, and the distance between the spray gun and substrate, and the surrounding atmosphere to obtain coatings with properties that meet the purposes used for them. This is done through understanding and studying these parameters and the extent of their impact on the structure and properties of the final coatings [8].

Practical part

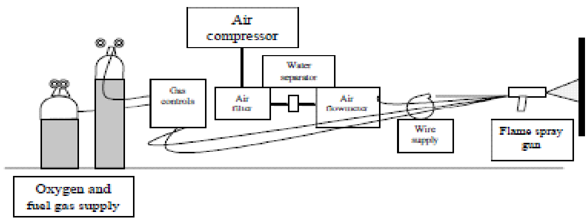
1- Raw materials used in the research:

Basalt rock was used and the main site of the rock is Germany (Rhineland-Palatinate). After cleaning the rock and drying it and then grinding it first with (Hummer) for the purpose of reducing the size of the rock to a suitable size to granules by less than about 8mm then the resulting granulated plate with a special mill (Mortar Grinder RM 200) made in Germany, where the rock was crushed for a period of (48) hours at the size of a granular [100 µm ≤] and then used a bonding material manufactured by the company (metco) No. (450) consisting of (Ni-Al) and a granular size (75-100µm), due to its good resistance to oxidation at high temperatures, and to the consistency of its melting with good bonding strength. Between the substrate and the ceramic coating layers.

2 - Method of preparation:

Cermet compounds were prepared by taking different proportions of the powder of the binder (Ni-Al) with weight ratios of (10, 25, 35, 50) % and were added to the basalt powder. Then the mixture of the base material was mixed with the binder well by using an electric mixer with (Teflon balls) for a period of (2hr), in order to obtain a homogeneous mixture. Then, primary thermal treatment of the Cermet composite powders was carried out before the coating process at a temperature of (150C) for a period of (2hr), using an oven containing (Carbolite) English-origin and Includes Eurotherm thermostat. Figure (1) shows the powders used.

The purpose of the process coating thermal treatment is to dry the powder components from the influence of moisture, and therefore the powder components will be in a good plasticity condition, qualified to produce coatings of good bonding strength with the base material. The dependence on adding a binder powder with a weight ratio (50%) was adopted, due to the high percentage of porosity and surface defects when adding a binder with a percentage higher or lower than (50%), as it gave weak mechanical properties to the cermet coatings due to the lack of spread and homogeneity of the bonding component materials with Ceramic oxide component are fine. And the following figure (2) shows a diagram of the flame spraying system.



Tests and measurements:

First : Test hardness

Was measured hardness way Vicker's Hardness models that have been repainted after making polished the process of fine-tuning before and after

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thermal treatment, and user impact is Stitches the diamond material shape of a Angle (136º) between the duplex opposite shed carrying amount (100 gm) with time shed the amount (10sec) is lifted automatically after lighting indicator light end of the specified time period and then the dimensions of calculation resulting impact on the two axes and two directions perpendicular and take five readings and calculating the average arithmetic to get on the value of the hardness of the digital screen installed on the device directly, the following relationship represents the Vickers hardness [9].

H_v=1.854…………………………………….(1)

Where that

HV: Vickers hardness

P: pregnancy Damocles (gm).

d_{av}: Average diameter impact.

The measured hardness in several different regions of the sample, where the parties took the hardness at the center and collected for an approximate average value of hardness.

Second: Adhesion Test

Adhesion test for coatings was carried out using a Microcomputer Controlled Electronic Universal Testing Machine (WDW-50E) manufactured by a German company (Time Group Inc.) according to ASTM (A370). Adhesion samples were installed in the tensioners' jaws as shown in Figure (3).

The following steps were followed when conducting the adhesion test: -

1 Preparing samples from the base material without coating with an equal number to the sprayed samples and with the same standard dimensions.

2- Performing chemical cleaning using alcohol for both non-sprayed samples and sprayed samples, in order to Cleaning of the effects of pollutants that hinder the two parts sticking together.

3- Use an epoxy adhesive to glue the two samples together (sprayed and non-sprayed), then put a regular thin layer of adhesive on the surface of the coating as it covers the entire area of the paint and then the two pieces are pressed together for about two hours, then put in a dry oven for (24hr) and degree Heat (50 ^{0}C). Before applying the tensile test, the adhesion uniformity must be taken into consideration, and that the strength of the intensity applied when performing the examination is completely perpendicular to the surface of the coating.

4- A load of each tension sample was shed with a tension rate of (1 mm / min), and until the failure of the sample occurred, the highest-rated load is recorded.

5- The adhesion strength or adhesion resistance of the compounding material has been calculated from the following relationship [10]:

Adhesion Force = ………… (2)

Where F: is the highest load bearing, A: the surface area of the sample.

Third: Wear Testing

The wear testing and Measurement friction force test was performed using(Pin-on-Disc) (a Wear-Friction Monitor ED-201) device of Indian origin as the device measures each wear height in units (µm) by a sensor connected vertically to a mask arm The sample senses the height of wear that occurs in the model during the test period and transmits the reading directly to an accurate digital scale, also works to measure the friction force between the sample and the disk by a sensor connected horizontally on the arm. It senses the resulting frictional force between the disk and the model in units (N) and transfers the reading directly to a scale Another accurate digit as the device contains a timer to measure the duration of the test In a minute suspension at the end of the specified

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period also it contains the holder of the weights used during the test period.

Fourth: Testing of porosity

The physical tests represented in the real porosity were performed by following Archimedes rule according to the international standard (ASTM C373-88) using the sensitive electrode accuracy (0.0001 g) according to the following steps: -

- The samples are dried for an hour using an electric oven at a temperature of

(150 ^{o}C) and left to cool inside the oven. Then the sample is weighed after being removed from the oven. This weight is called dry weight (Wd).

- The samples are placed in boiled distilled water for a period of (5) hours. The samples are then transferred to a container containing distilled water at room temperature for 24 hours. After samples are removed, only suspended surface water is removed. The models are then weighed and this weight represents the saturated weight (WS).

- The sample is weighed as suspended and immersed in distilled water by a sensitive suspension scale and this weight is the suspended weight (WI (.

The total porosity (T.P.) is then calculated using the relationship below [10].

T.P. = × 100% …………… (3)

As:

T.P. : The total porosity ratio of the sintered body.

B.D. : Sintering body density (volumetric density) (g / cm3)

Results and discussion

1- Hardness test results:

Through the review of the results obtained for the values of hardness samples with different proportions of the addition of the coating material with material bounding before to the thermal treatment, we find that the values ranged between (650HvT) ratio

[50% (Ni-Al) + 50% Basalt)] to (499HvT) for [35% (Ni-Al) + 65% (Basalt)]. As shown in Table (1):

.No	%Mixing ratio	Micro hardness (HV)
1	**50% Basalt Ni-Al%50**	**650**
2	**90% Basalt Ni-Al%10**	**580**
3	**75% Basalt Ni-Al%25**	**525**
4	**65% Basalt Ni-Al%35**	**499**

From these results, we note that the best value of the hardness was at the rate of deposits [50% (Ni-Al) + 50% (Basalt)] This proves what has been discussed in the porosity of the subject later, as the lower value of the porosity like highest value of hardness and at the same extension ratio . Figure 4 represents the relationship between hardness values and spraying distance ratios of various additions and before to the thermal treatment of the samples.

Notes and follow the figure above that the hardness values of a few start when the distance between the spray gun and the sample small, and these values begin to increase, the more distance until we get to the best values and highest at the distance (15 cm), after which the hardness begins to decrease gradually. And when conducting the thermal treatment of samples with standard specifications with a distance of (15 cm) for a period of (1.5 hr) and at temperatures of (750, 950, 1100) °C. We

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observed a noticeable change in the hardness values of the layer of cermet coating, as the value increases to (1150H_vT) at the best Heat treatment (1100) °C as shown in Figure(5). This is due to the increase in the bonding between the atoms of the coating layer due to the heat, Which led to the homogeneity of the coating layers and the decrease in surface defects, as was noted by the low percentage of porosity and therefore the increase in the hardness values of the layers of the coating (11).

The research results confirmed the presence of a clear change in the hardness values, as all values were in a state of increasing, Which shows that the direction of the grain has begun regularly gradually, and that all the stresses generated during the hardening of the droplets have been removed, and that there is a state of intricacy and strong correlation between the layers of the coating and the state of growth Crystalline reaches its optimum condition at (1100 °C). As it is believed that, there is a state of homogeneity and bonding between the mineral bonding substance and the basalt particles that remove the pores. As for the continuation of high temperatures above (1100 ° C), a sudden change was observed, which led to a sharp drop in the value of hardness. The reason for this is due to the increased porosity of the coating layer, which led to a decrease in the density of the resulting layer, which reduces the resistance of the resulting layer to penetration, and then reduces the hardness values. In addition, the rise in temperature may lead to melting and partial evaporation of aluminum, because of that increasing the porosity, because of that reducing the hardness of the resulting compound layer [12]. The thermal treatment of the collected composite material layers has not been performed in vicious air conditions, which leads to the possibility of oxidation and heterogeneous distribution of the material's particles, which gives lower efficiency to the coating layers. The unloaded atmosphere encourages the mechanical stresses of the coating material, which impedes its hindrance to the deformations caused by the stitching tool in checking the hardness and thus reduces the hardness value and the mechanical properties of the cermet coating layer. As the thermal treatment time increases, the grain's growth process continues, and mechanical stress decreases, and thus the hardness value increases [11,12]. Generally, it was confirmed that the best degree of heat treatment can be obtained with good properties of the coatings layers at (1100 ° C) for a time ((1.5hr), where we obtained here high-density coatings and good bonding strength with few oxidizing particles.

Adhesion test results:

Adhesion strength can be defined as the force equivalent to the force required to remove a unit area of the coating layer from the substrate or is the bonding force between the substrate surface and the cermet coating layer. In view of the difficulty in providing the necessary samples to measure the adhesion strength, four basic readings were adopted to measure them, and at spraying distances (10, 15, 20, 25) cm only, these measurements were made on samples with standard specifications.

The results of examining these models showed the value (11.74 MPa) of the adhesion strength before conducting the heat treatment, and the value (13.91 MPa) after conducting the thermal treatment on the samples for a period of (1.5 hr) and at a degree (1100^0C), as shown in Figure (6).

As it is clear from the figure above, we find that the values of bonding strength are few when the distance between the spray gun and the substrate is short, then these values increase with increasing the spray distance until we reach the best and highest values for the strength of bonding at the distance (15 cm), then the values begin to gradually decrease with increasing Spray distance.

This is due to the increase in the spraying distance that leads to the drop of the molten coating material dropping to the surface of the substrate, and thus its kinetic energy is small, and therefore the speed of its collision with the substrate surface is small, and it is not sufficient for the occurrence of

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fusion or adhesion between it and the substrate surface, and thus be The bonding area to the substrate surface is weak. Whereas, the lower spraying distance leads to less adhesion force also due to the high porosity due to the high temperature of the molten droplets, thus leading to a scattering of these drops in different directions [12].

As we mentioned a while ago, the best value of bonding strength was at the spraying distance ((15 cm) and this is consistent with what we got in the porosity and hardness tests, and in both cases before and after the heat treatment of the samples.

3- **Results of wear.**

The wear is one of the important properties of the material surface, which is defined as the loss of matter from the surface of the metal due to the friction of the moving parts. From the initial experiments, the amount of projected load was determined (15 N), using a different slip velocity, and the load-shedding period for each test was (20 min).

In addition, Figure (7) shows the relationship between the slipping speed and the wear rate, which decreases when increasing the slipping speed for all prepared samples. In addition, a clear decrease in wear rate is observed from the figure when the percentage of basalt addition or the binding substance is (50%), and the reason for this is due to high hardness, and improves the mechanical properties of the coating layers, thus no deformation of the plastic, resulting in increased wear resistance and particle contact with the surface.

But when the addition rate is high, it leads to reducing the durability of the bonding between the substrate and the coating layer as a result of the occurrence of soft distortion resulting from friction, and the rise in temperature, which led to a decrease in the hardness values and the presence of (cracks) and the beginnings of the occurrence of a process of separation and thus increases wear [11].

As for the samples that contain the percentage of addition (35%) of the binding material, the wear rate increases significantly, and there is a process of separation of the coating layers, and the presence of cracks. The lack of the ratio of the addition of the binding substance to the ratio of (50%), has a clear effect on the wear rate, where exposure of the coating layer to a relatively high wear rate has been observed, and also when the basalt ratio exceeds the ratio of (50%), cracks have appeared on the surface of the coating or Separation, which indicates that the wear rate of the permeate coating layer is affected by the added basalt ratio. That is, the lowest wear rate was at 50%. The results obtained by wear rate confirm that the most important factors affecting it are hardness And that increasing it reduces the wear rate and increases the strength of adhesion, and this is consistent with what has been obtained from But the researcher E.Rabinowicz)) [13] who has studied the wear rate change with hardness.

4-**Porosity test results:**

The results of experimental measurements of porosity showed the appearance of different ratios of the pores in the coating material according to the difference in the four sedimentation ratios approved in our research, which is (50, 35, 25, 10) % of the combined substance (Ni-Al) with the corresponding basalt. Where we find that the percentage of pores ranged between (12.6%) for the ratio [(35% (Ni-Al) + 65% (Al_2O_3)] and between (6%) for the[(Ni-Al) 50% + 50% (Basalt)]. At a perfect, spray distance of (15cm).

In addition, Figure (8) shows the relationship of porosity with different spraying distances when using different proportions of the binding substance (Ni-Al), and it was observed that the lowest porosity rate is at the deposition rate of (50%) where the porosity was within (6%).

The figure above also shows that the porosity of the ratios added used in general are very high when the spraying distance is few, and they begin to decrease

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gradually as this distance increases, until we reach the lowest proportions of the porosity, at the spraying distance ((15 cm), after which they start to rise again, This is due to the loss of regular distribution of molten particles from the spray gun on the surface of the substrate[14], since the speed and temperature of the molten partical at the spray center are more than at the border, and therefore the particals of the molten material solidifies before reaching the substrate in the broder region, which leads to create voids or pores.

For the purpose of reducing the porosity percentage in the resulting cermete coating material, the thermal treatment of samples with standard specifications and at the best spray distance (15cm) was carried out, as the specifications at which the lowest value of porosity was recorded before the thermal treatment. Different (750, 950, 1100, 1200) °C, and time (1.5hr), a noticeable change in the porosity percentage has been observed, as its value decreased to 2.6%) as the lowest value when thermal treatment (1100 °C) as shown in Figure (9)). This change in the porosity value is due to the formation of bonding areas between the coating layers cermet due to the occurrence of sintering and diffusion of the atoms by transferring the atoms between them and trying to close the pores when conducting the thermal treatment, and the heat treatment has a great effect on increasing the hardness and density of the samples [16].

Conclusions

The most important conclusions that can be obtained from the current research is the possibility of conducting a thermal flame spraying process for basalt with the presence of a binder that helps to bond and bond the powder during coating, as was obtained the least possible porosity and at optimal conditions from sintering (1100^0C) and spraying distance (15cm) and the mixing ratio (50%), where it reached its value to (2.6%) as the lowest porosity value. As for the rest of the results, the hardness has given the greatest hardness ($1150H_vT$), the highest adhesion strength (13.91 MPa), and the lowest wear of all sliding in the same conditions Optimization mentioned above.

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