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STUDY OF LOW PRESSURE COLD SPRAYED AL+AL203+ZN COATINGS AND THE INFLUENCE OF THE SPRAYING PARAMETERS IN COATING PROPERTIES

Introduction. The cold spraying technique was developed in the Soviet Union in the 80's. Mainly, the process is characterized from other Thermal Spraying coating techniques from the use of much more lower operative pressures and significantly lower process temperatures. The coatings are formed when powder materials are accelerated to supersonic velocities by the use of a convergent-divergent nozzle to consequently be impacted on a substrate; the bonding phenomena has been a controversial point of discussion, but there is an agreement on that bonding is due a high degree of plastic deformation on non melted particles during their impact [1].

The Low Pressure Cold Spraying Technology (LPCS) is characterized for using air as the accelerated fluid with inlet pressures from 5 to 9 atm and a top temperature that reaches the 630 Celsius. The acceleration of the particles through the diverging gas-stream is due the resultant drag force applied to their surfaces; this approach converge in the idea that not only the gas velocity is the responsible for particles acceleration, but the density of the gas as well which is dependent on the Mach number of the accelerated stream [2]. In LPCS a wide range of powder materials (i.e. Cu, Al, Ni, Zn) can be co-sprayed with ceramic particles as Al2O3 [3]. The main reasons for using ceramic particles are: to propagate the surface activation while spraying and to clean the nozzle while metallic particles are hammered and better deformed in the process in comparison of spraying them without ceramics; different studies [3-5] have shown that the addition of ceramic particles give results on better coatings adhesion and better density; for this reason it is acceptable to say, that the ceramics addition to the metallic matrix in the LPCS process acts as a reinforcement for the MMC (Metal Matrix Composite) [6].

The aim of this study was to characterize the mechanical properties of Al+Al203+Zn coatings in order to get more information about their adhesion strength and microhardness dependent on their spraying temperature.

1. Experimental Procedures

In this investigation a A-20-11 (60%wt.%Al+15wt.%Al2O3+25wt.%Zn) commercial powder (Fig. 1) from Obnisk Center for Powder Spraying (OCPS) was sprayed with a DYMET 405 Cold Spraying equipment available at the National Aerospace University of Ukraine. Aluminum 2024 substrates with a diameter of 24.7 mm for Adhesions tests and 50 x 30 mm substrates for metallographic studies were prepared for spraying with sanding paper P360. The SK-20 Nozzle with an Exit Diameter of 4.9 mm was used to accelerate the powder within three different stagnation temperatures - 424 C, 526 C and 632 C. Five different specimens sets were prepared in order to spray them at different stagnation temperatures.

The Coatings were characterized using a SELMI REM-106 Scanning Electron Microscope (SEM). The ASTM E3-01 for Preparation of Metallographic Specimens was followed for the substrates of this study; the specimens were etched using dilute hydrochloric acid (HCl) in order to better distinguish the borders of the deformed particles. The Deposition Efficiency was measured for each Stagnation Temperature under the standard ISO 17836-2004.

Mechanical testing was performed on the coatings in order to determine their adhesive-cohesive strength and micro-harnesses. A tensile strength machine was used in order to determine the Adhesive-Cohesive strength of the coatings according to the ASTM 633 Standard; four tests per coating were performed to determine the average adhesive-cohesive strength at every stagnation temperature. Micro-Hardness tests were also performed under the ASTM E92 Standard (Standard Test Method for Vickers Hardness of Metallic Materials).

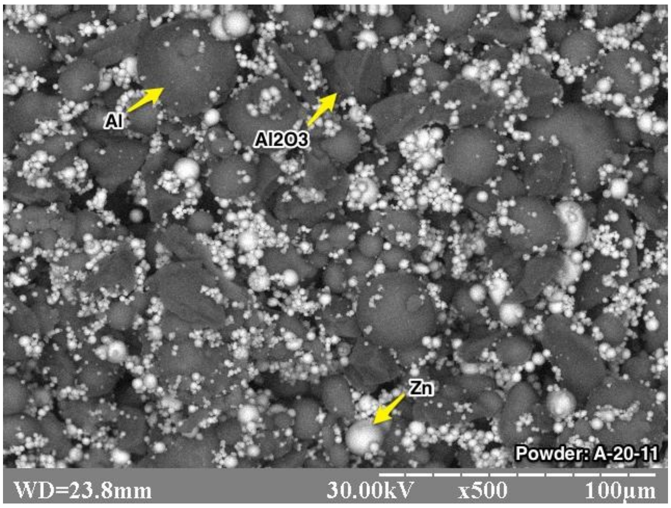

Fig. 1 - Morphology of powder A-20-11 Powder in a blend of 60%wt.%Al+15wt.%Al2O3+25wt.%Zn provided by OCPS

2. Mechanical Properties of Coatings

Mechanical testing was performed on the coatings in order to determine their adhesive-cohesive strength and micro-harnesses. A tensile strength machine was used in order to determine the Adhesive-Cohesive strength of the coatings according to the ASTM 633 Standard; four tests per coating were performed to determine the average adhesive-cohesive strength at every stagnation temperature. Micro-Hardness tests were also performed under the ASTM E92 Standard (Standard Test Method for Vickers Hardness of Metallic Materials).

2.1 Bond Strength

The ASTM C 633 standard for Adhesion or Cohesion Strength of Thermal Spray coatings [8] studies the adhesion strength for coatings sprayed at different stagnation temperatures. The A-20-11 powder blend was sprayed at different spraying stagnation temperatures - 424 C, 526 C and 632 C - with a constant stagnation pressure of 0.8 MPa with the DYMET 405 Low Pressure Cold Spraying equipment.

Under the ASTM C 633 specifications 5 testing samples for each stagnation temperature were studied. Epoxy ED-20 was selected for this study and tested for its maximum adhesive strength presenting 22 MPa (SD 3) of adhesive bonding strength. Test samples were prepared for the spraying operation with sanding paper P360. Coatings of ≈350μm were evenly applied on the test sample. Tensile specimens were assembled as specified in ASTM C 633 using the Epoxy

ED-20, which was curated in 12 hours at ambient temperature. Fig. 4.1 shows an image of a tensile specimen allocated into a self-aligning device before the tensile strength test operation.

Tensile strength was applied for each of the specimens with five runs for each stagnation temperature and material configuration. Fig. 3 shows the results of the adhesion strength study. The adhesion strength for A-20-11 coatings decreases when increasing the stagnation temperature presenting a cohesive failure mode in all the cases.

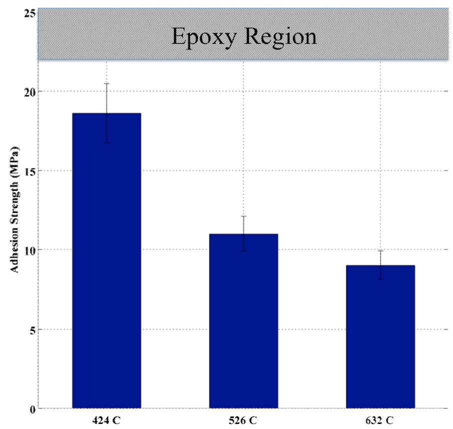

Fig. 2 – Adhesion test results for A-20-11 coatings sprayed at different stagnation temperatures

2.2 Micro-Hardness

The micro-hardness for coatings sprayed at different stagnation temperatures is studied under the ASTM E92 Standard (Standard Test Method for Vickers Hardness of Metallic Materials) [9]. The A-20-11 powder blend was sprayed at different spraying stagnation temperatures - 424 C, 526 C and 632 C - with a constant stagnation pressure of 0.8 MPa with the DYMET 405 Low Pressure Cold Spraying equipment. The Vickers hardness was determined using a load of 50gr. for all the samples. Fig. 4 shows the results for micro-hardness readings.

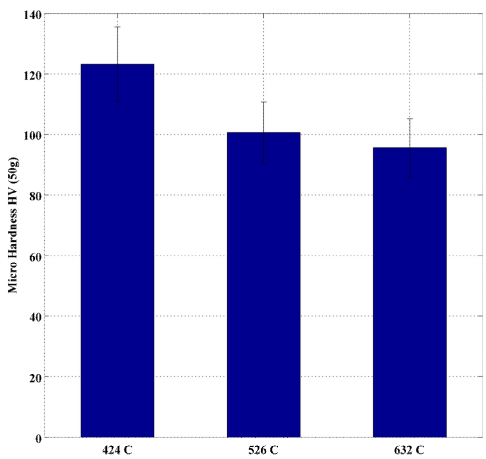

Fig. 3 – Results of micro-hardness readings.

Conclusion In this work, the characterization of Low Pressure Cold Sprayed coatings at several stagnation temperatures was presented. The A-20-11 aluminum based material powder MMC blend was sprayed at different stagnation temperatures - 424 C, 526 C and 632 C - and a constant stagnation pressure of 0.8 MPa using the Dymet 405 Cold Spraying system. The coatings were applied onto Aluminum 2024 substrate specimens. The standard ASTM C 633 was used in order to determine the bond strength of coatings sprayed at the different stagnation temperatures; The adhesion strength for A-20-11 coatings decreases when increasing the stagnation temperature presenting a cohesive failure mode in all the cases. The ASTM E92 Standard was applied in order to determine the micro hardness of coatings; A-20-11 coatings presented a decrease in micro hardness when spraying it at higher stagnation temperatures. The decrease in micro hardness when spraying the material at higher stagnation temperatures can be attributed to erosion of the particles because the higher temperatures after impacting the substrate. Further research is recommended in order to determine the yield adhesion strength of A-20-11 coatings.

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STUDY OF LOW PRESSURE COLD SPRAYED AL+AL$_2$0$_3$+ZN COATINGS AND THE INFLUENCE OF THE SPRAYING PARAMETERS IN COATING PROPERTIES

Low Pressure Cold Spraying (LPCS) is a thermal spraying technique for applying high-density coatings on almost any surface. The main features of the LPCS is that Air is used for the powder materials acceleration through a DeLaval Nozzle with a maximum operation temperature of 630 C in a pressure range of 5 to 9 atm. The powders used in LPCS are usually MMC (Metal Matrix Composite) blends using Alumina very often as the Ceramic part of the composition. The aim of this study is to investigate the effect of the stagnation spraying temperature on the coating properties produced with the Dymet 405 Low Pressure Cold Spraying system and aAl+Al203+Zn powder blend. The coatings are submitted to analyses using a SEM microscope, Micro-Hardness testing and Adhesion-Cohesion measurements.

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ДОСЛІДЖЕННЯ ПОКРИТТІВ AL + AL_20_3 + ZN, НАНЕСЕНИХ ХОЛОДНИМ НАПИЛЕННЯМ НИЗЬКОГО ТИСКУ, ТА ВПЛИВ ПАРАМЕТРІВ НАПИЛЕННЯ НА ВЛАСТИВОСТІ ПОКРИТТІВ

Холодне напилення низького тиску (LPCS) - це метод термічного напилення для нанесення покриттів з високою щільністю на різноманітні поверхні. Основними особливостями LPCS є те, що для прискорення порошкових матеріалів через сопло Лаваля використовується повітря з максимальною робочою температурою 630 ° C в діапазоні тисків від 5 до 9 атм. Порошки, що використовуються в LPCS - це, як правило, металокомпозитні суміші, з використанням в основному алюмоокисів в якості керамічної частини складу. Метою даного дослідження є вивчення впливу стагнації температури напилення на властивості покриттів, нанесених з використанням установки холодного напилення низького тиску ДИМЕТ 405 і порошкової суміші Al + Al_20_3 + Zn. Аналіз покриттів виконано за допомогою мікроскопа SEM, випробувань мікротвердості і вимірювань адгезії-когезії.

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ИССЛЕДОВАНИЕ ПОКРЫТИЙ AL + AL_20_3 + ZN, НАНЕСЕННЫХ ХОЛОДНЫМ НАПЫЛЕНИЕМ НИЗКОГО ДАВЛЕНИЯ, И ВЛИЯНИЕ ПАРАМЕТРОВ НАПЫЛЕНИЯ НА СВОЙСТВА ПОКРЫТИЙ

Холодное напыление низкого давления (LPCS) – это метод термического напыления для нанесения покрытий с высокой плотностью на различные поверхности. Основными особенностями LPCS является то, что для ускорения порошковых материалов через сопло Лаваля используется воздух с максимальной рабочей температурой 630 °C в диапазоне давлений от 5 до 9 атм. Порошки, используемые в LPCS - это, как правило, металлокомпозитные смеси, с использованием в основном алюмооксидов в качестве керамической части состава. Целью данного исследования является изучение влияния стагнации температуры напыления на свойства покрытий, нанесенных с использованием установки холодного напыления низкого давления ДИМЕТ 405 и порошковой смеси Al + Al_20_3 + Zn. Анализ покрытий выполнен с помощью микроскопа SEM, испытаний микротвердости и измерений адгезии-когезии.