ChemTech

International Journal of ChemTech Research
CODEN (USA): IJCRGG ISSN: 0974-4290
Vol.9, No.04 pp 707-711, 2016

www.sphinxsai.com

Surface properties of pressure die cast(PDC) Al 7075 using laser texturing and electrodeposition Zinc-Nickel alloy coatings

G.Sundaramali, P.A.Jeeva, S.Karthikeyan*

School of Mechanical Engineering,VIT University,Vellore-632014,India

Abstract : Al 7075 pressure die cast parts are being used as aircraft materials because of its high density and tensile strength. However, the uncoated PDC Al 7075 is showing lack of mechanical properties such as hardness, wear and corrosion resistances. We have attempted to improve the wear resistance and corrosion resistance of pressure die cast Al 7075 alloys by combining laser texturing and Zn-Ni coatings. The surface roughness, micro hardness and wear resistance studies were evaluated and found that Zn-Ni alloy plating on PDC Al 7075 could significantly improve the said mechanical properties. The coatings are found to with stand 620 hrs in sea water without the formation of corrosion products on its surface.

1. Introduction

Tools for high pressure die casting are imperilled too much unadorned stress state due to mechanical and fluid dynamic effects, as well as to thermal fatigue. Bulk as well as surface of tools are engrossed by the stresses, however it is quite manifested that the optimal performances are to a great level determined by the state of the surface, being these zones the most stressed. In other words there is matter for the surface coatings , the aim of this a key technology, being to permit to lengthen the lifetime of the products with improved mechanical properties , simultaneously reducing costs and saving natural resources.

Thermal spray techniques [1-4] have become an important part of surface engineering and of net-shape forming processes. However, the operation of PDC parts at high temperature exposure in thermal spray coatings processes become peril to the life of components. The alternate candidate for improving the life of PDC Al 7075 is an Zinc- Nickel alloy plating by electrodeposition. The real use of Zinc-Nickel Alloy plating is fetching more popular because the plating for car parts needs high corrosion resistance. Zinc-Nickel Alloy plating is used for parts of the engine is in mandate because it does not get hydrogen embrittlement so it is used in the manufacturing of parts for aircraft. The plating for aircraft parts needs high corrosion resistance and low hydrogen embrettlement. Now cadmium-titanium Alloy plating it is being altered that Nickel Alloy plating be used instead. In this paper, authors have attempted to develop Zn-Ni alloy coatings on laser textured PDC parts made of Al 7075. These are an effective way to ensure surface protection against destructive effects of wear, corrosion [5] and oxidizing phenomena in sea water medium and can be applied in majority of industrial sectors in order to improve mechanical properties of new parts or for reconditioning worn out parts made of Pressure Die cast Al 7075.

2 Experimental

2.1 Laser Texturing on Al 7075 PDC samples

The creation of micro roughness by means of laser texturing is considered as one of the best pre-treatment process for creating strong adhesive coatings. In this study, CETAC LSX-200 Pulse Laser was used with wavelength of 1064 nm producing 25 ns pulses at 309 /micro meter. The laser beam was focussed at the PDC Al 7075 surface with a rectangular slit of size 18 x 5 mm and with a cylindrical lens having a focal length of 550 mm. The low cost, high flexibility and acceptable absorption of this wavelength make this type of laser well suited for surface texturing. The craters were made by 1–4 pulses repeated in the same location whilst the troughs were created by generating a line of overlapping pulses using a pulse repetition rate of 27 kHz and varying the laser scan speed. The laser beam was scanned using a galvanometric scanner with an F-theta focussing lens and controlled by a PC. Initial characterisation tests were performed on commercially available PDC parts made of Al 7075.

The mechanical properties of the Zn-Ni coatings on PDC Al 7075 specimens have been evaluated by Eddy current Thickness tester, Vicker's micro hardness measurements (ASTM E-384), Taber abrasion resistance (ASTM D-4060) and corrosion resistance using salt spray test(ASTM B-117)] were made to evaluate the mechanical properties of the coatings as detailed below.

2.2**Coatings Thickness test**

The thickness of Zinc-Nickel coatings obtained from proprietary coating formulation on PDC Al 7075 were measured by Metrix+ coat measurer F+N (Combine) as per ASTM E309-11.The thickness of the coatings was 60 microns and duration of electrodeposition was 50 minutes.

2.3**Micro hardness measurements**

Micro hardness measurements for all the as plated as well as heat treated PDC AL 7075 specimens (20 x 50 x 2 mm3) and were made by Vicker's harness tester as per ASTM E-384 with a load of 100 g.A diamond shaped indentation was made on each sample at 8 different places and the average value of hardness was measured from the diagonal of indendation on Vicker's scale using the formula.

V.H.N = (1854 x load) / d2

where d = diagonal of the indentor

However, the instrument displayed V.H.N directly using digital read out.

2.4Taber abrasion resistance measurement

The abrasion resistances of the Zinc-Nickel coated specimens of size 100 x 100 x 4 mm3 were measured as per ASTM D-4060 through Taber abraser in as plated and heat treated conditions. The abrading wheels were allowed to rotate on the coatings at a load of 100 g. Before the start of the experiment the specimen were accurately weighed. Then, the wheels are allowed to rotate against the deposit for 1000 cycles with the above load. After that the specimens were removed and weighed again. The experiment was repeated for another 1000 cycles on the specimens. The average weight loss was taken as the Taber wear index or Abrasion resistance.

Taber wear index = Average weight loss (in mg) for 1000 cycles

2.5 Salt spray test for corrosion studies

The salt spray test were performed as per ASTM B 117 made with Zn-Ni coated PDC Al 7075 surfaces. The corrosion degree of the samples was evaluated by average weight loss which was visibly noted by the appearance of formation of black rust spots on the coated samples used under annealed conditions. This test has established that the corrosion resistance of the coatings is higher in sea water medium[6-7].

3. Results and discussion

3.1 Characterisation and texturing

A matrix of individual asperities was generated on the PDC Al 7075 by varying the pulse energy between 0.15 mJ and 0.7 mJ and varying the number of pulses for each crater between 1 and 5. The depth and diameter of these craters were then measured with an optical microscope (Leica DM6000M) with depth measurement capability. By varying the laser scan speed between 62.0 mm/s and 1250 mm/s, lines were generated for a range of laser pulse overlaps (from 0% to 95%). This was performed on the PDC Al 7075 surfaces at two selected pulse energies, 0.5 mJ and 0.7 mJ, with the width and depth of the resulting troughs measured optically. A two dimensional 'hexagonal' arrangement of pulses was used , in order to generate a homogeneous surface structure with the aim of achieving a consistent adhesion of Zinc-Nickel alloys coatings on Al 7075 PDC parts with higher wear resistance, regardless of the direction of motion.

The micro roughness thus produced will serve as anchoring points for Zn-Ni alloy coatings with excellent adhesion.

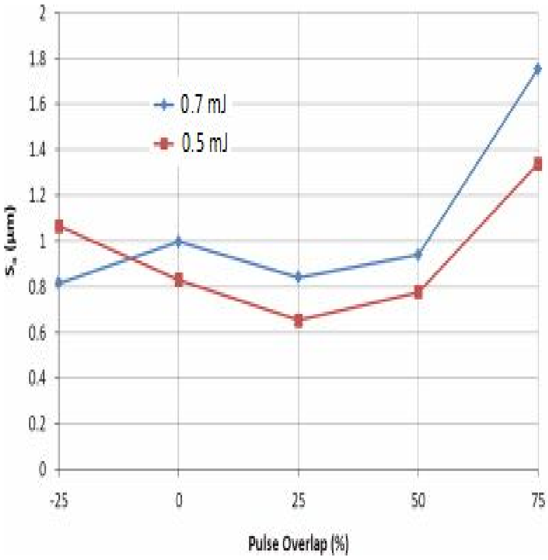

Fig. 1. Arithmetic average surface roughness, *S*a, as a function of pulse overlap.

The above figure 1 shows that increasing the pulse overlap also increases the arithmetic average (S_a) surface roughness of the sample, as was expected, however the roughness appears to correspond to the measured wear resistance . The same trend was observed for several different surface roughness parameters, including RMS roughness (*S*q) and peak-to-trough depth (*S*t), indicating that, the surface roughness is the most important parameter contributing to the increased adhesion which will ultimately improve the wear and corrosion resistances.

3.2 Micro hardness measurements

The results of micro hardness of the electrodeposited trivalent coatings measured by Vicker's hardness tester as per ASTM E-384 are given in Table 1. The higher hardness of Zn-NI coatings can be attributed to the formation of uniform metallic layers in the coatings.

The increased hardness values for Zn-Ni alloy coatings after annealing at 300^{o}C is due to the precipitation of intermetallic phases of Zn and Ni metals.

Beyond 400^{o}C, a decreased trend in hardness was noticed due to the removal of coating layers at that temperature.

Table 1. Micro hardness measurements for Zn-Ni alloy coatings on Al 7075 PDC

S.No	Coatings	Micro hardness (V.H.N) Load:100g		
		As plated surface	Heat treated at 300°C	Heat treated at 400°C
1.	Pressure die cast Al 7075	115	243	220
2.	PDC Al 7075+ Zn-Ni coatings	185	410	362

3.3 Evaluation of abrasion resistance for Zn-Ni coatings on Al PDC parts

The results of abrasion resistance of the coatings measured by Taber abraser are presented in table 2.It has been found that Zn-Ni coatings improved the abrasion resistance both as plated as well as heat treated conditionsat 300°C. This is due to the presence of intermetallic phases by Zn-Ni contents. The increased value of abrasion resistant after heat treatment may be due to the precipitation hardening of Zno particles.

Table 2. Abrasion resistance for Zn-Ni alloy coatings on Al 7075 PDC

S.No.	Nature of the system	Taber wear index (load 1000g) for 1000 cycles (in grams)	
		As plated	Heat treated at 300°C
1.	Zn-Ni coatings on Al 7075 PDC	0.014	0.007

a. Salt spray test

The progress of corrosion ofZn-Ni alloy coated Al 7075 PDC samples using salt spray test are shown in table 3. For Al 7075, it is noticed that 40%rust formed on uncoated sample at 60 minutes stay in salt spray chamber. 1% rust area formation on heat treated Zn-Ni coatings after 610 hours stay in salt spray chamber.

Table 3.Results of salt spray analysis

Time (hr)	Uncoated Al 7075 PDC samples	Appearance of coatings Heat treated Al 7075 PDC samples
0	Nil	Bright
1	40% rust area	Semi dull
42	Fully corroded	Semi dull
120	Fully corroded	Semi dull
240	Fully corroded	Semi dull
480	Fully corroded	Dull
610	Fully corroded	1% rust area
700	Fully corroded	7 % rust area
1200	Fully corroded	50% rust area

4. Conclusion

The introduction of Zinc- Ni alloy coatings on Al 7075 PDC samples were successfully demonstrated. Also the coatings were found to improve the hardness,wear and corrosion resistance of the Al surfaces. The application of laser texturing on Al 7075 PDC could improve the adhesion of coatings which significantly contribute improvement of mechanical properties of air craft machineries.

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