HIGH-PRECISION DETERMINATION OF RESIDUAL STRESS OF PLASMA SPRAYED COATINGS

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Abstract

The residual stresses play a significant position in the production of Plasma sprayed coatings. The substrate material was nickel-based alloy (SS304), and CoNiCrAlY was plasma-sprayed on the substrate as the bond coating. As the top coating, zirconia with 8 mol% yttria and Zirconia Ceria powder was plasma-sprayed on the substrate. The residual stress was measured by a X-ray diffraction method. In this investigation, the residual stress was measured by $\sin^2 \psi$ x-ray diffraction method in plasma sprayed Yttria Stabilised Zirconia and Zirconia Ceria powder coatings.

I INTRODUCTION

Atmospheric Plasma spray[1] coating involves the plasma generator which consists of a circular copper anode, and a thoriated tungsten cathode. The electric arc discharge supported by a generator through the connectors heats up the working gases, which expand in the atmosphere forming a jet [2]. The powder, mixed in a working gas, is injected into the jet. The powder sprayed melts and impacts the substrate. This forms the coating. Residual stress is the stress that exists within a material without application of an external load [3], or it can be described as the stress which remains in a body that is stationary and at equilibrium with its surroundings. The residual stress is also measured by Diffraction methods [4,5]. In this method when the X-rays are passed over the substrate diffraction takes place. The angle at the maximum diffracted X-rays is used to determine the residual stress by obtaining the inter planar spaces of the diffraction planes using Bragg's law[6,7]. The residual stresses are identified when the *d* spacing are different than that of an unstressed state compared to stressed state. The difference in d spacing is proportional to magnitude of the residual stress.

II EXPERIMENTAL PROCEDURE

The substrate material was nickel-based alloy satainless steel grade 304. with a length of 50mm, a width of 50mm and a thickness of 5mm. The bond coating CoNiCrAlY was plasma sprayed on the substrate. The thickness of the bond coating was about 35µm.

Figure 1 Rectangular specimen after coating process (Magnification : 1X)
[Yttria Stabilized Zirconia (8% Y_2O_3+ 92% ZrO_2)]

Figure 2 Rectangular specimen after coating process (Magnification : 1X)
[Zirconia Ceria Powder (25%CeO_2 + 8%Y_2O_3 + 67% ZrO_2)]

Yttria Stabilised Zirconia (8% Y2O3+ 92% ZrO2) was sprayed by plasma spay process on one sample and Zirconia Ceria powder (25%CeO2 + 8%Y2O3 + 67% ZrO2) was prayed by plasma spay process on another sample with 3MB gun for a typical dc torch operating at 40 kW with Metco MN plasma spray system and GH Nozzle with arc current of 500 Amps and Arc voltage of 70 Volts as shown in figure 1 and figure 2. Argon was used as the primary gas at a flow rate of 80 – 90 LPM and hydrogen was used as the secondary gas at a flow rate of 15 – 18 LPM. The distance between the nozzle and the substrate was kept as 80 mm. The thickness of the top coat was kept as 250µm.

The residual stress measurement was carried out confirming to ASTM E2860-12**.**The residual stress measurement for the ten specimens of each coating composition were conducted by X-ray diffraction method (PANalytical's Empyrean XRD). The Copper K-alpha Radiation was used as an X-ray tube. The sample stage was tilted to 0°, 45°, and 90° for scanning the specimen. Both θ and 2θ arms were moved to collect the data with the scan step size of 0.02deg in the range of 49.249º to 51.2490° deg. There was no intense peak at higher angles other than the peak at 50.25deg. Total Measurement time was 30 minutes. This comes under Unidirectional Stress analysis, where Φ (rotation) of the sample will be kept constant and the tilt will be varied. The variables used were, its scan and sample tilt. The instrumental error is less than 0.02deg with respect to linearity. Software Xpert Stress calculates the stress values according to the data collected and the X-Ray elastic constant. The lattice strain will be calculated and then the normal/shear stress will be calculated. Without X-Ray Elastic Constant value (XEC), the calculation will only be of Strain values. Polarisation factor is 1, since no monochromator was used. Only k-beta filter was used. Unidirectional stress analysis examines one Phi-direction only (one series of sin2ψ measurements; possibly extended with 180° rotated values) and only calculates values for the measured normal stress $\sigma\varphi$ and the measured shear stress $\tau\varphi$ (i.e. in the tilting direction of the measurement). The residual stress is calculated by unidirectional stress analysis.The residual stress measurement was carried out at PANalytical, Chennai.

III RESULT AND DISCUSSION

The residual stress measurement was performed by X-ray diffraction method (PANalytical's Empyrean XRD). The principle of unidirectional stress analysis was used to determine the residual stress. The residual stress was measured for the specimen coated by Zirconia Ceria powder and was found to be 71MPa. The residual stress was measured for the specimen coated by Yttria Stabilized Zirconia powder and was found to be 202 MPa. Hence the residual stress created by the Zirconia Ceria powder is less compared to Yttria Stabilized Zirconia powder. Figure 3.shows the XRD pattern of the coated samples.

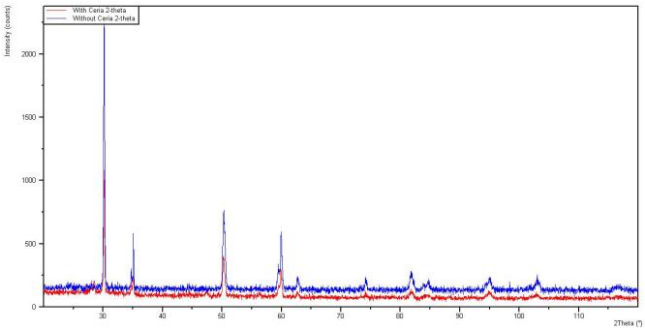

Figure 3. XRD pattern of the coated samples

IV CONCLUSION

Yttria Stabilized Zirconia and Zirconia Ceria powder coatings were deposited by Atmospheric Plasma Spray process on 304 grade stainless steel. The coating thickness was taken as 250 µm since it is the optimum coating thickness for turbine blades[8]. NiCoCrAlY was used as a bond coat. Plasma spray process was used to form deposits of Yttria Stabilised Zirconia (8% Y2O3+ 92% ZrO2), and with proportions of Ceria, the Zirconia Ceria powder (**25%**CeO2 + 8%Y2O3 + 67% ZrO2). The residual stress measurement revealed that the residual stress developed on Zirconia Ceria powder coated samples was found to be 71MPa and the residual stress developed on Yttria Stabilized Zirconia powder coated samples was found to be 202 MPa. The residual stress developed on the Zirconia Ceria powder coated samples is less compared to Yttria Stabilized Zirconia powder coated samples.

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