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Laser Ultrasound Technique for Material Characterization of Thermal Sprayed Coatings

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Abstract

This research focused on characterization of mechanical properties in Nickel-Aluminum coating with different thermal technique and processing parameters at high temperature environment up to 295℃. With the laser ultrasound technique (LUT), guided acoustic waves are generated to propagate on the Ni-Al sprayed coatings. By measuring dispersive phase velocity followed by SCE-UA inversion algorithm. The Young's modulus of coatings which fabricated by HVOF technique is higher than APS technique.

1. Introduction

Thermal spray is an industrial coating process that consists of a heat source (plasma, flame or others) and a coating material in a powder which is melted into tiny droplets and sprayed to the surface of substrate at high velocity. Even though using the same thermal spray technique and processing parameters, there still is a difference of the coating and result in material property. Nickel-Aluminum alloy is a special material in thermal spray technique. Comparing to other metal and ceramic material, the low porous rate and well adhesive interaction are used for middle layer of bonding. Because the thermal spray technique and processing parameters generates the difference of microstructure in coating easily and result in changes of material property. The characterizing on material property of coating became more important. Traditionally, the material property characterizing depends on tensile testing. Regarding to thin film material, the specimen of tensile testing manufacture is hard to prepare and develop to on-line measurement. This research focused on characterization of mechanical properties in Nickel-Aluminum alloy coating by using laser ultrasound technique (LUT) combined with SCE-UA inversion algorithm.

2. Specimens

Nickel-Aluminum alloy coating specimens were provided by Industrial Technology Research Institute (ITRI). There are two kind of thermal spray technique manufactured Nickel-Aluminum alloy coating by atmosphere plasma spray (APS) and high velocity oxygen fuel (HVOF). Among these samples, the substrate is made of 304 stainless steel (SS304) plate, which thickness is 5mm. The coating material was made of Nickel-Aluminum powder (Ni-5wt%Al) which provided by Powder Alloy Corporation (PAC co.). The distinct of APS processing parameter is flow velocity of hydrogen, which is 5, 9.5 and 14 SLPM respectively as listed Table 1. On the other hand, the distinct of HVOF processing parameter is flow velocity of oxygen, which is 340, 380 and 420SLPM. All of these specimen labels are listed in table 1.

Table 1 Nickel-Aluminum allot coating specimens

Label	Technique	Material	Velocity
ANi_SLPM5	APS	Ni-5Al	5 SLPM
ANi_SLPM9.5	APS	Ni-5Al	9.5 SLPM
ANi_SLPM14	APS	Ni-5Al	14 SLPM
HNi_SLPM340	HVOF	Ni-5Al	340 SLPM
HNi_SLPM380	HVOF	Ni-5Al	380 SLPM
HNi_SLPM420	HVOF	Ni-5Al	420 SLPM

3. Experimental measurement

Dispersion relations of guided wave propagation in Nickel-Aluminum alloy coatings with 20℃, 50℃, 100℃, 150℃, 200℃, 250℃ and 295℃ environment temperature are measured with a laser-generation/laser-detection laser ultrasound technique (LUT). The experimental configuration consists of a pulsed Nd:YAG laser for generation and a laser interferometer for detection as shown in **Fig. 1**. While the environment temperature reaching a steady state, the generation laser beam is scanned in the axial direction. After the waveforms at each step are collected, a set of B-scan data can be acquired.

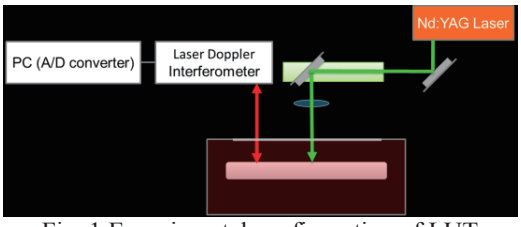

Fig. 1 Experimental configuration of LUT

4. Inversion technique

Following the measurements on the dispersion spectra of guided waves propagating in a double layer plate and combine with a theoretical model, an inversion procedure can be employed to obtain properties of the samples. The inversion method in this study is based on SCE-UA algorithm

to extract properties from the measured dispersion spectra is illustrated in a block diagram in **Fig. 2**.

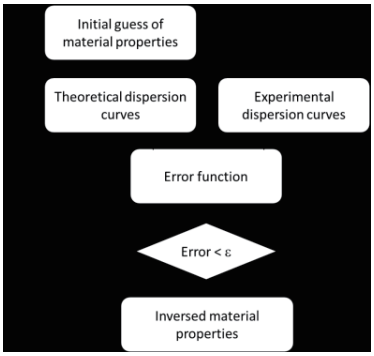

Fig. 2 A flowchart showing the inversion procedure

5. Result and Discussion

Fig. 3 and **Fig. 4** shows the measured dispersion curves of specimen ANi_SLPM5(1) and HNi_SLPM340(1), respectively. The surface wave velocity for all of Nickel-Aluminum alloy coating samples decreased as temperature increased. However, we can observe the quantitative phenomena from dispersion spectra only, so that the inversion algorithm is employed in order to obtain material property at elevated temperature.

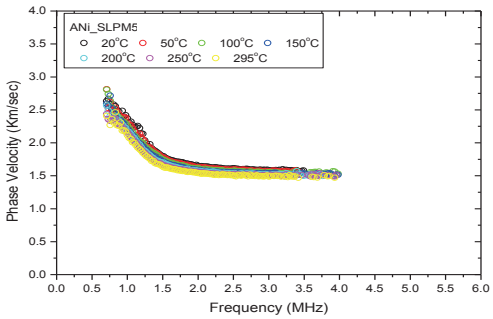

Fig.3 Measured dispersion curves of specimen ANi_SLPM5 at elevated temperature

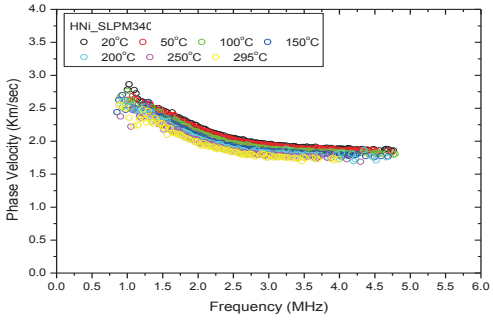

Fig. 4 Measured dispersion curves of specimen HNi_SLPM340 at elevated temperature.

Inversion results of Young's modulus for the Nickel-Aluminum alloy coatings with different environment temperature are shown in **Fig. 5**. It is founded that the Young's modulus decreases as the temperature increases. In addition, The Young's modulus of coatings which fabricated by HVOF technique is higher than APS technique. Moreover, if the gas flow velocity of thermal spray procedure were high, the Young's modulus will greater for both techniques.

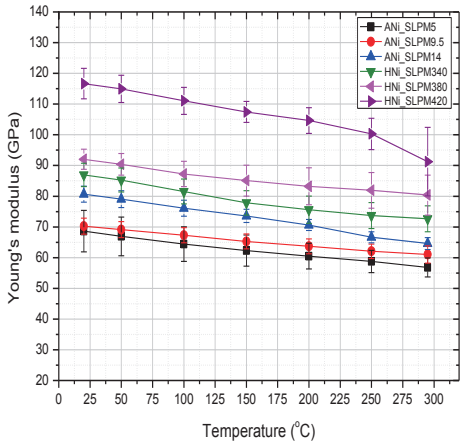

Fig. 5 Inverted Young's modulus for the Nickel-Aluminum alloy coating at different temperature**.**

6. Conclusion

The mechanical properties of Ni-Al coating which fabricated by thermal spray technique is not stable enough, there are large number of data need to analyze. But the traditional measurement for mechanical property spends too much time because the specimen preparation. This research demonstrates a nondestructive, non-contact laser ultrasound technique combined with inversion algorithm to measure the material properties of film layers by thermal spray technique at elevated temperature environment with high accuracy.

Reference

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