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Nondestructive measurement Material Characterization of Thermal Sprayed Nickel Aluminum Coatings by using laser ultrasound technique

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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. This technique is potentially useful to probe the material characterization at high temperature environment in a remote and non-destructive way.

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Keywords: NDE; Material Characterization; Thermal spray coatings; Laser ultrasound 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 changes of 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 cohesive layer of bonding. Traditionally, the material property characterizing depends on tensile testing.

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Regarding to the thin film material, the specimen of tensile testing manufacture is hard to prepare and develop to on-line measurement. Recently, ultrasound techniques based on surface acoustic waves (SAW) draw more attention due to long range inspection and As a result, 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. Specimen

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 420 SLPM. 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. Experiment Setup

The measurement for material property of Nickel-Aluminum alloy coatings uses LUT combined with inversion algorithm to obtain its dispersion curves at different temperature in the temperature-controlled closed oven. The oven is operated under 20□, 50□, 100□, 150□, 200□, 250□ and 295□. 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.

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 procedure applying on inversion technique to extract properties from the measured dispersion spectra is illustrated in a block diagram shown in figure 2. In this study, we employed the global optimal algorithm (SCE-UA) to extract material property. The purpose of global optimal algorithm is used to avoid the mismatch of local extreme value

which derived from the error function while characterizing material properties.

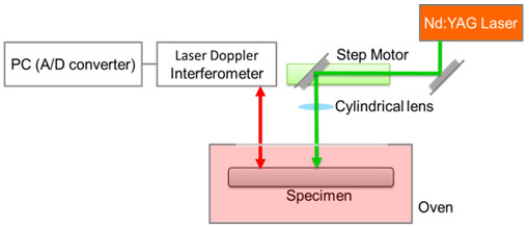

Fig. 1. Experimental configuration of LUT.

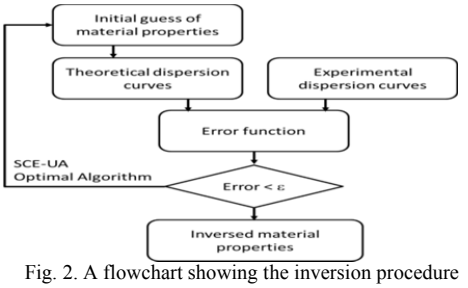

Fig. 2. A flowchart showing the inversion procedure

5. Result and discussion

The measured results of Nickel-Aluminum alloy samples are compare with thermal spray technique and processing parameters. First, we consider the experimental result of the same thermal spray technique but different gas flow velocity samples. In figure 3, we can noticed that if the gas flow velocity of processing parameters were high, the surface wave velocity of coating will be fast with different thermal spray technique.

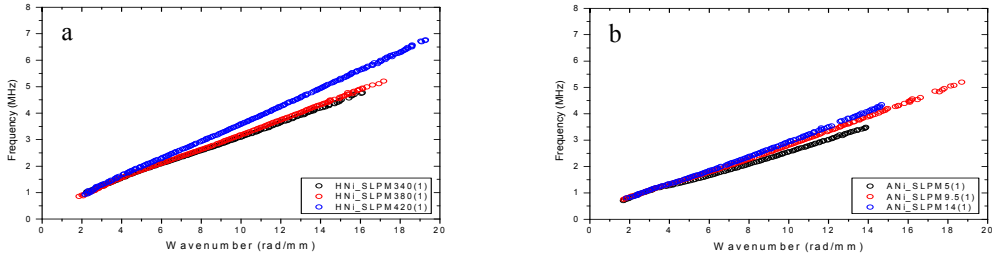

Fig.3.(a) Dispersion spectra for APS technique; (b) Dispersion spectra for HVOF technique.

Fig. 4 shows the measured dispersion curves of specimen ANi_SLPM5 and HNi_SLPM340, 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.

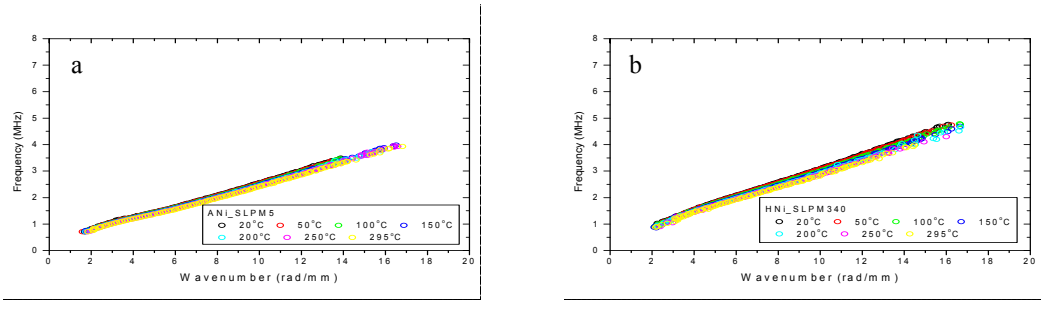

Fig.4 (a) Dispersion spectra of ANi_SLPM5 at elevated temperature; (b) Dispersion spectra of HNi_SLPM340 at elevated temperature.

Inversion results of Young's modulus for the Nickel-Aluminum alloy coatings with different environment temperatures 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.

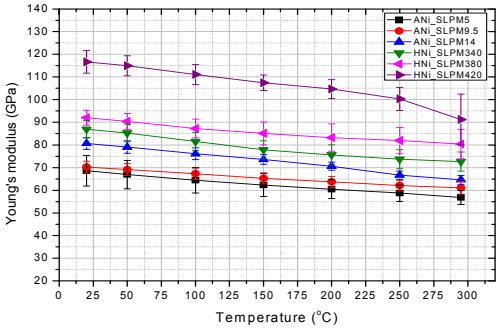

Fig. 5. Inverted Young's modulus for the Nickel-Aluminum alloy coating at different temperature**.**

6. Conclusion

The properties of film layer which fabricated by thermal spray technique is not stable due to its difference within coating micro-structure. But we can still find out that no matter coating is fabricated by APS or HVOF technique, the surface wave velocity become fast while gas flow velocity of processing parameter is higher. In the elevated temperature measurement, the Young's modulus of samples with different manufacturing decreased as temperature increased. 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 room and elevated temperature environment with high accuracy. References

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