JTTEE5 19:429–438
DOI: 10.1007/s11666-009-9440-0
1059-9630/$19.00 © ASM International

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Evaluation of the Flexural Rigidity of Sandwich Structures Using Experimentally Obtained Mechanical Properties of the Constituents

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(Submitted April 23, 2009; in revised form September 15, 2009)

Prediction of mechanical performance of sandwich constructions is a difficult task due to the complex nonlinear and inelastic behavior of the constituent materials. This study tries to utilize an analytical model to estimate the mechanical performance of sandwich structure based on the mechanical properties of the constituents. To this end, the mechanical properties of the core and skin materials were examined separately. The mechanical behavior and deformation mechanism of Ni alloy foam structures have been studied using uniaxial compression testing. The mechanical properties of alloy 625 coating were determined using tensile testing. The flexural rigidity of sandwich structures were calculated using experimentally obtained elastic moduli of the alloy 625 coating and Ni alloy foam. The model was also used to calculate the flexural rigidity of sandwich samples with different skin thicknesses. This study also investigates the effect of post fabrication heat treatment on the mechanical performance of the sandwich structures.

Keywords air plasma spraying, compression testing, flexural rigidity, nickel alloy foam, sandwich structures, tensile testing

1. Introduction

Sandwich structures are considered as viable engineering constructions due to their unique structural, physical, and mechanical properties. Typically, sandwich structures consist of two thin skins (faces) and a lightweight thicker core. Sandwich structures can be realized with a great variety of materials both for skins and the core. Facing layers (skins) generally are selected from a stiff and strong material while the inner core component is a low-density material. Owing to their excellent performance, sandwich structures find widespread use in astronautic and aeronautic applications, marine and offshore industries, train and car structures, wind turbine blades, home appliances, and civil structures. Their structural, physical, and mechanical characteristics can be tailored based on service requirements through selection of different materials and manufacturing processes.

An extensive amount of study has been done in the design, fabrication, and performance of sandwich structures with open cell and closed cell foam cores, truss cores, and honeycomb cores (Ref 1-3). These advanced types of sandwich structures exhibit mechanical performance characteristics comparable to conventional materials at much lower weight and potentially lower cost. Sandwich structures with open cell core exhibit lower thermal conductivity and have lower thermal capacity compared with solid materials and structures. This type of sandwich structures is considered as suitable for being used at high temperatures applications. They will satisfy the requirements for high temperature applications such as low cost, low density, resistance against high temperature, resistance against corrosion, good formability, and ease of production. For high temperature applications, it is necessary to use those materials which possess good physical and mechanical properties at elevated temperatures for skin and core sections. Ni-based superalloy such as alloy 625 is a good candidate for skin component. Alloy 625 as a superalloy offers a combination of microstructural stability, strength, ductility, and toughness at elevated temperatures, which normally cannot be provided by other metallic compounds (Ref 4). Material for core section needs to exhibit good mechanical properties especially at

This article is an invited paper selected from presentations at the 2009 International Thermal Spray Conference and has been expanded from the original presentation. It is simultaneously published in *Expanding Thermal Spray Performance to New Markets and Applications: Proceedings of the 2009 International Thermal Spray Conference*, Las Vegas, Nevada, USA, May 4-7, 2009, Basil R. Marple, Margaret M. Hyland, Yuk-Chiu Lau, Chang-Jiu Li, Rogerio S. Lima, and Ghislain Montavon, Ed., ASM International, Materials Park, OH, 2009.

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high temperature while having low weight. Nickel aluminide intermetallics exhibit acceptable mechanical behavior at room temperature and their mechanical properties improve with increasing temperature (Ref 5). Ni alloy foam structures are expected to exhibit outstanding mechanical and physical properties, such as relatively low specific weight, high specific strength, and high stiffness. The sandwich structure consisting of a Ni alloy open cell foam covered by alloy 625 is expected to be a good candidate for high temperature applications.

There are numerous methods for fabrication of foam-cored sandwich structures, such as investment casting, deformation forming, welding, and coating (e.g., thermal spray, chemical vapor deposition, slurry). Thermal spray technique such as Air Plasma Spraying (APS) is a suitable method for rapid deposition of thick sections of superalloy material on the both sides of the foam structure. This type of sandwich structure is easy to fabricate, and, therefore, the need for adhesive bonding between the core and the skin will be eliminated. Figure 1(a) shows the fabricated sandwich structure by deposition of alloy 625 on Ni alloy foam. Cross section of APS-deposited skin on foam core shown in Fig. 1(b) indicates good adhesion with almost no visible interface between the skin and the core.

Sandwich structures are of most interest for structural applications involving flexural loading, since their structure presents no distinct advantages in specific strength or specific stiffness for in-plane loading conditions. Although not all the potential applications of high temperature foam core sandwich structures require exceptional structural performance, the behavior of the structures under flexural loading is often important and provides an indication of the integrity of the sandwich structure. Face (skin) layers carry almost all of the bending and in-plane loads whereas the core sections act only to reinforce and stabilize the facings. Therefore, strengthening of facing components may result in increase in total stiffness of the sandwich structure. It is assumed that heat treatment can strengthen the skin (coatings) by increasing metallurgical bonding between splats.

Analysis of mechanical performance of sandwich construction with foam core and APS-deposited superalloy skins is a difficult task due to the complex geometry of the core and nonlinear and anisotropic behavior of the constituent materials. In general, flexural loading tests can be used to qualitatively characterize the mechanical performance of the sandwich structures.

Azarmi et al., has previously reported the results of an investigation on the mechanical performance of the same type of sandwich structure under four-point bending load condition (Ref 6). They have also monitored damage development in the sandwich structures during four point bend testing, followed by direct observation of tested sandwich samples at failure to monitor crack propagation due to flexural loading. There was no skin delamination observed in any sandwich sample regardless of skin thickness after four point bending test. It indicates strong adhesion between plasma-sprayed skin and foam core. The flexural rigidity of the as-fabricated samples under four point bending was significantly increased after heat treatment for both skin thicknesses.

Results from Ref 6 indicated that sandwich samples with a thicker skin have a higher flexural rigidity, which indicates the effect of skin thickness. The dominant failure mode observed for all the sandwich samples with skin thickness of 0.5 mm was the skin indentation.

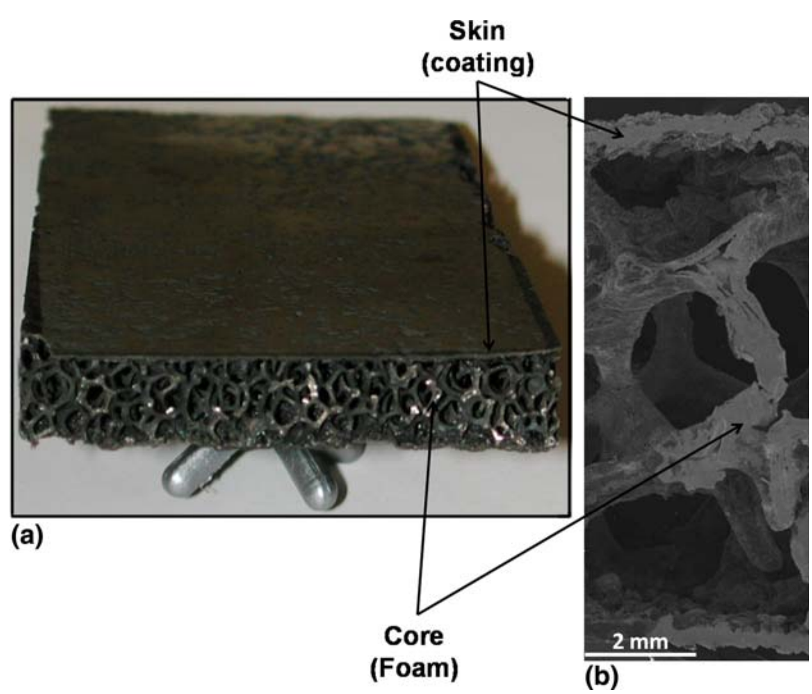

Fig. 1 (a) Fabricated sandwich structure by APS deposition of alloy 625 on Ni alloy foam, (b) cross section of skin and core

According to Ref 7, skin indentation is a type of failure when top skin fails due to the flexural loading. Cracks and fractures can be clearly seen in the regions under loading supports. The results indicated a linear behavior in the elastic region, but beyond the linear regime, the stress increased nonlinearly, due to plastic indentation of the skin. The rapid decrease in the load occurs when a crack develops in the skin, leading to failure of the sample. The dominant failure mode for sandwich structures with skin thickness of 0.1 mm was core yielding. In this case, the skin is not stiff enough to carry the load, and failure of the structure depends on the foam strength. The results indicated a linear behavior in the elastic region but when the stress passes the elastic limit of the foam, the load increases nonlinearly due to the plastic deformation and/or localized fracture of struts in the foam core. At failure, a crack extends through the thickness of the foam.

However, this study tries to understand the mechanical behavior of the sandwich structure by examining the mechanical properties of its constituents (Ni alloy foams and APS-deposited skin) separately. First, the stress-strain curve for the as-received and heat-treated foam structure was determined using uniaxial compression testing. Second, the stress-strain curve for the as-sprayed and heat-treated alloy 625 coating was determined using tensile testing. Finally, the flexural rigidity of the as-fabricated and heat-treated sandwich samples were calculated using the elastic moduli of the alloy 625 coating and the Ni alloy foam. The model was also used to calculate the flexural rigidity of sandwich samples with different skin thicknesses to verify the accuracy of the model and to understand the effect of skin thickness on the predicted mechanical performance of sandwich structures. This study also investigates the effect of post-fabrication heat treatment on the mechanical performance of the sandwich structures.

2. Experimental Procedure

2.1 Compression Test on Foam Structures

The mechanical properties and deformation mechanism of the as-received and heat-treated Ni alloy foam structures by performing uniaxial compression testing have been studied. Ni alloy foams fabricated by Fibernide Ltd., Brampton, Canada. The strut thickness of the as-received nickel alloy foams ranged from 0.3 to 0.8 mm, and the strut length ranged from 0.3 to 3 mm with an average pore size of 2.5 ± 1.5 mm. The as-received foam sheets were (*L*) 178 mm × (*W*) 101 mm × (*T*) 9 mm and filled with graphite. This graphite was removed from the foam prior to preparation of samples for compression test by low temperature oxidation in air followed by mechanical agitation. Ni alloy foam samples were cut from the Ni alloy foam sheets to the dimensions of 9 mm *D* × 9 mm *H* (i.e., $D = H$). Some samples were heat treated according to the cycles indicated in heat treatment section. Foam samples were then compression tested using a screw-driven testing machine (SHIMADZU, AG-I, Tokyo, Japan) at a strain rate of 10^{-3} s^{-1}. The longitudinal strain was computed from top plate displacement divided by the original height of samples. The tests were terminated after the load dropped and remained almost constant following a peak value. The chemical composition of Ni alloy foam by Inductively Coupled Plasma-Atomic Emission Spectroscopy (ICP-AES) is 10.5 wt.% Al, 573.53 ppm Co, 500 ppm Si, 340.59 ppm Fe, 5 ppm Mn, and remainder Ni. The analysis shows that no impurity or alloying element is present at a level greater than 600 ppm other than aluminum, with its presence at a level of about 10 wt.%.

2.2 APS Deposition of Alloy 625

Alloy 625 powder (Metco AMDRY 625, Troy, MI) was air-plasma sprayed using a Praxair (formerly Miller Thermal) SG-100 torch (Praxair Surface Technologies, Indianapolis, IN) mounted on a computer-controlled robotic arm at atmospheric pressure. The nominal composition of alloy 625 powder is 21.5 wt.% Cr, 8.5 wt.% Mo, 3 wt.% Nb, 3 wt.% Fe, 0.5 wt.% Co, and the remainder Ni. The nominal particle size is in the range of 45-90 μm. The optimized process parameters as determined in the previous study were used for deposition of alloy 625 coatings on the foam structure (Ref 8). Table 1 shows spraying parameters used in this study. A coating of about 0.5 ± 0.1 mm was produced on the foam by depositing 18 passes of the alloy 625. A coating of about 0.1 ± 0.05 mm was produced on the foam by depositing three passes of the alloy 625. The substrate temperature during deposition was measured by thermocouples imbedded at the midplane of the foam, one at the center and one near both edges of the substrate. The measured temperature had plateaus of ~230 °C after three passes and ~340 °C after 10 passes. The substrate was constantly cooled by air blowing during spraying process.

2.3 Tensile Test on APS-Deposited Alloy 625

Tensile tests were performed on a number of as-sprayed and heat-treated samples. Tensile specimens were made from APS alloy 625 coatings deposited on the Ni alloy foam after machining and separation of the coating from the substrate. Owing to the size limitations of the coatings, sub-size tensile test specimens were made parallel to the splat plane according to ASTM E8M-04 (Ref 9). Coatings were cut to the required dimensions (50 mm × 5 mm × 0.5 mm) using electrical discharge machining (EDM) equipment. Each sample was slightly

Table 1 Air plasma spraying parameters

Parameter	Value
Powder average size, μm	78
Spray distance, mm	50
Feed rate, g/min	28
Ar gas flow, sl/min	55
Current, A	630
Power, kW	25

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machined on both sides using a surface grinder to ensure there were no surface asperities. The test setup consisted of top and bottom grips, and an extensometer attached to the sample for measuring the change in length of the gage section during the test. A jig was used during mounting of the specimens to minimize any misalignment. Tensile tests were performed using a screw-driven testing machine (SHIMADZU, AG-I, Tokyo, Japan) at a strain rate of 10^{-4} s^{-1}. The tests were terminated after fracturing the specimens.

2.4 Heat Treatment

All the tensile samples made from alloy 625 coating were subjected to stress relieving heat treatment at 899 °C for 4 h under low pressure (~10^{-6}-3 × 10^{-6} MPa) using a high-temperature vacuum furnace (R. D. WEBB Co, Natick, MA) prior to tensile test. This heat treatment eliminates the residual stress in the tensile samples during machining process. Extra post-deposition heat treatments were applied to the as-sprayed structure to improve coating properties. It has been shown that heat treatment of a coating structure can enhance cohesion between the individual lamella by diffusion across splat boundaries, and elimination of internal fine porosity (Ref 10). Although the main reason for the heat treatment is to improve mechanical properties of the as-sprayed coating, in an as-fabricated sandwich construction both the skin (alloy 625 coating) and the core will undergo the heat treatment process. It means that the foam structure must be heat treated at the same condition as applicable for coating. Extra care must be taken to avoid damaging the foam structure. Various temperatures recommended for solution annealing of the conventionally processed alloy 625 were used for the as-sprayed alloy 625 and Ni alloy foam separately to investigate their effect on the mechanical properties of each. Heat treatment at 1100 °C gave the best response for strengthening of the coating and foam components. Tensile testing samples made from alloy 625 coating, and compression testing samples made from Ni alloy foam were heat treated at 1100 °C for 5 h under low pressure (~10^{-6}-3 × 10^{-6} MPa) using the above mentioned vacuum furnace. Figure 2 presents the heat treatment cycle in this study. Figure 3 show microstructures of alloy 625 (a) as deposited, and (b) heat treated for 5 h. It is clearly visible from Fig. 3(a) and (b)

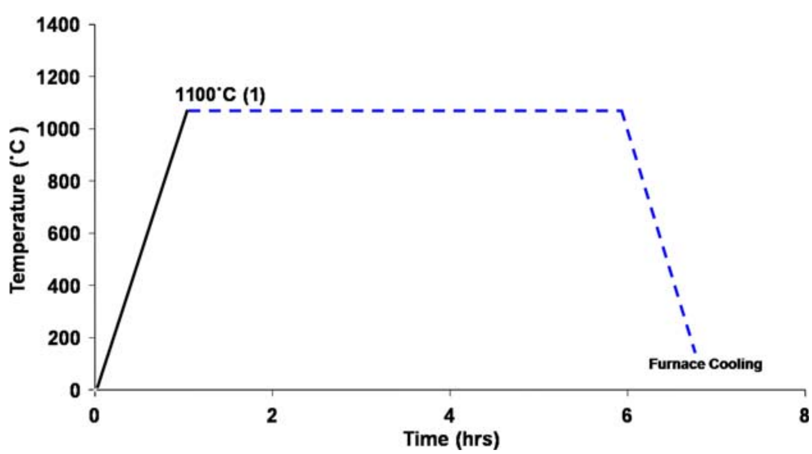

Fig. 2 Heat treatment cycle for the APS processed alloy 625 and Ni foam in this study, based on conventional heat treatment schedules

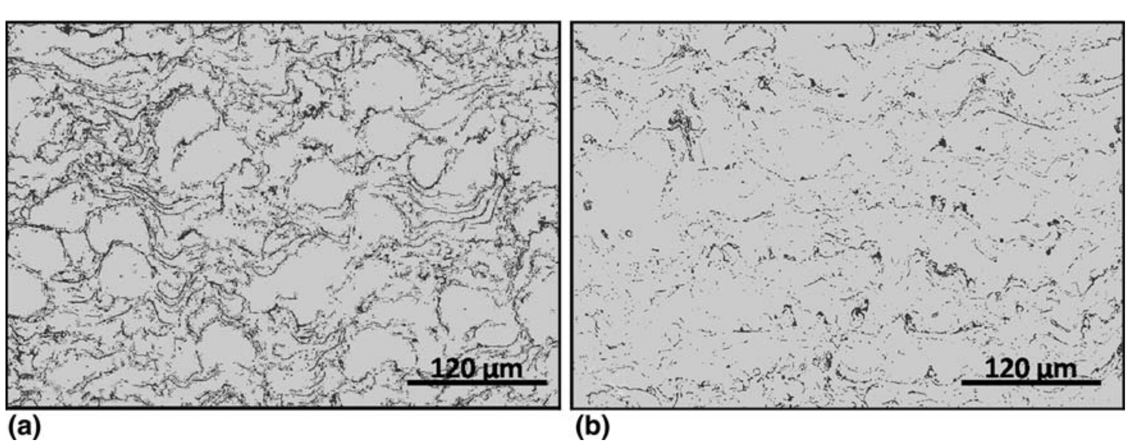

Fig. 3 Low magnification SEM image of cross-section of alloy 625 coating, (a) as-sprayed, (b) heat treated

that the amount of splat boundaries (dark regions) is lower in the heat-treated sample.

3. Analysis of Mechanical Behavior of Sandwich Structures

Sandwich structures subjected to general bending, shear, and in-plane loading display various failure modes. General theories describing the mechanical behavior of traditional composites can be applied to sandwich structures if the transverse and torsional shear effects were added to them (Ref 11). The skin loading can be either compression, tension, or shear as shown in Fig. 4. It is believed that under uniaxial bending load, the top skin is in compression condition and the bottom one is in tension. The core always carries shear loads, but skins are thin and will transmit a significant fraction of the applied load to the core, possibly causing a significant local deformation (Ref 12). The strength of a sandwich structure as a composite structure is mainly dependent on the loading directions and types, the mechanical properties of the constituents (e.g., skin, core, bounding materials), and the geometric dimensions.

Typically sandwich structures are subjected to out-of-plane loadings where the primary loads are applied perpendicular to the panel surface. Thus, they are expected to be strong and stiff in bending. A number of recent studies have attempted to determine important aspects of the mechanical behavior of sandwich structures subjected to bending conditions. Flexural properties of sandwich constructions, such as the core shear stress, skin bending stress, and flexural rigidity can be obtained from analytical solutions and flexural tests (Ref 11, 13). In fact, flexural rigidity ($\mathrm{EI}_{(\mathrm{eq})}$) is the summation of flexural rigidity of sandwich structure constituents.

$$\mathrm{EI}_{(\mathrm{eq})} = E_{(\mathrm{c})} \cdot I_{(\mathrm{c})} + 2(E_{(\mathrm{f})} \cdot I_{(\mathrm{f})}) \quad \text{(Eq 1)}$$

where ($I_{(\mathrm{c})}$, and $I_{(\mathrm{f})}$) are second moment of area of core and face components. The flexural rigidity of the sandwich beam, $\mathrm{EI}_{(\mathrm{eq})}$, can be derived from Eq 1 as follows (Ref 14):

$$\mathrm{EI}_{(\mathrm{eq})} = \frac{E_{\mathrm{f}}btd^2}{2} + \frac{E_{\mathrm{f}}bt^3}{6} + \frac{E_{\mathrm{c}}bc^3}{12} \quad \text{(Eq 2)}$$

where (E_{f}) and (E_{c}) are the elastic moduli of the skin and core materials, respectively, (d) is the sandwich thickness, (c) is the core thickness, (t) is the skin thickness, and (b) is the sandwich width.

Equation 2 was derived based on the assumption that thickness of the skin is significantly smaller than the thickness of the core. In this case, d is equal to the thickness of the sandwich beam (Ref 15). This assumption will introduce error into the calculation which increases with increase in skin thickness according to this equation. The equation was rederived according to the "*Parallel axis theorem*", yielding Eq 3, where d^* is the distance between the center lines of the upper and lower skins. It is expected that prediction of mechanical performance using Eq 3 will result in more accurate results.

$$\mathrm{EI}_{(\mathrm{eq})} = \frac{E_{\mathrm{f}}bt(d^*)^2}{2} + \frac{E_{\mathrm{f}}bt^3}{6} + \frac{E_{\mathrm{c}}bc^3}{12} \quad \text{(Eq 3)}$$

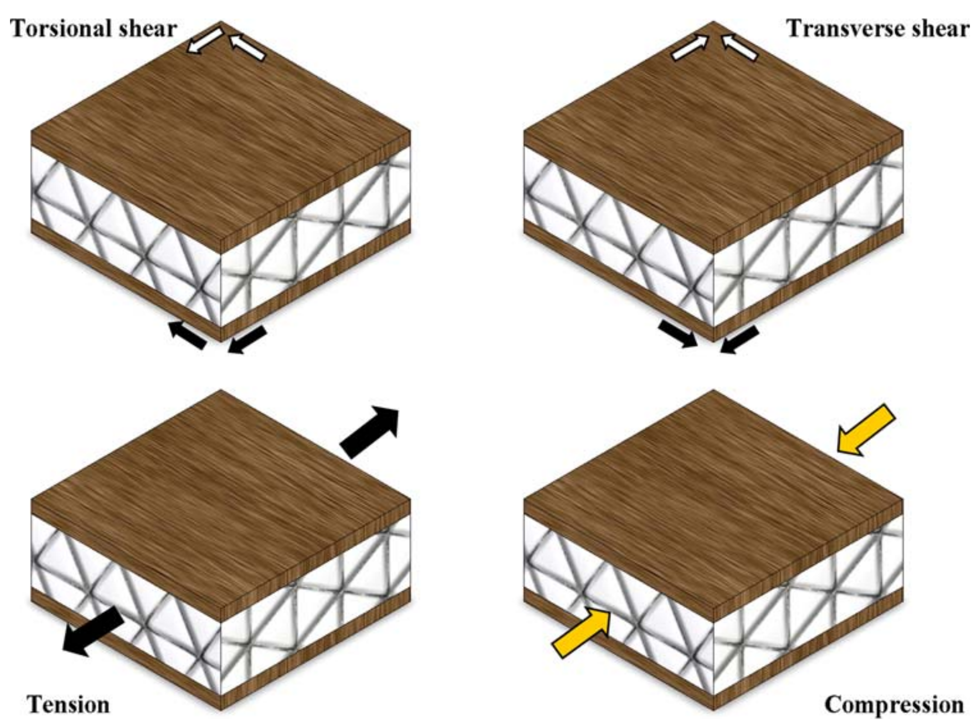

Fig. 4 Skin loadings in sandwich structures

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4. Results and Discussion

4.1 Compression Test

The open-cell foam structures investigated in this study are represented by a network of connected struts. Foam structures with a relative density of 0.1 (where struts occupy 10% of the volume) are known as *bending-dominant structures*. The main deformation mechanism in this type of structure is bending of struts (cell edges) (Ref 7). Recent studies on open-cell foams indicate that for a given level of porosity, structural parameters such as cell shape and size have low influence on the elastic modulus of this structure (Ref 16, 17). Open-cell foams are generally not completely isotropic, and show better stiffness and strength when loaded parallel to their major principal directions (Ref 18). When they are subjected to loads perpendicular to their major direction, they may collapse.

Collapse in open-cell foams depends mainly on the material. When the force exerted on foam made from a ductile material (i.e., metallic foams) exceeds the elastic limit, cell collapse is mainly due to the formation of plastic hinges in the cell edges. In Fig. 5(a) the stress-strain curves resulting from compression tests on three as-received foam samples are shown, and in Fig. 5(b) the curves for the three 5 h heat-treated samples are shown. Although

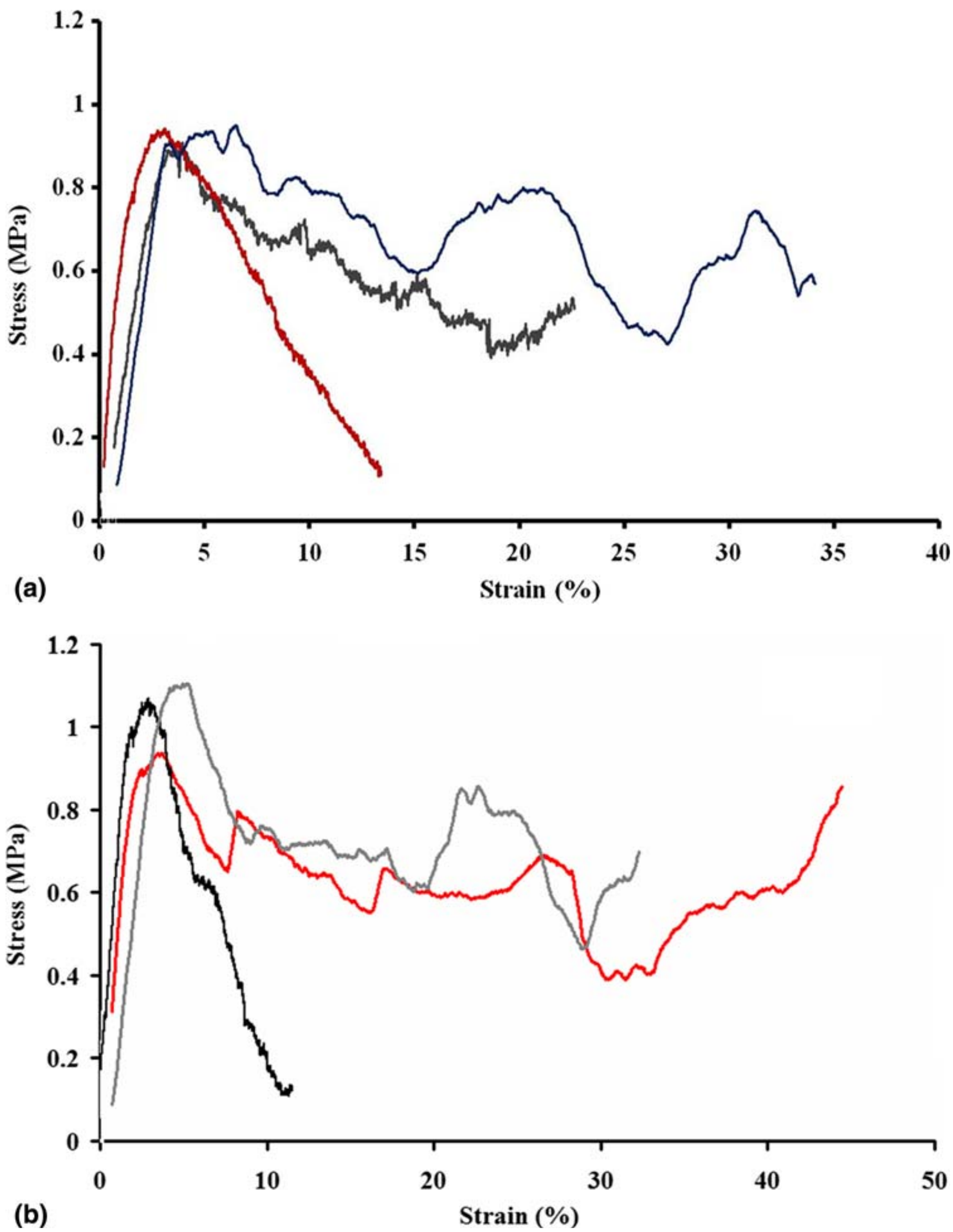


Fig. 5 Stress-strain curve resulting from compression test on (a) three as-received Ni alloy foam samples, (b) three 5 h heat-treated samples foam samples

there are significant differences among the curves beyond the yield point, the different stages of deformation can be recognized in each of them. Three distinct stages of deformation can be seen in all the graphs. In the first stage where struts deform elastically, the slope of the curve was used to determine the elastic modulus of the foam. In the second stage, the stress in the foam struts exceeds the yield stress corresponding to the plastification in foam struts. Plastic deformation continues in the struts followed by collapse of cell edges in the weaker struts. The collapse and overlap of weak struts may cause local densification in the foam resulting in a sudden increase in the stress. The compression tests were stopped at about 50% strain.

Table 2 shows compression test results for the as-received and the heat-treated Ni alloy foam samples. Compression tests were performed on at least six specimens for each condition. The relatively large scatter in the measured values reflects the effect of inhomogeneity in the shape and size of the pores and their distribution in the foam samples. The values for elastic modulus obtained from the compression tests are close to those results reported by Bell for the same foam structure (Ref 19). These results show that the elastic modulus of the foam samples was approximately doubled after heat treatment. However, heat treatment had a smaller influence on the yield strength of foam samples. It can be due to the fact that the foam was made from over plating nickel with 10% aluminum. According to Al-Ni phase diagram, no phase change is possible at this temperature and concentration. It explains the absence of any significant influence of heat treatment on the yield strength of the foam structure. Heat treatment may increase elastic moduli of foams due to elimination of small pores and strengthening of the metallurgical bonding between Aluminum layer and Nickel matrix due to diffusion.

Figure 6 shows a typical compression sample before and after compression testing. There is almost no barreling observed in the compressed samples indicating that the collapse of struts and densification of the foam was responsible for the large deformation.

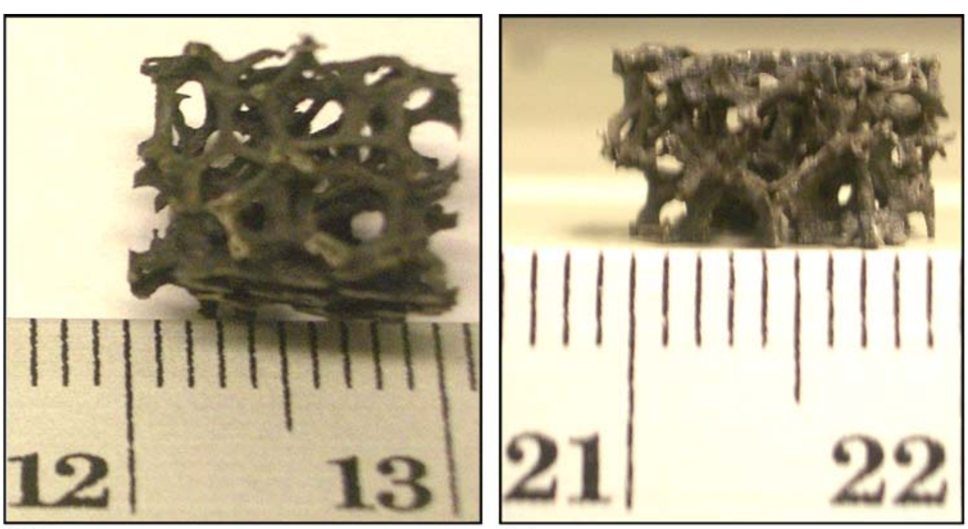
Table 2 Mechanical properties of Ni alloy foam determined from compression tests

Ni alloy foam samples	Yield strength, MPa	Elastic modulus, GPa
As-received	0.9 ± 0.1	0.020 ± 0.005
Heat treated (5 h)	1.2 ± 0.2	0.04 ± 0.01

Average of 6 measurements ± 1 standard deviation

4.2 APS Deposited Alloy 625

The global properties of thermally sprayed deposits generally are very different from those of fully dense materials. It is difficult to establish a relationship between microstructure and mechanical characteristics of a thermally plasma sprayed coating. There are huge differences between microstructure of the plasma sprayed coatings with lamellae type structures and conventionally processed materials with a dense and homogeneous microstructure. Microstructures of plasma-sprayed coatings are characterized by the existence of pores, splat boundaries, microcracks, unmolten particles, and unwanted phases (i.e., oxides). These features influence the mechanical properties of coatings. The stress-strain curve for the as-sprayed coating consists only of a linear region; fracture occurs without any significant plastic deformation, as shown in Fig. 7. The stress-strain curves of the heat-treated sample show some small plastic deformation at the end of the linear elastic region for the heat-treated sample after 5 h. The elastic modulus of the sprayed sample perpendicular to the spray direction (transverse elastic modulus) was computed through the ratio of the stress to strain in the linear elastic region of the stress-strain curves.



(a) (b)

Fig. 6 Ni alloy foam sample (a) before, and (b) after compression test

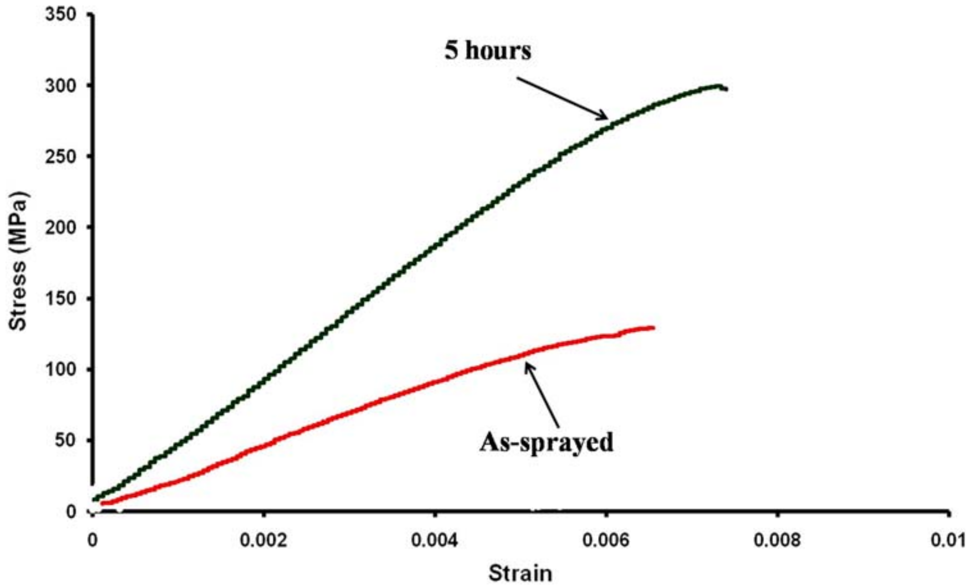


Fig. 7 Stress-strain curve of as-sprayed and heat-treated alloy 625 coating samples resulted from tensile test

Table 3 Mechanical properties of APS deposited alloy 625 resulted from tensile test

Alloy 625 samples	Yield strength, MPa	Elastic modulus, GPa
As-sprayed	140 ± 15	20 ± 1
Heat treated (5 h)	305 ± 10	44 ± 3

Average of 4 measurements ± 1 standard deviation

The results of the tensile testing experiments on the as-sprayed and the heat-treated alloy 625 are tabulated in Table 3. Tensile tests were performed on, at least, four specimens for each condition. The relatively large scatter in the measured values reflects the inhomogeneity in the microstructure typical of plasma-sprayed materials. The elastic modulus and yield strength of the conventionally processed alloy 625 are 205 GPa and 320 MPa, respectively (Ref 20). As shown in Table 3, the elastic modulus of the as-sprayed samples was as low as 10% of that reported for the conventionally processed alloy 625. The yield strength for the as-sprayed samples was approximately 25% less than that of the conventionally fabricated alloy 625.

Figure 8 shows a specimen of an as-sprayed alloy 625 tensile samples before and after testing. The test specimen did not exhibit any significant plastic strain before failure, showing typical brittle fracture features. Although the microstructural investigation on this coating indicated that it is quite dense (Ref 21), the bonding between splats in plasma sprayed coatings is typically weak and does not cover the entire contact area between the splats (Ref 22). Porosity, cracks, and weak bonding between splats contribute to displacements under applied stress, resulting in a lower apparent elastic modulus. A previous study has shown that the effective heat treatment can improve the tensile properties of the as-sprayed alloy 625 (Ref 23). Heat treatment of a coating may enhance cohesion between the individual lamella through diffusion bonding across the splat boundaries and elimination of fine porosity. A successful heat treatment operation can also reduce residual stresses due to the high cooling rate and impact energy of the droplets during the process. The results indicated a significant improvement in the

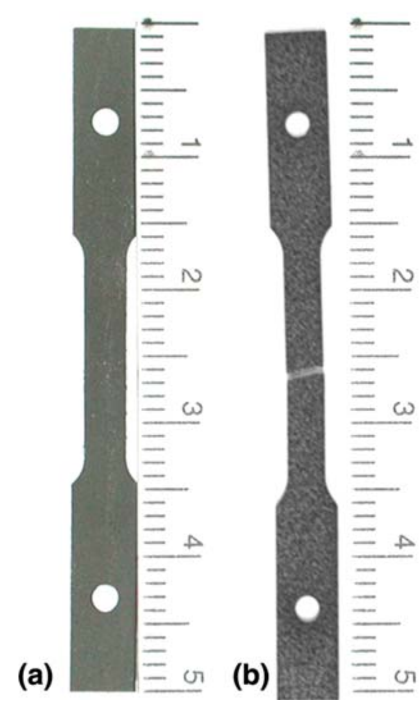


Fig. 8 As-sprayed alloy 625 tensile samples (a) before, and (b) after test

Table 4 Comparison of the calculated $EI_{(eq)}$ for the as-fabricated and heat-treated sandwich samples (5 h) with different skin thicknesses using Eq 1 and 2

	As-fabricated Skin thickness, mm		Heat treated Skin thickness, mm	
	0.1	**0.5**	**0.1**	**0.5**
$EI_{(eq)}$ (Nm^2) using Eq 1	1.71	10.10	3.40	20
$EI_{(eq)}$ (Nm^2) using Eq 2	1.68	8.80	3.35	17.50

mechanical properties of the as-sprayed coatings due to the post-deposition heat treatment. According to Table 3, the elastic modulus and yield strength of the as-sprayed samples were approximately doubled after heat treatment for 5 h.

4.3 Flexural Rigidity of Sandwich Structures

Table 4 lists the calculated $EI_{(eq)}$ for the as-fabricated and heat-treated sandwich samples with skin thickness of 0.5 and 0.1 mm using Eq 1 and 2. The elastic moduli of the sprayed alloy 625 and the Ni alloy foam used in both equations were obtained from tensile tests and compression tests on coating and foam samples, respectively.

The result indicated that the skin thickness has a remarkable influence on the mechanical performance of sandwich beams. The thicker skin results in larger value for the calculated flexural rigidity of the sandwich samples. It is also clear from the calculated results that the post-fabrication heat treatments, regardless of the skin thickness, have improved the mechanical performance of the as-fabricated sandwich structure. The flexural rigidity was significantly increased after the 5-h heat treatment. The results obtained from thin skin sample can be compared to the ones obtained from flexural loading test on the similar samples as reported previously (Ref 6). However, there is a huge discrepancy between the results for thick skin samples. Samples with skin thickness of 0.1 mm had $EI_{(eq)}$ of 1.2 ± 0.1 and 2.6 ± 0.3 Nm^2 for as-fabricated and heat-treated samples, respectively (Ref 6). Samples with skin thickness of 0.5 mm had $EI_{(eq)}$ of 4.5 ± 0.5 Nm^2 for as-fabricated and 5.6 ± 0.5 Nm^2 for heat-treated samples. It confirms the validity of the suggested analytical model to estimate the mechanical performance of thin skin sandwich structure based on the mechanical properties of the constituents.

5. Conclusion

Sandwich structures are of most interest for structural applications involving flexural loading, since their structure presents no distinct advantages in specific strength or specific stiffness for in-plane loading conditions. This study reports the results of an investigation on the mechanical properties of sandwich structures for high temperature applications fabricated by APS technique. The mechanical performance of sandwich structures was predicted from the mechanical properties of its constituents rather than performing flexural loading test on sandwich beams. The results of uniaxial tensile test on skin section (coating) and uniaxial compression test on the core section (foam) were useful to predict the flexural rigidity of sandwich beams. Tensile tests were performed on both the as-sprayed and the heat-treated coating samples. Compression test was performed on the as-received and the heat-treated foam samples. The results of the tensile tests and compression test helped us to predict the mechanical performance of the as-fabricated and heat-treated sandwich structures. The influence of the skin thickness on the mechanical performance of the sandwich beams was also studied. The following conclusions can be drawn.

- The average value for elastic modulus obtained from compression test on the as-received foam samples is 0.02 GPa. The yield stress obtained for the as-received sample is 0.912 MPa. The elastic modulus and yield stress of the as-received Ni alloy foam samples have slightly changed on heat treatment.
- The elastic modulus of the as-sprayed specimens parallel to the coating plane was found to be 90% lower than that for the conventionally processed structures. The elastic modulus of the heat-treated samples was improved significantly and doubled after heat treatment for 5 h.
- The flexural rigidity of the as-fabricated samples calculated as 1.71 and 10.10 Nm^2 for sandwich beams with skin thicknesses of 0.1 and 0.5 mm, respectively.
- Sandwich samples with a thicker skin have a higher flexural rigidity which indicates the effect of skin thickness.
- The predicted flexural rigidity of the as-fabricated samples was significantly increased after heat treatment regardless of skin thicknesses.
- The predicted rigidity for the sandwich structures with a 0.1-mm skin thickness was approximately 30% higher than the measured values; the discrepancy between the predicted and measured values was larger for the sandwich structures with a 0.5-mm skin thickness.

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