A Comparative Study of the Vibration Damping Capacity of Superalloys

J. Wang and D.D.L. Chung

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A comparative study of nickel-base, iron-base, and iron-nickel base superalloys showed Inconel MA754 (oxide dispersion strengthened) to be particularly high in vibration damping capacity.

Keywords damping, Haynes 242, Haynes 263, Inconel 909, Inconel MA754, Inconel MA956, iron, loss tangent, nickel, storage modulus, superalloy

1. Introduction

Superalloys are known for their high strength and modulus at high temperatures. However, little attention has been given to their vibration damping capacity (Ref 1), in spite of the importance of damping in essentially all structures. The vibration damping of a metal strongly depends on its microstructure, so the damping capacities of different superalloys are expected to differ. This article provides a comparative study of the vibration damping capacity of superalloys, including nickel-base, iron-base, and iron-nickel base superalloys. The damping capacity is expressed by the loss tangent, whereas the stiffness is expressed by the storage modulus. High values of both loss tangent and storage modulus are desired for vibration reduction. Therefore, both quantities were measured in this study for each superalloy.

2. Experimental Methods

The materials studied were nickel-base superalloys (Haynes 242, Haynes 263, Haynes International, Kokomo, IN; and Inconel MA754, Inco Alloys International, Huntington WV); iron-base superalloys (Incoloy MA956 and iron-nickel base superalloys (Incoloy 909 and Inconel 718; Inco Alloys, International, Huntington, WV). Haynes 242, Haynes 263, Incoloy 909, and Inconel 718 are precipitation hardenable alloys. Incoloy MA956 and Inconel MA754 are oxide dispersion strengthened alloys; MA stands for mechanical alloying. Table 1 shows the composition of each alloy. The precipitation hardenable alloys were cold rolled and annealed, but were not precipitation hardened, except for Haynes 263, which was studied both before and after precipitation hardening. The aging treatment of Haynes 263 was carried out in air at 800 °C for 8 h, followed by air cooling.

Metallography was performed by mechanical polishing, followed by chemical etching using a solution consisting of 50 mL methanol, 50 mL hydrochloric acid, and 2.5 g cupric chloride.

Dynamic mechanical testing was performed using a Perkin-Elmer Corp. (Norwalk, Connecticut) DMA7e instrument under dynamic flexure by three-point bending at a frequency of 0.2 Hz, with a displacement in the range of 5 to 9 μm and a temperature of 475 °C. The span in three-point bending was 20 mm. The sample length (in the span direction) was in the range of 20 to 25 mm. The sample width was 6 mm or less, and the sample thickness was in the range of 0.5 to 1.2 mm. The loss tangent, tan δ, and storage modulus were measured simultaneously.

3. Results and Discussion

Table 2 shows the loss tangent and storage modulus of the superalloys. The highest value of the loss tangent was exhibited by Inconel MA754. The second highest value of the loss tangent was exhibited by Haynes 263. Heat treatment of Haynes 263 had little effect on the loss tangent, but increased the storage modulus.

As high values of both loss tangent and storage modulus are desired for vibration reduction, the product of these two quantities is a figure of merit, which is known as the loss modulus. Table 2 shows that the highest value of the loss modulus was exhibited by Haynes 263 after heat treatment, mainly due to the high value of the storage modulus of this alloy. The second highest value of the loss modulus was exhibited by Inconel MA754, mainly due to the high value of the loss tangent of this alloy.

Figure 1 shows an optical micrograph of Inconel MA754. The bright regions in the micrograph are titanium carbonitrides, whereas the fine dark particles are probably yttria, which is the dispersed oxide phase that strengthens the alloy. The microstructure is fine.

Figure 2 shows an optical micrograph of Haynes 263 (heat treated). The fine dark particles in the micrograph are precipitates, which provide the strengthening. The precipitate phases can be carbides, γ', γ'', δ, and η. The microstructure is coarse compared to Fig. 1.

Three of the six superalloys studied were nickel-base. Two of the superalloys (Haynes 242 and Haynes 263) were precipitation hardenable. Inconel MA754 was oxide dispersion strengthened. The results in Table 2 suggest that, at least for nickel-base alloys, oxide dispersion strengthened alloys are superior in damping to precipitation hardened alloys. This is at-

J. Wang and **D.D.L. Chung,** Composite Materials Research Laboratory, State University of New York at Buffalo, Buffalo, NY 14260-4400.

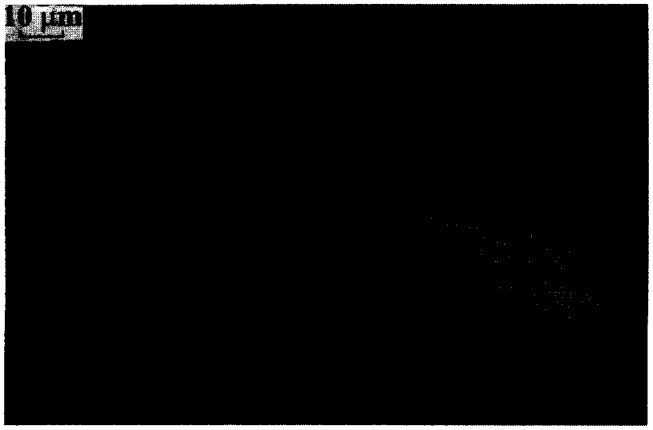

Fig. 1 Optical micrograph of Inconel MA754

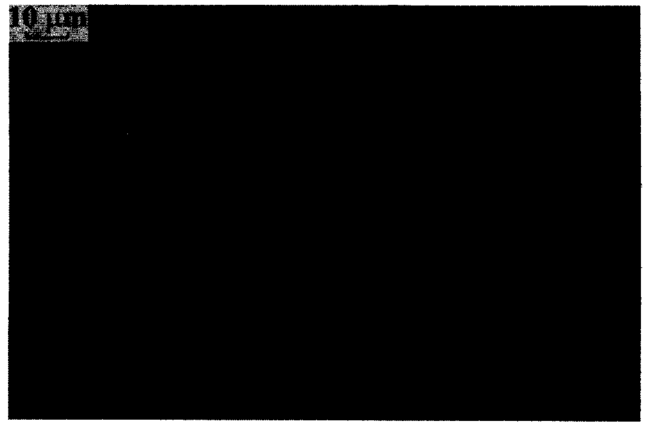

Fig. 2 Optical micrograph of Haynes 263 (heat treated)

Table 1 Composition of superalloys

	Composition, wt%													
Alloy type	**Ni**	**Fe**	**Mo**	**Cr**	**Co**	**Mn**	**Si**	**Al**	**Ti**	**Nb**	**C**	**B**	**Cu**	**Y_2O_3**
Haynes 242	62.5	2.0	25.0	8.0	2.5	0.8	0.8	0.5	...	...	0.03	0.006	0.5	...
Haynes 263	52.0	0.7	6.0	20.0	...	0.6	0.4	0.6	2.4	...	0.06	...	0.2	...
Incoloy 909	38.0	42.0	...	...	13.0	...	0.4	0.03	1.5	4.7	0.01	...	...	...
Inconel 718	52.5	18.5	3.0	19.0	...	...	...	0.5	0.9	5.1	...	...	0.15	...
Incoloy MA956	...	74.5	...	20.0	...	...	...	4.5	0.5	...	...	...	...	0.5
Inconel MA754	78.5	...	...	20.0	...	...	...	0.3	0.5	...	...	...	...	0.6

Table 2 Loss tangent, storage modulus, and loss modulus of superalloys at 475 °C

Alloy	Tan δ, 10^{-2}	Storage modulus, 10^{11} Pa	Loss modulus, 10^{9} Pa
Haynes 242	0.56	1.20	0.67
Haynes 263	0.61	1.55	0.95
Haynes 263(a)	0.58	2.25	1.31
Incoloy 909	0.06	1.21	0.07
Inconel 718	0.51	1.66	0.85
Incoloy MA956	0.17	0.50	0.09
Inconel MA754	1.09	1.03	1.12

(a) Heat treated

tributed to the finer microstructure in the oxide dispersion strengthened alloy (Fig. 1) compared to the precipitation hardened alloy (Fig. 2).

Comparison of the loss tangent of Incoloy MA956 and Inconel MA754 (both oxide dispersion strengthened) suggests that nickel-base superalloys are superior to iron-base superalloys in vibration damping, at least among oxide dispersion strengthened superalloys.

That precipitation hardening of Haynes 263 did not affect the damping capacity means that slippage at the interface between precipitate and matrix did not contribute to damping. Nevertheless, the precipitates increased the storage modulus.

4. Conclusions

A comparative study of various nickel-base, iron-base, and iron-nickel base superalloys showed Inconel MA754 to be particularly high in the vibration damping capacity due to its fine microstructure. The study also showed Haynes 263 (precipitation hardened) to be particularly high in the storage modulus due to its precipitates.

Reference

1. W. Hermann and H. Sockel, *ASTM Special Technical Publication 1304*, 1997, p 143