Acoustic loss at substantial ultrasonic strain in 6Al-6V-2Sn and sintered 6Al-4V titanium

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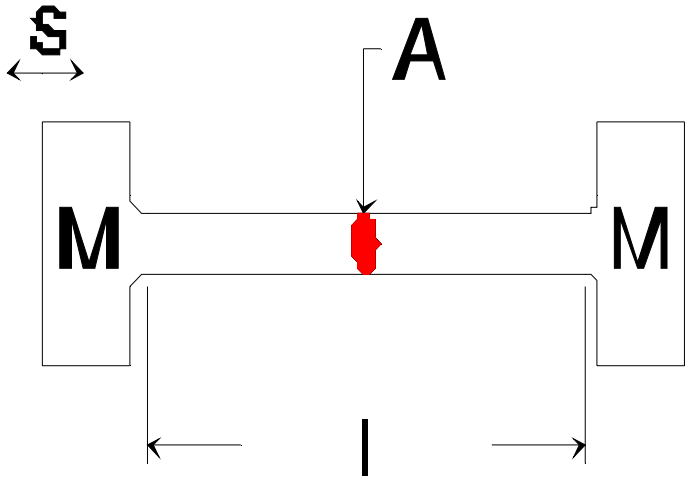
Mason Mass-Spring-Mass (MSM) Resonator

- Stress confined to spindle portion and substantially uniform throughout
- Abrupt transition in cross sectional area permits generation of substantial stress from modest input excursions



Approximate frequency, stress and energy relations

$$f = \frac{\sqrt{\frac{EA}{l\left(\frac{M}{2}\right)}}}{2\pi} \qquad \sigma = \frac{s}{l}E \qquad E_s = \frac{\sigma^2 V}{2E}$$

Heat and thermal relations

$$\frac{dQ}{dt} = \frac{dQ_m}{dt} - \frac{dQ_l}{dt}$$

$$T = \frac{(T_b - T_a)}{(t_b - t_{a)}} t$$

$$\frac{dQ_l}{dt} = KT$$

$$Q_m = \left[\rho CV + \frac{K(t_b + t_a)}{2} \right] (T_b - T_a)$$

$$K = \frac{\rho CV}{t_d} \ln\left(\frac{T_1}{T_2} \right)$$

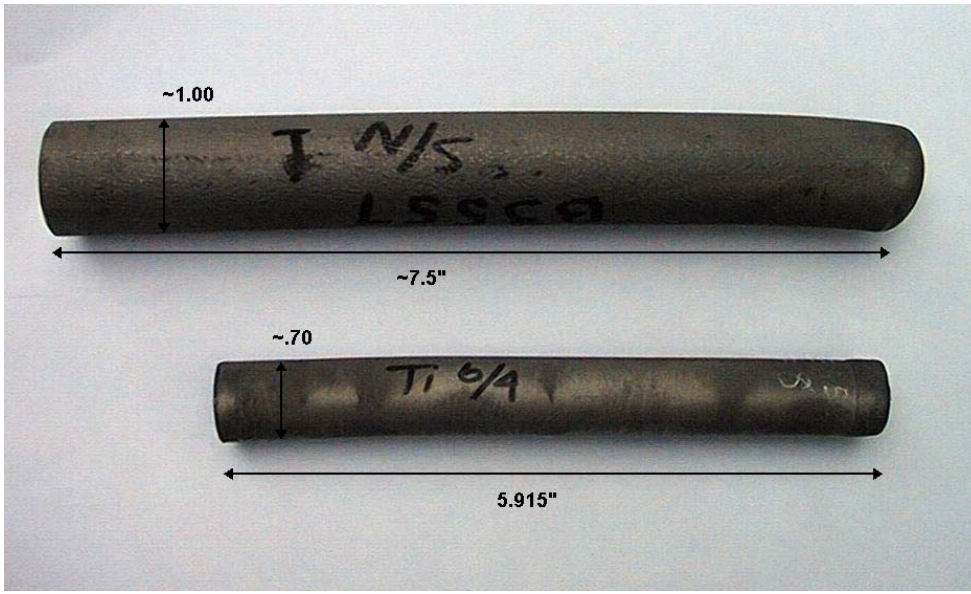
$$E_l = \frac{Q_m}{f(t_b - t_a)}$$

$$Q_m = \rho CV(T_b - T_a) + K\int_{t_a}^{t_b} T dt$$

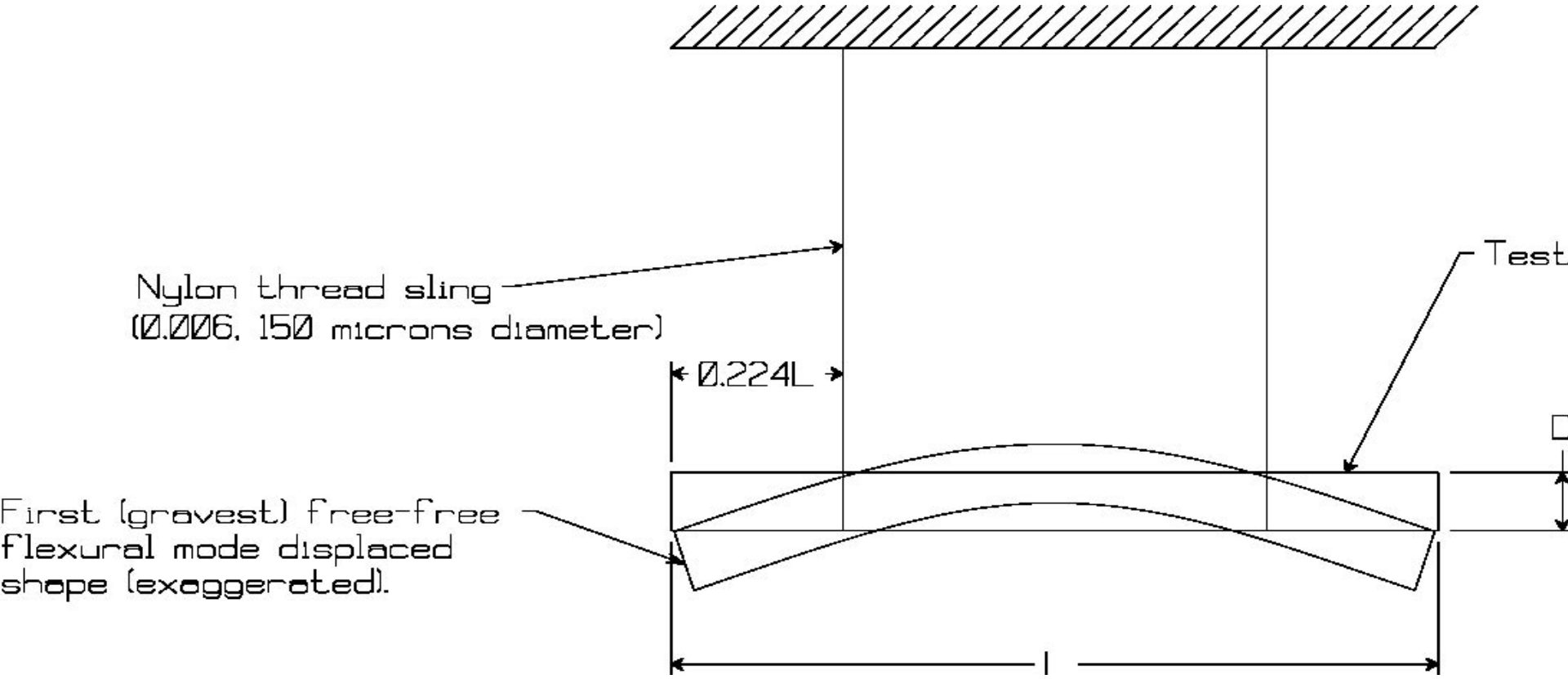
$$Q = \frac{\pi\sigma^2 Vf(t_b - t_a)}{E\left[\rho CV + K\frac{(t_a + t_b}{2} \right](T_b - T_a)}$$

Sintered 6Al-4V samples as received

- 1. Upper: 10% titanium carbide added to improve machinability
- 2. Lower: 6Al-4V



Measurement of modulus by chiming



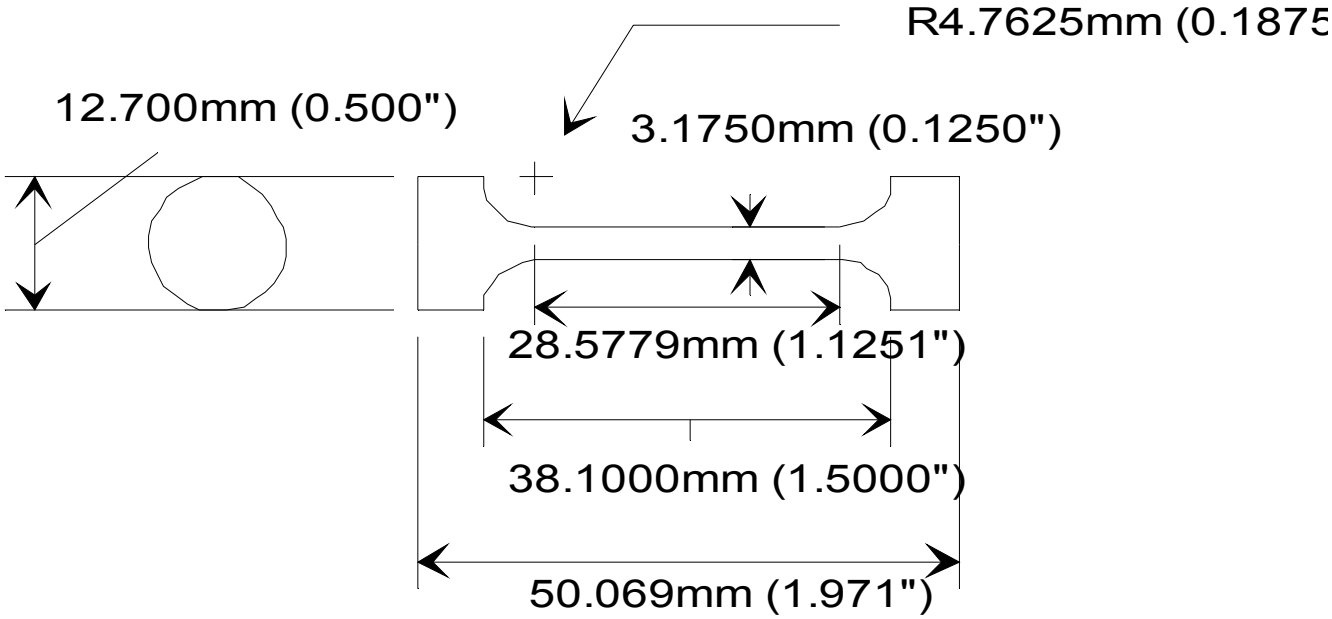
$$c = \frac{32 l^2 f}{\pi D (3.0112)^2}$$

$$E = \rho c^2$$

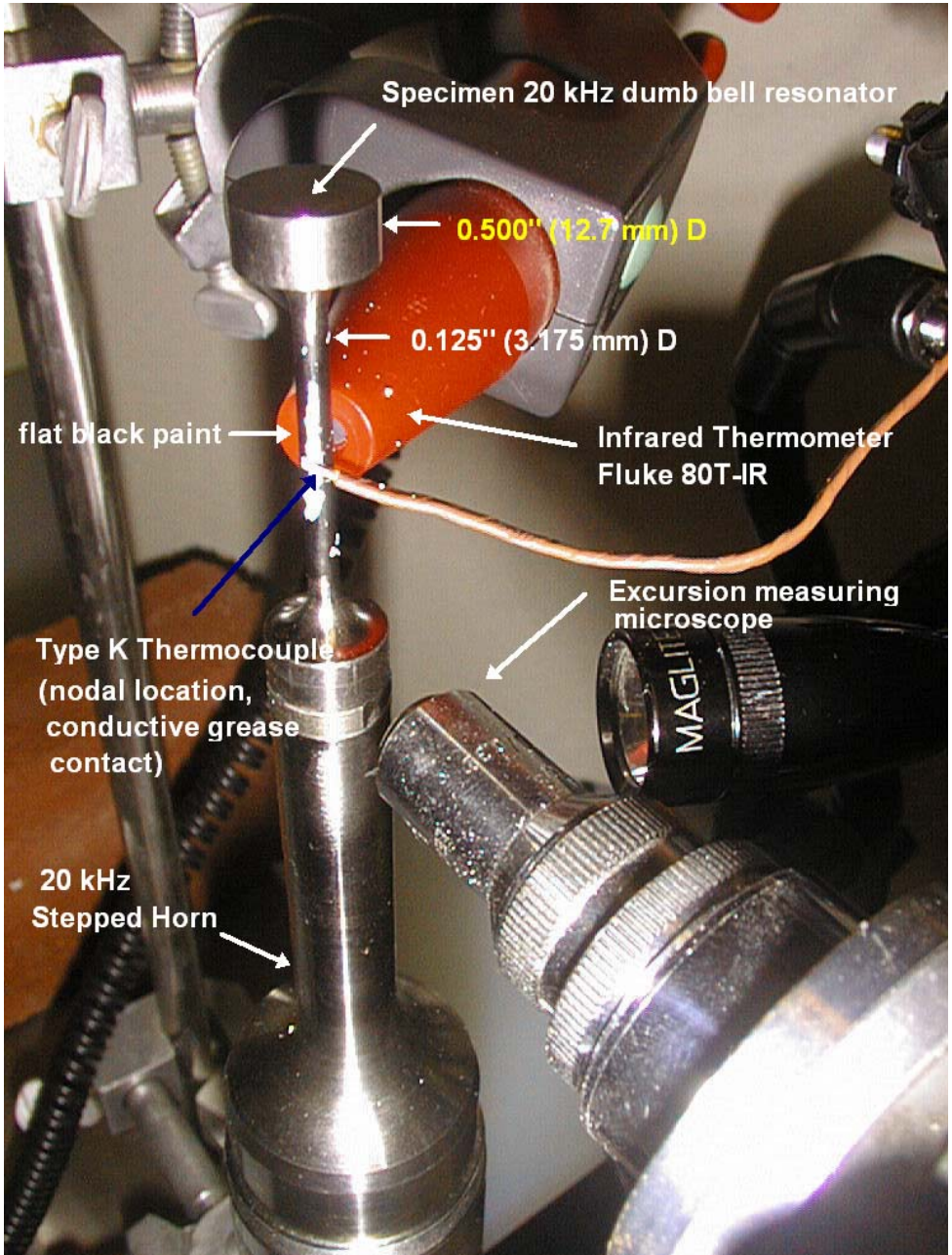
Density and elastic modulus of sintered samples

Sample	Density, Kg/m^3 ($lbsf/in^3$)	Modulus, GPa (Mpsi)
1 (10 percent TiC)	4400 (0.16)	117 (17)
2 (6-4)	4400 (0.16)	122 (18)

20 kHz MSM test resonator



Test apparatus arrangement

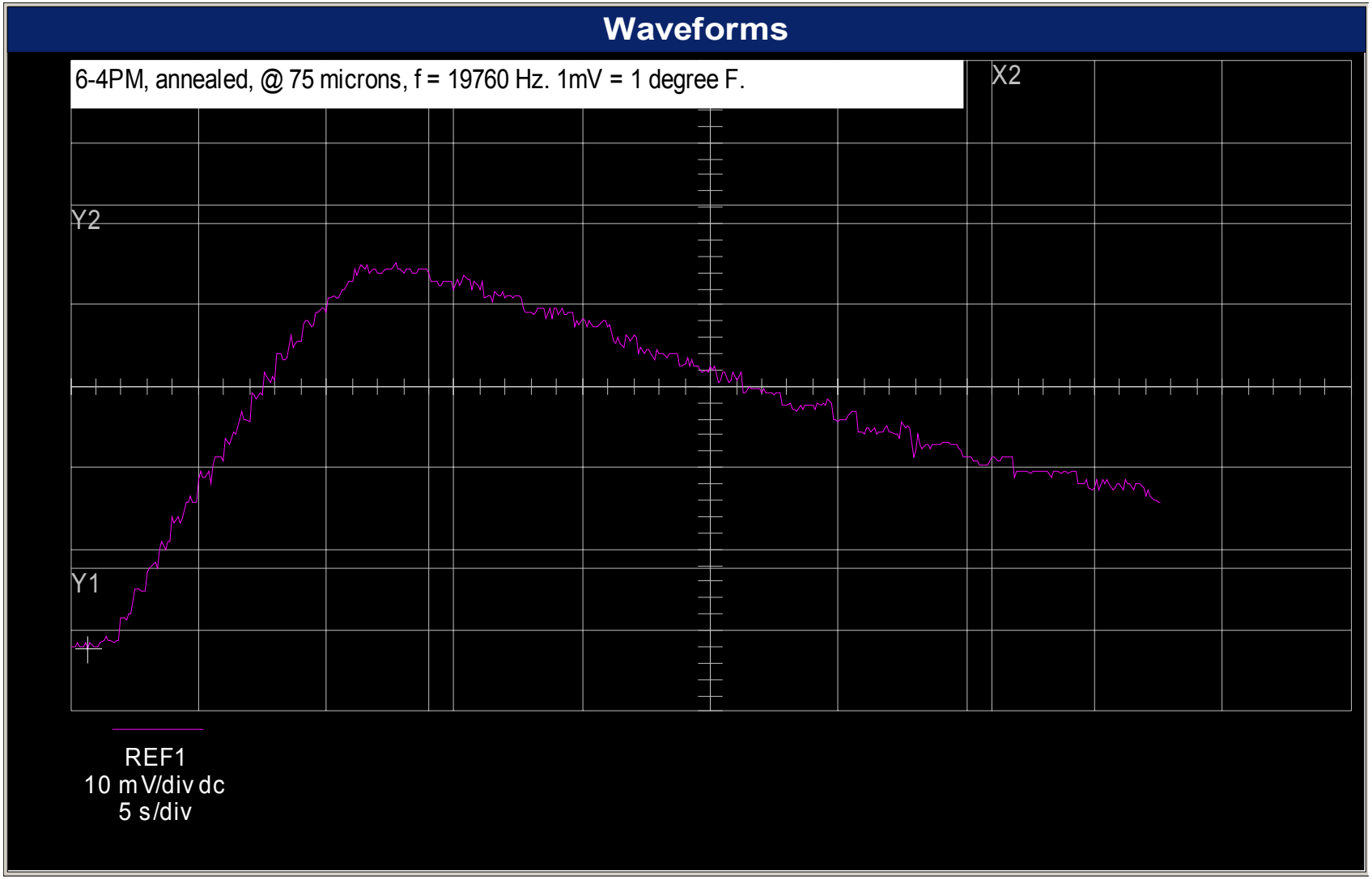


Typical thermal measurement data

Specimen	s, microns (.001in)	Duration, s	dT_{av} ,^{o}C (^{o}F)	Computed stress[1], MPa (kpsi)	Strain %	Comment
	64 (2.5)	10	8.33 (15.0)	260 (37)	0.21	
	76 (3.0)	10	11.9 (21.5)	310 (44)	0.24	

Computation is within ten percent of these values obtained by both finite element modal analysis and oundary value solution of the wave equation applied to a step-wise model of the geometry. Computation f Q using the simplified analysis is within fifteen percent of values tabulated.

Spindle temperature variation with time



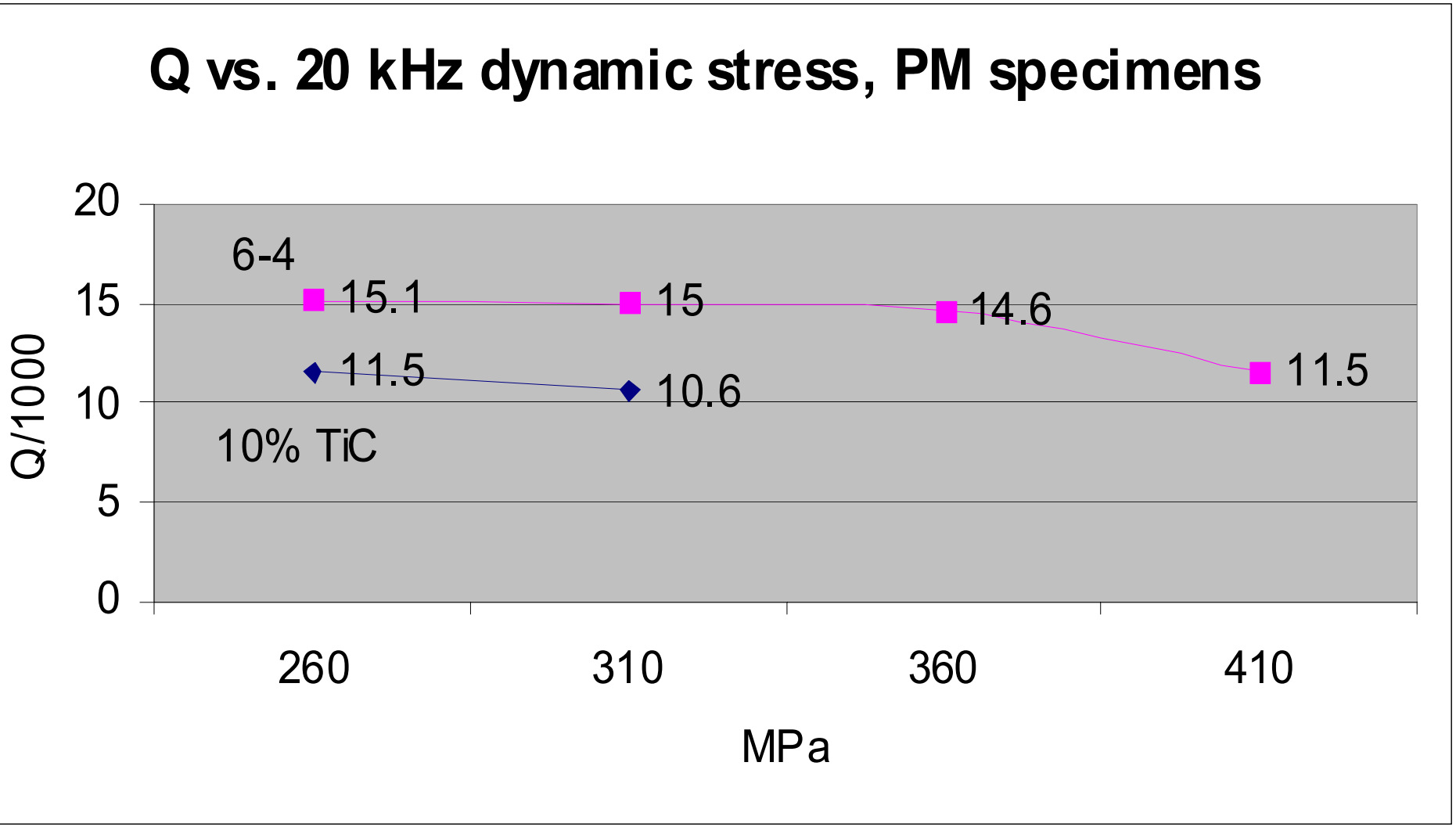
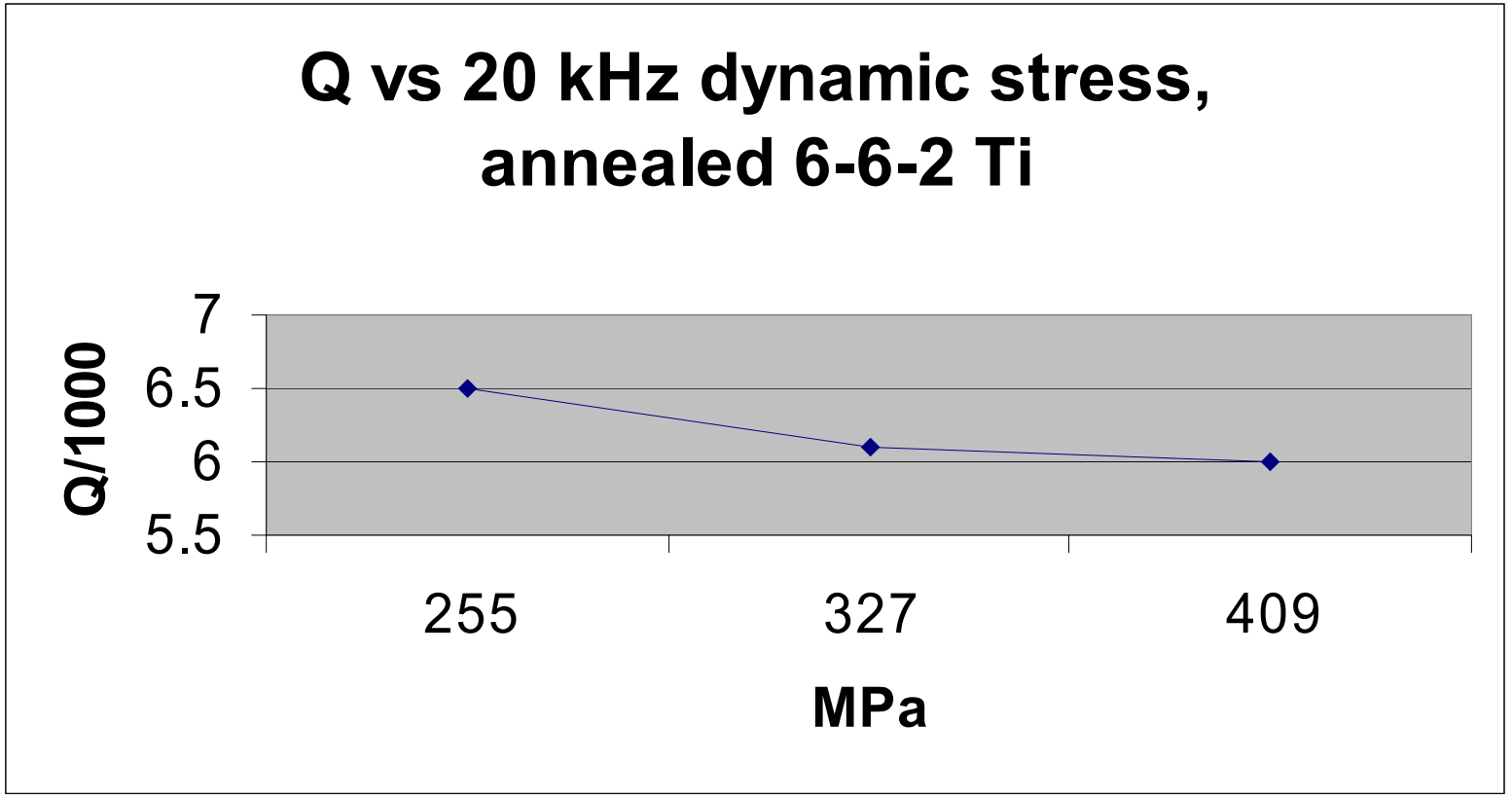

Q vs. 20 kHz dynamic stress, PM specimens
Q/1000
20
15
10
5
0
6-4
15.1
15
14.6
11.5
11.5
10.6
10% TiC
260
310
360
410
MPa

Table 3
Density and Elastic moduli for 6Al-6V-2Sn sample

Density, Kg/m^3 ($lbsf/in^3$)	Modulus, GPa (Mpsi)
4510 (0.163)	99.3 (14.4)



Endurance Test 6-6-2 alloy

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