Load Unit Deflection Correction for Forced Vibration Test System

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ABSTRACT

A correction for the errors due to load unit deflection is presented and examples are given that show the effectiveness of the correction on typical data. Displacement errors are typically induced through deflections of the load cell, extension rods, and fixtures, with the load frame contributing a very small effect. With this correction, forced vibration test systems can be used over a wide range of frequencies, amplitudes and temperatures to give accurate material dynamic characterization data for specimens in shear, compression, tension, or bending with minimal changes in specimen geometry or fixtures. Work so far has been conducted on metallic samples. Work remaining includes collection of data on samples to be included in the Damping Technology round robin.

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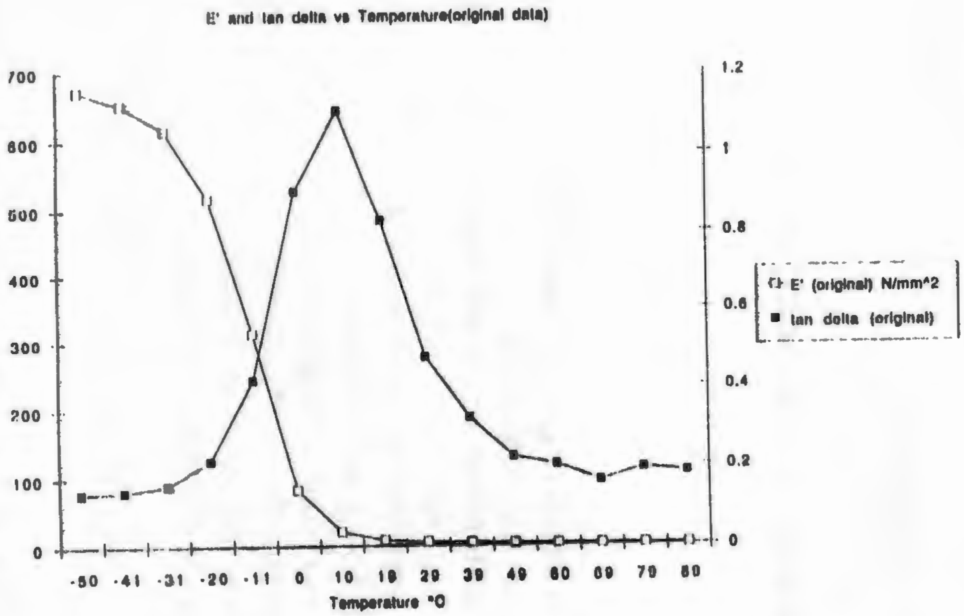

This is the original data submitted to the round robin. The specimen was a 25 mm diameter by 12.5 mm high compression button. Test conditions were 10 hz constant frequency with an expected 2% prestrain and a dynamic strain of 0.1%. One sample and one set of transducers was used to collect all the data. System full scales are ±10,000 N and ±25 mm. Data "looks good", but modulus at cold temperature was reported to be low.

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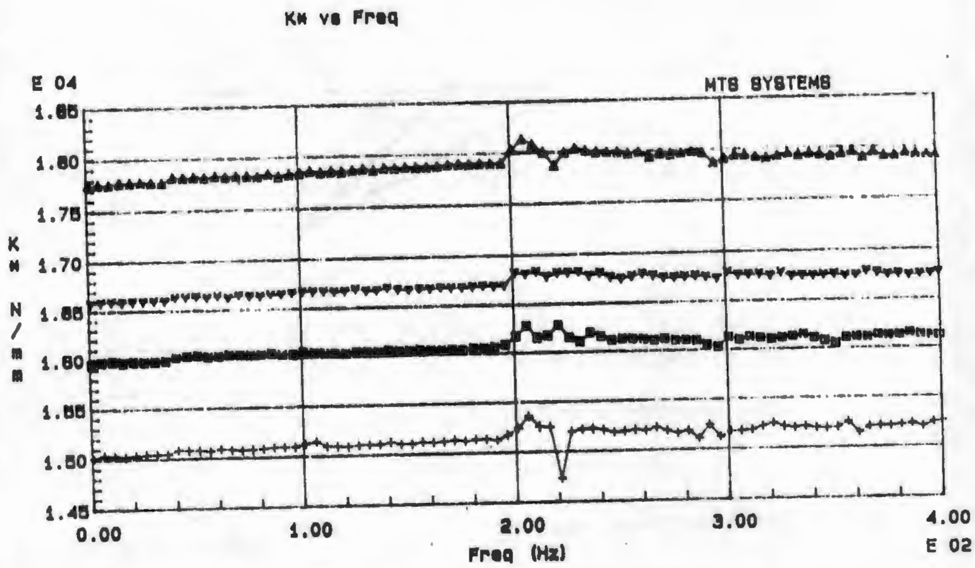

	Test	Proc	Mean (N)	Amp (mm)
▲	SHRT01	STUBE1	-1400	.08
▼	SRT31	STUBE1	-1400	.08
□	SRT51	STUBE1	-1400	.08
+	SRT81	STUBE1	-1400	.08

This is an example of data taken on a metallic spring with different lenth extension rods added to the loading path. It shows very clearly the errors due to ignoring the load unit deflections.

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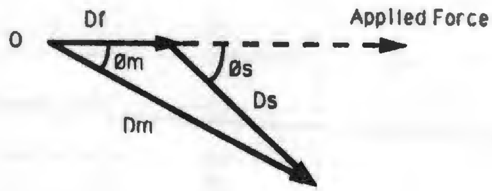
LOAD UNIT DEFLECTION CORRECTION



Df - frame deflection

Dm - measured deflection

Ds - actual specimen deflection

Øm - measured phase angle

Øs - actual specimen phase angle

DISPLACEMENT CORRECTION

$$Ds = \sqrt{Dm^2 + Df^2 - 2DmDf\cos Øm}$$

PHASE ANGLE CORRECTION

$$Øs = \tan^{-1}\left(\frac{\sin Øm}{\cos Øm - Df/Dm}\right)$$

This is the mathematical formula for the load unit deflection correction as we have implemented it on our systems for dynamic mechanical analysis. It was provided to MTS by one of our customers and agrees well with theoretical and experimental results.

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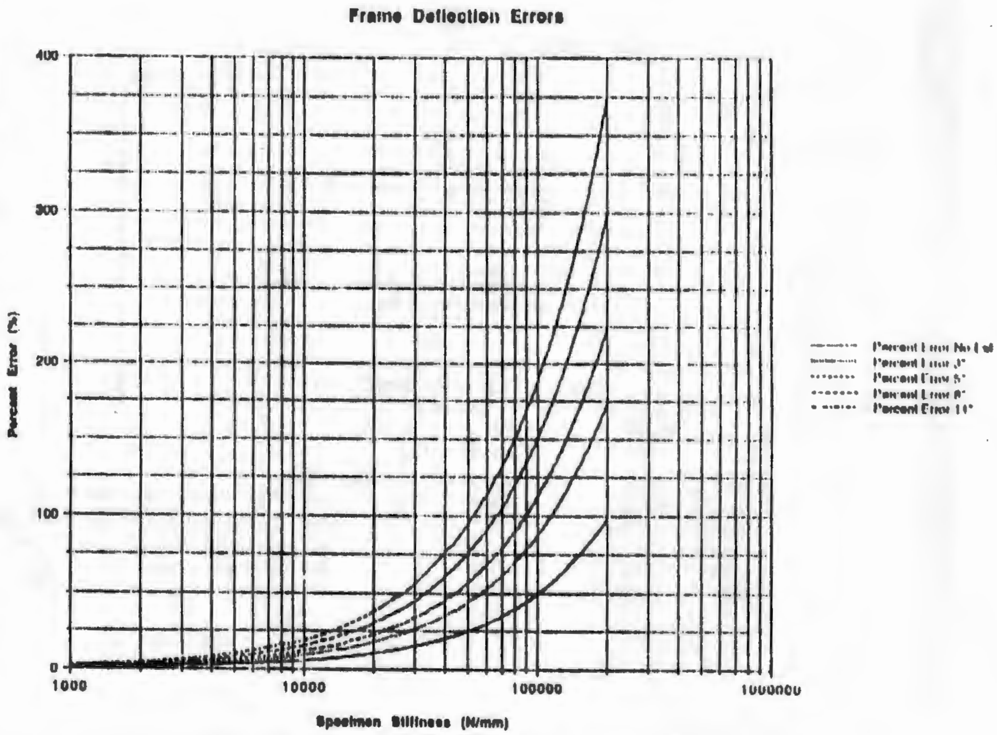

This graph gives typical errors for a forced vibration test system. We have used hollow extension rods to minimize moving mass errors and allow dynamic property measurements at frequencies up to 1000 hz. The error with no extension is due to load cell deflections. A combination of strain gaged load cell and piezoelectric device is used to measure long term mean levels and high resolution dynamic amplitudes.

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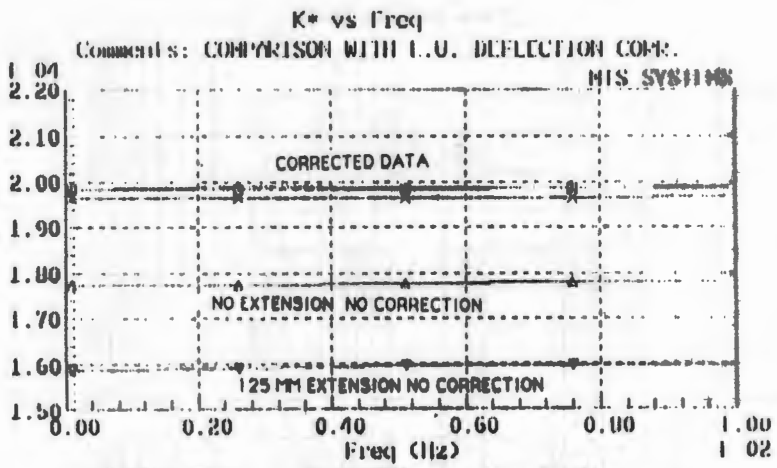

	Test	Proc	Mean (N)	Amp (mm)	
^	SHRT02	STUBE	-1400	.06	NO EXTENSION NO CORRECTION
v	SR152	STUBE	-1400	.06	125 MM EXTENSION NO CORRECTION
⊔	STTFT1	TUBE	-1400	.06	NO EXTENSION WITH CORRECTION
+	STTFT1	TUBE	-1400	.06	75 MM EXTENSION WITH CORRECTION
×	STTFTK	TUBE	-1400	.06	125 MM EXTENSION WITH CORRECTION

This graph compares the data collected on a metallic spring with no correction and with the proposed correction. This shows a dramatic improvement from 20% error to less than 1%. The system LVDT is used to measure the errors and the specimen deflections

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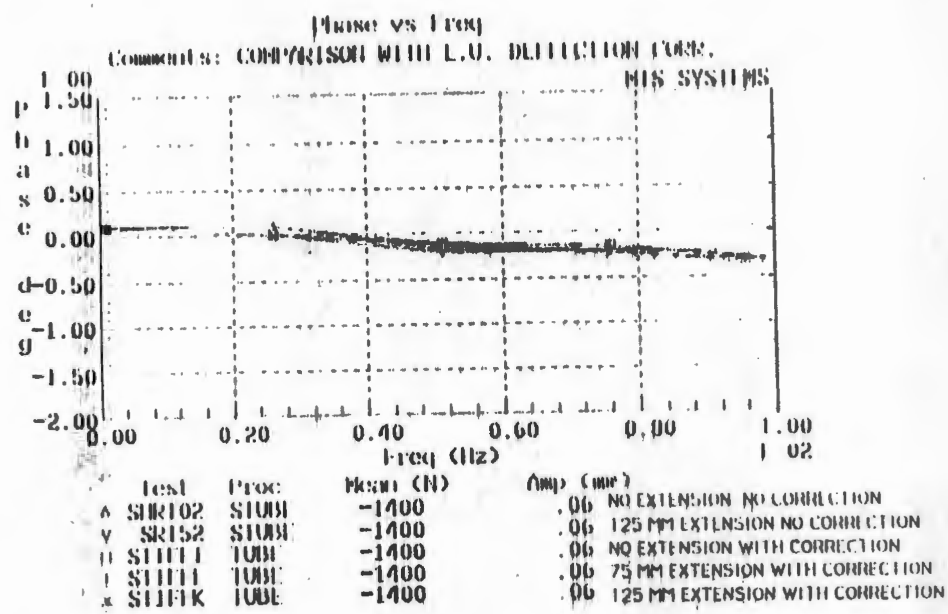

This graph compares the data collected on a metallic spring with no correction and with the proposed correction. This shows no effect on phase angle measurements. There was some concern that the correction would increase the scatter in the phase angle since there is division by numbers close to zero and multiplication of numbers close to zero.

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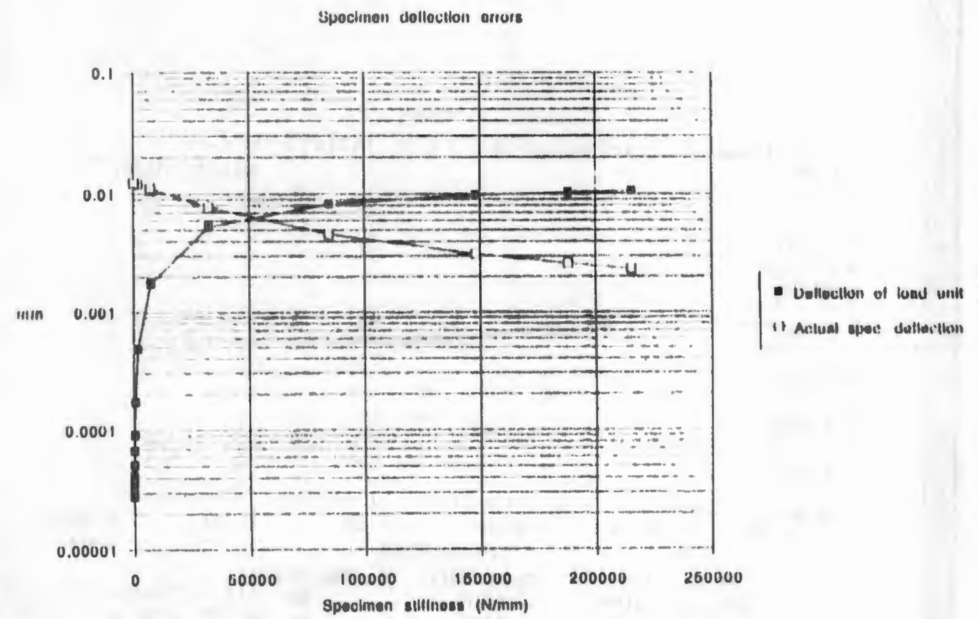

This graph shows the tradeoff between specimen deflections and load unit deflections for the test setup we have used for temperature property measurement. If the accuracy of the load unit deflection correction is questioned, solid extension rods can be used as long as test frequencies are low.

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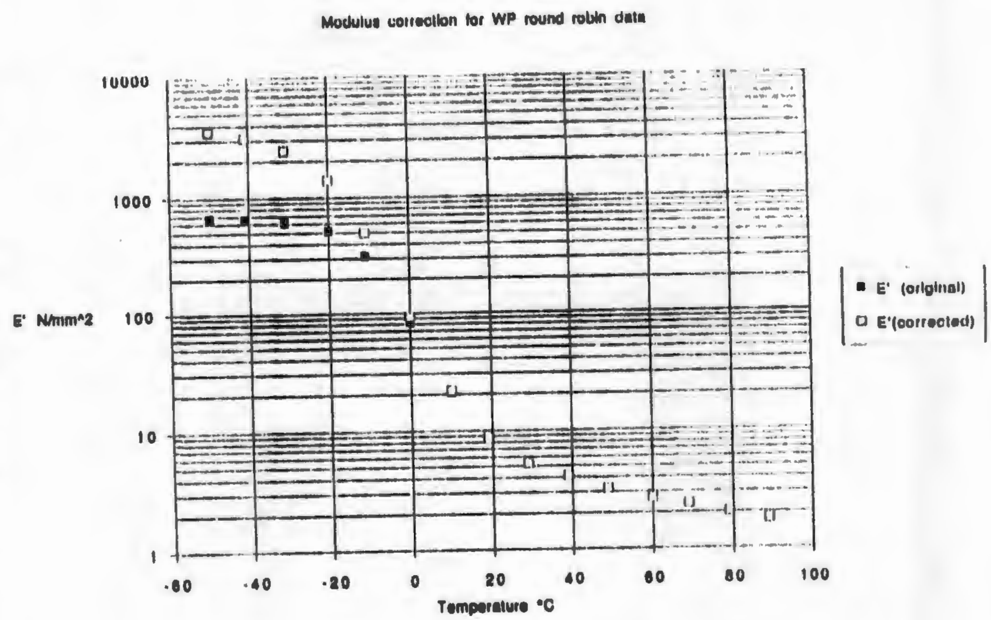

This graph compares the data before and after the correction has been applied. The correction is made to existing data so actual specimen dynamic strains were lower than expected. Original measured maximum modulus was 700 N/mm^2, corrected modulus is 3600 N/mm^2 in compression compared to a reported 4200 N/mm^2 in tension. The reduction in modulus could be due to the manner of loading or the low strain amplitudes. Further work will be done to collect extensional modulus data with full strain amplitudes.

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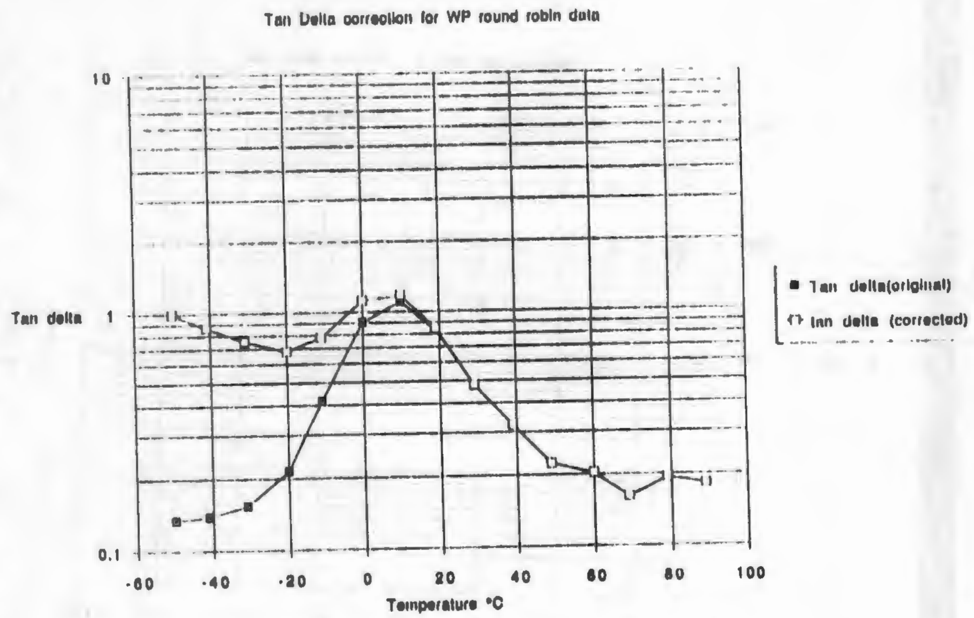

This graph compares the data before and after the correction has been applied. The correction is made to existing data so actual specimen dynamic strains were lower than expected. This may explain the strange tan delta behavior at low temperatures. Additional work will be done to verify the low temperature tan delta measurements on the round robin material.

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