VIBRATION DAMPING PERFORMANCE - WHAT WE SHOULD KNOW ABOUT IT

By:

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ABSTRACT

The vibration damping performance of materials that are used in the automotive industry, are usually evaluated by either: (1) Geiger Thick-Plate Test Method, or (2) Complex Modulus Test Method. Both of these methods have certain limitations, though the second method is a superior one since it can measure the damping performance with temperature and frequency. This paper discusses the limitations of the way data is typically presented using this method and proposes a procedure for overcoming these limitations. This procedure allows for the rank-ordering of damping materials by composite damping properties obtained using different size Oberst bars.

Introduction

The interior noise in a car has been of a concern for quite a while. In recent years it has become more important due to the high demand of customer satisfaction. The trend now is to have a better fuel economy car with lighter body panels (less total weight of the car), and still have very powerful engines. In this respect, the interior noise concern is becoming very important. Also with unitized body constructions, the structure-borne noise due to vibration of the floor pan and other interior body panels is becoming increasingly important. One way to reduce this noise is to treat vibrating panels with damping materials. These materialss will reduce the vibration of the panels and therefore reduce the structure-borne noise inside the car. This paper discusses two different test methods that are currently used in the automotive industry to evaluate the vibration damping performance of various materials. These are: Geiger thick-plate test method and complex modulus test method. The paper discusses the advantages and limitations of both test methods. Finally, a technique to rank order the performance of various damping materials, based on composite damping properties obtained by the complex modulus method, is presented here.

Geiger Thick-Plate Test Method

The damping performance using this test method is expressed in terms of decay rate. The decay rate is a measure of dissipation of the vibrational energy of the damping material. The set-up consists of a 6 mm (1/4 inch) thick and 500 mm by 500 mm (20 inch by 20 inch) steel plate which is supported at 4 points along the plate's nodal line. It is supported by isolation mounts to minimize losses. The plate is excited in its fundamental frequency mode (typically between 130 and 160 Hz) by an electromagnet at the center of the plate. The vibration is detected by either an electromagnetic transducer, a small accelerometer, or even a microphone placed near the plate to measure the sound pressure caused by the plate. The damping performance is determined by measuring the vibrational decay after the test plate is excited and the excitation then suddenly removed. The results of the measurements are normalized to a frequency of 160 Hz. This method can be used for evaluating materials at several temperatures.

The advantages to the Geiger thick-plate test method are:

- o Measurements are made at several temperatures.
- o Provides data relatively quickly for rank ordering materials.
- o Easy to interpret data (units of dB/sec).

The disadvantages to this method are:

- o Provides data at only one frequency.
- o Does not provide a material property.
- o Though the thick plate dimensions can be varied, the thickness is usually much greater than the thickness of automobile panels.

Complex Modulus Test Method

This method is sometimes called the Oberst Bar Method after H. Oberst. The set-up consists of a thin metal bar to which the damping material is bonded. This forms a composite bar which is also the test sample. The bar is clamped at one end and free on the other end. The bar, using an electromagnetic transducer, is excited with a random noise or a sweep-sine wave to determine the resonant peak frequencies of the various modes of vibration. The response of the bar is sensed by a pick-up transducer which can be an electromagnetic transducer, a strain gauge or a small accelerometer. The frequency response consists of several resonances which are characteristic of the bar configuration. The half-power band width (frequency difference between 3 dB down points from the resonant peak) of each mode in the response spectrum is read (Figure 1). The damping performance is expressed in terms of the composite loss factor (η_c). The term, η_c, is computed from the measured data. The composite loss factor at each resonant frequency is the ratio of the half-power band width (Δf) over the resonant frequency (f) i.e., $\eta_c = {}^{\Delta f}/_{f}$. With additional information from testing the bare bar alone, the damping properties of the damping material can also be computed.

The advantages of the complex modulus test method are:

- o Measurements are made at several different frequency modes and temperatures.
- o Can compute material loss factor if bare bar is tested, in addition to testing the composite bar. The material loss factor allows one to predict the performance of the material in an application.
- o Rank order materials using composite loss factor if tests are done with the same bare bar material type, size, and test configuration (free-layer, constrained layer, etc.).

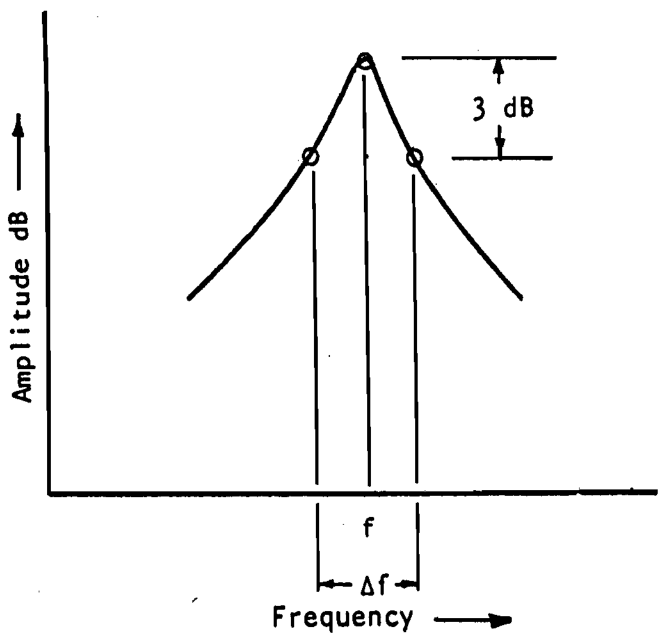

Figure 1 Variables Used to Determine Loss Factor of the Test Sample

The disadvantages to this test method are:

- Calculation for material damping properties can be laborious without a computer.

- To get meaningful results of material damping properties at a wide range of temperatures, more than one test configuration (free layer, constrained layer, etc.) may be needed.

Comparison of Composite Data

If a given number of damping materials were tested according to the complex modulus test method, the performance of these materials can be rank-ordered based on the composite loss factor. Time and effort to test the bare bar and subsequently to compute the material damping properties would not be necessary.

The use of rank-ordering materials by composite loss factor, however, has its limitations. The problem arises when trying to compare damping materials which were tested with different bar dimensions or configurations. To overcome this problem, the first step would be to compare damping materials by the material damping values.

The material damping properties can be estimated from composite damping values if an assumption can be made. The assumption is that the modulus of the bare bar is relatively constant over the temperature range and frequency range of the damping test. By estimating a constant value for the modulus of the bare bar (for example, the modulus of steel equals 20×10^{10} Pa (29×10^{6} psi)), the resonant frequencies of the bare bar can be calculated and hence, the damping material properties. The estimate can be improved if data is available on the change of the modulus of the bare bar with temperature and frequency.

Once the material properties are computed for each damping material for a comparison, there still exists the problem of discrete values at different frequencies and perhaps different temperatures. This can, however, be overcome with the use of the reduced-frequency nomogram technique[1]. It should be noted that the purpose of this paper is not to show how the reduced frequency technique works but to use reduced frequency technique to rank-order damping performance without conducting extensive tests. However, a brief description of the development of a reduced frequency nomogram from discrete material property values follows below.

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[1] Jones, D. I. G., *A Reduced-Temperature Nomogram for Characterization of Damping Material Behavior*, The Shock and Vibration Bulletin, Bulletin 48, Part 2, pp 13-22, (September 1978).

When the modulus of a material versus frequency is plotted for given temperatures, what results is a series of curves as shown in Figure 2. If each of these curves is shifted horizontally by a given factor, what then results is a single continuous curve of modulus versus frequency made up from the data of different temperatures. The same can be done for material loss factor versus frequency data of different temperatures. The curves obtained by this procedure are shown in Figure 3. The curves are calculated by a curve fitting technique. This allows for the interpolation of material damping properties between the discrete measured values at temperatures and frequencies within the range of the test. The frequency axis is on the right-hand-side and the temperature lines run diagonally. To obtain the loss factor for a given frequency and temperature, (e.g.: frequency 10 Hz and temperature T_o in Figure 4), simply mark horizontally from the frequency scale and diagonally along the temperature line to the point of intersection. Then mark vertically to the loss factor curve and read the values from the left-hand-side scale. The same can be done for obtaining values of modulus at a given frequency and temperature from the modulus curve of the nomogram.

To test the procedure of comparing composite damping properties for rank-ordering materials tested with different bar sizes, two different complex modulus tests were done. Rather than verifying the procedure by rank-ordering two or more materials, it would be more appropriate to see if a material would rank the same with itself when tested with two different bar sizes. For this case, the same damping material was tested by the complex modulus test method configured for free layer damping on one side of a thin steel bar and on one side of a thick steel bar. The damping material was a homogeneous material.

Having obtained the composite damping data, the modulus of steel was estimated to be 20×10^{10} Pa (29×10^{6} psi) and the material damping properties were computed. The computed material damping properties obtained with the thin steel bar were then compared with those of the thick steel bar. This was done by first preparing a reduced frequency nomogram for the material damping properties obtained by the use of the thin steel bar (Figure 5). The curves from this nomogram were then overlaid on the material damping property values of obtained using the thick steel bar (Figure 6). As can be seen, the curves fit the second set of data reasonably well. This proves that the damping material rank-ordered the same with itself for both bar sizes when the composite damping data only was provided.

Concluding Remarks

This paper discusses the advantages and limitations of two different vibration damping test methods that are used in the automotive industry, namely Geiger thick-plate test method and complex modulus test method. A technique, based on the results of the complex modulus tests method, has been discussed here to rank-order damping performance based on composite loss factor data obtained by different size Oberst bars.

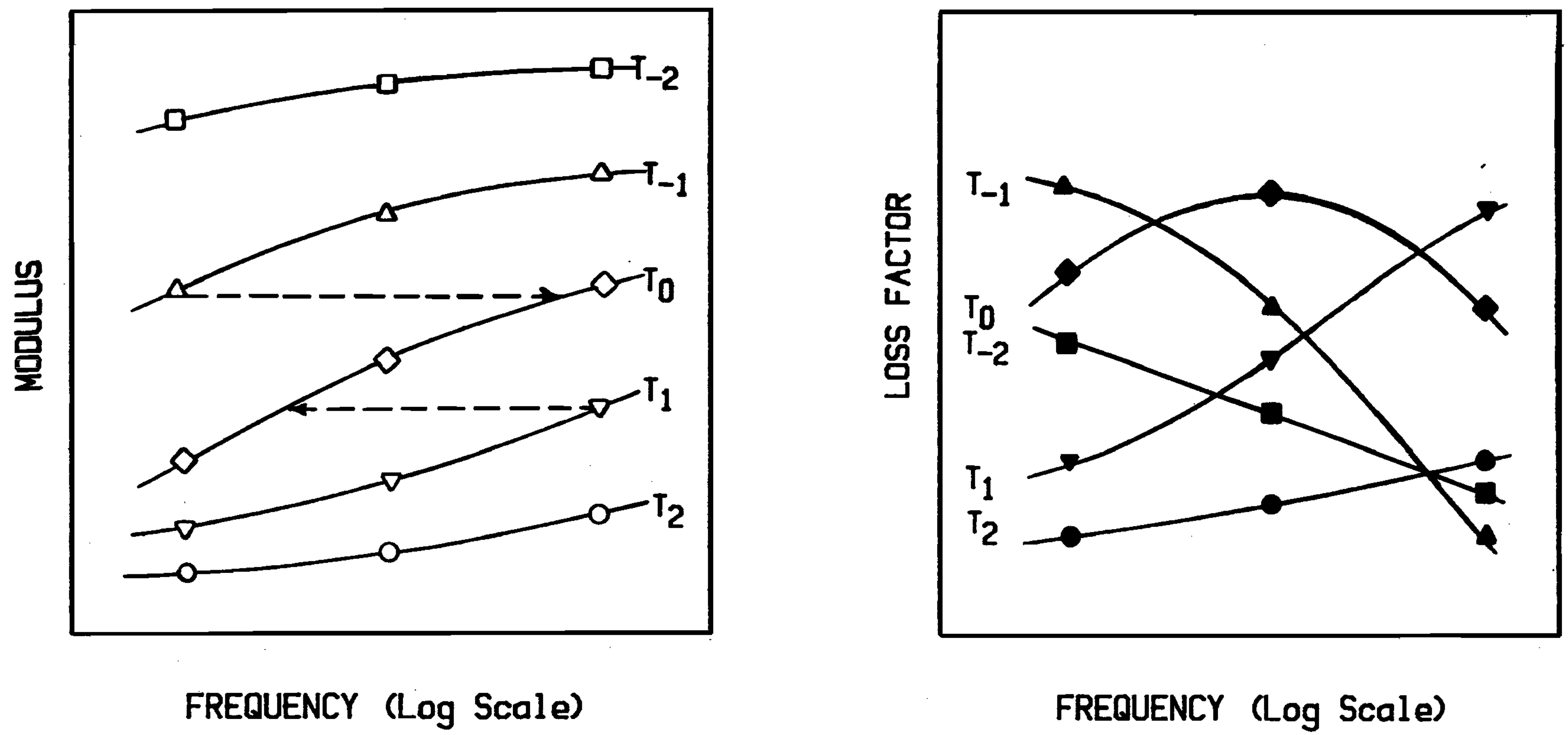

Figure 2 Variation of Modulus and Loss Factor with Frequency and Temperature

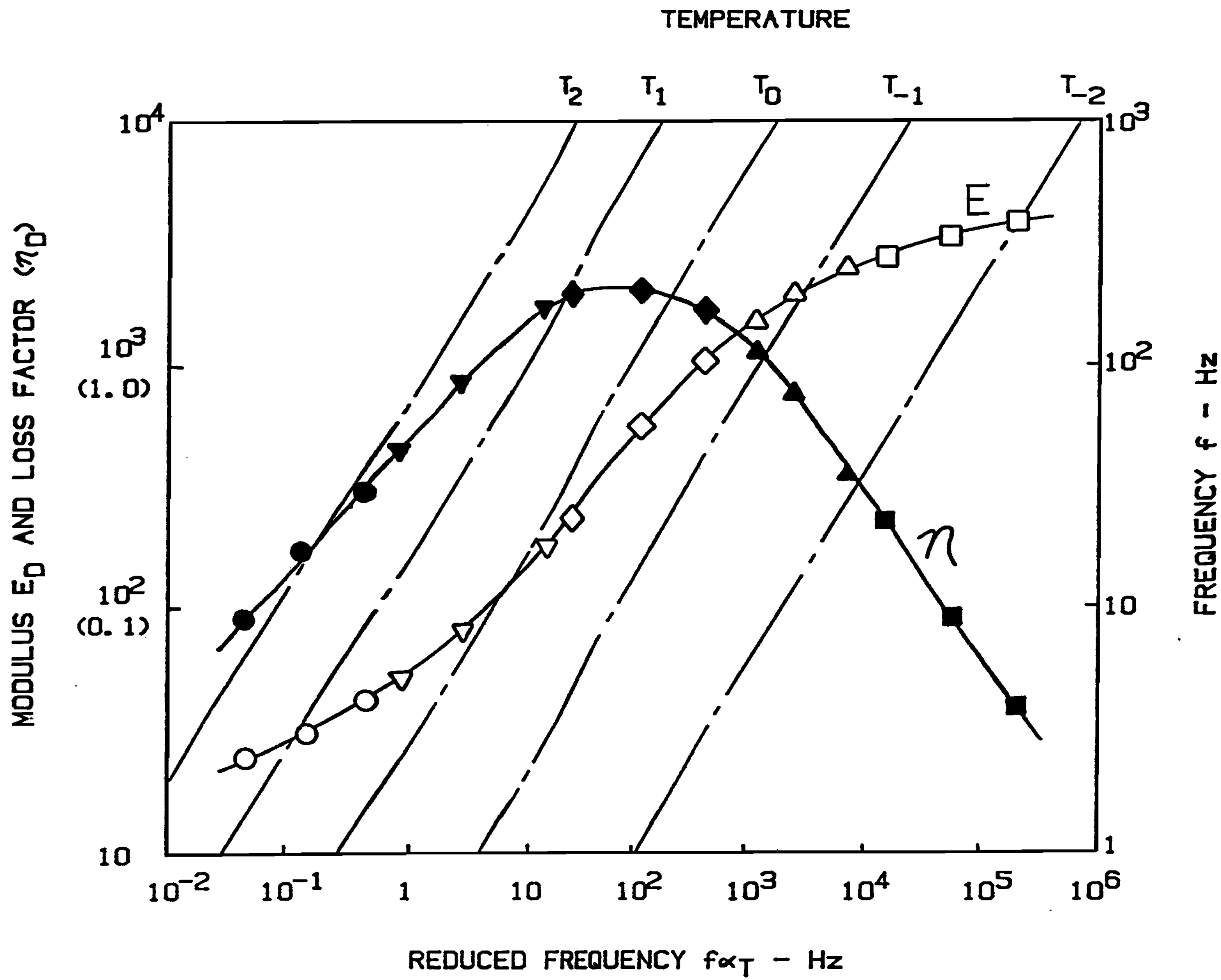

Figure 3 A Typical Reduced Frequency Nomogram

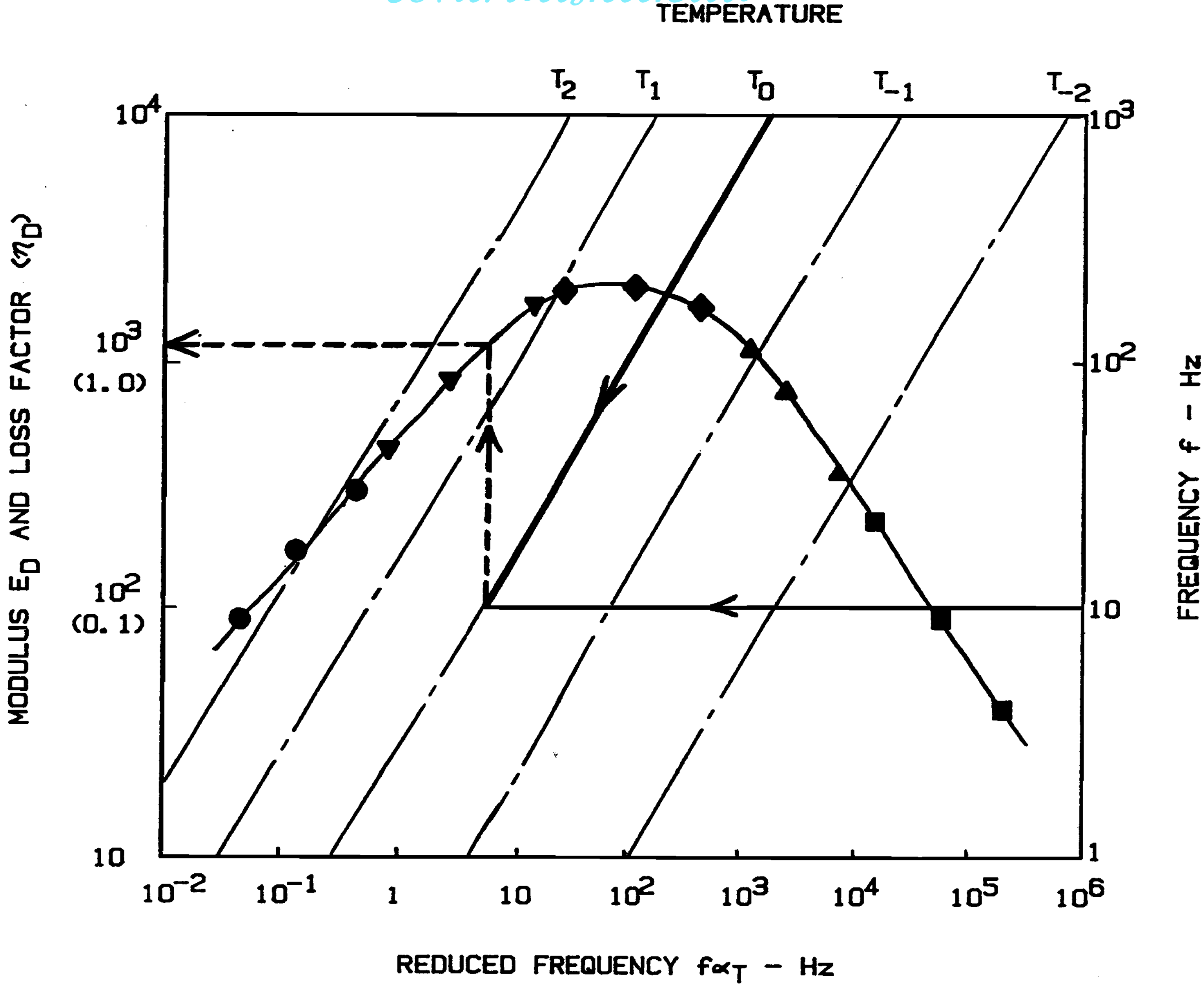

Figure 4 Interpretation of Data from a Reduced Frequency Nomogram

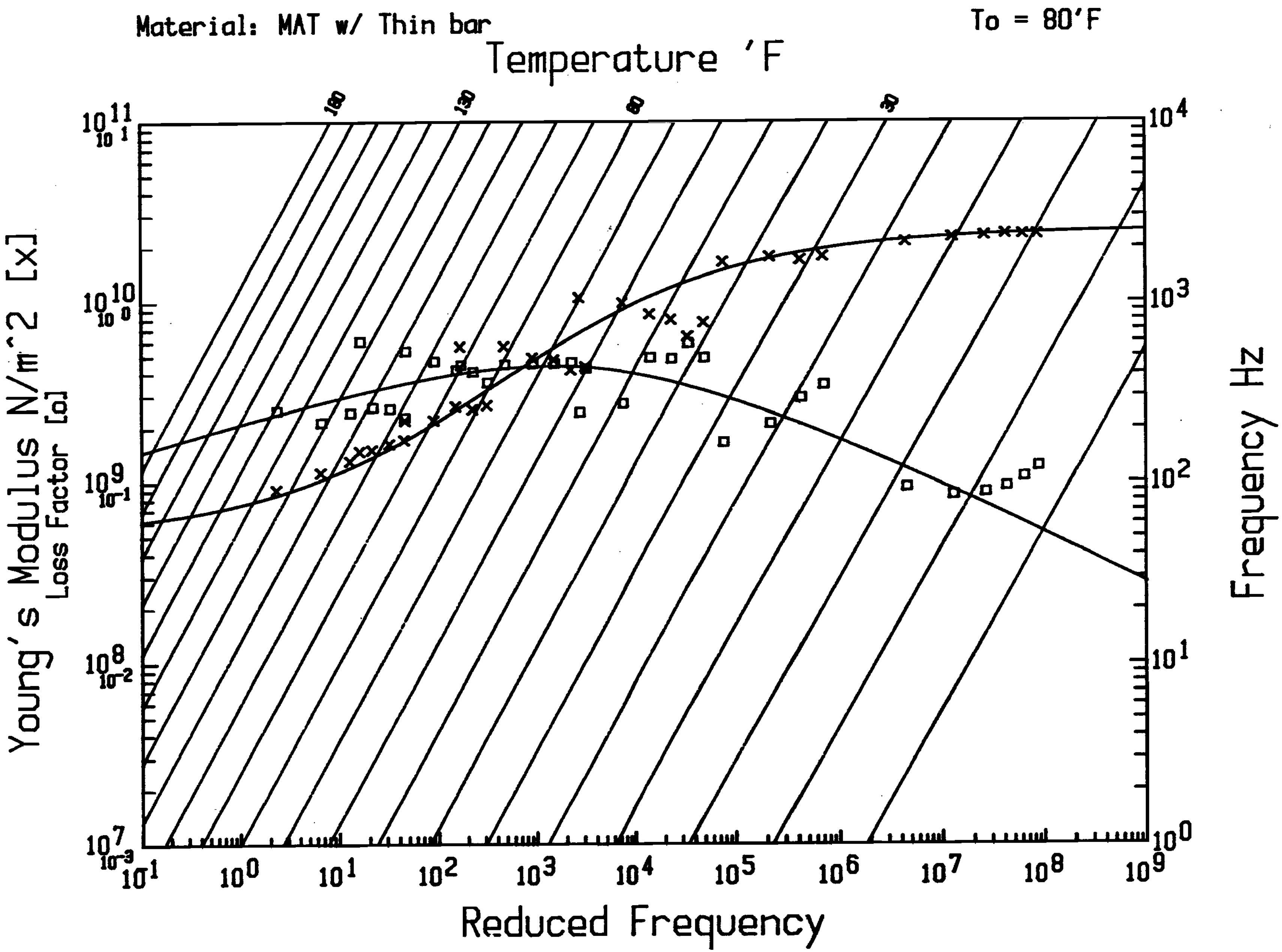

Figure 5 Reduced Frequency Nomogram with Thin Bar

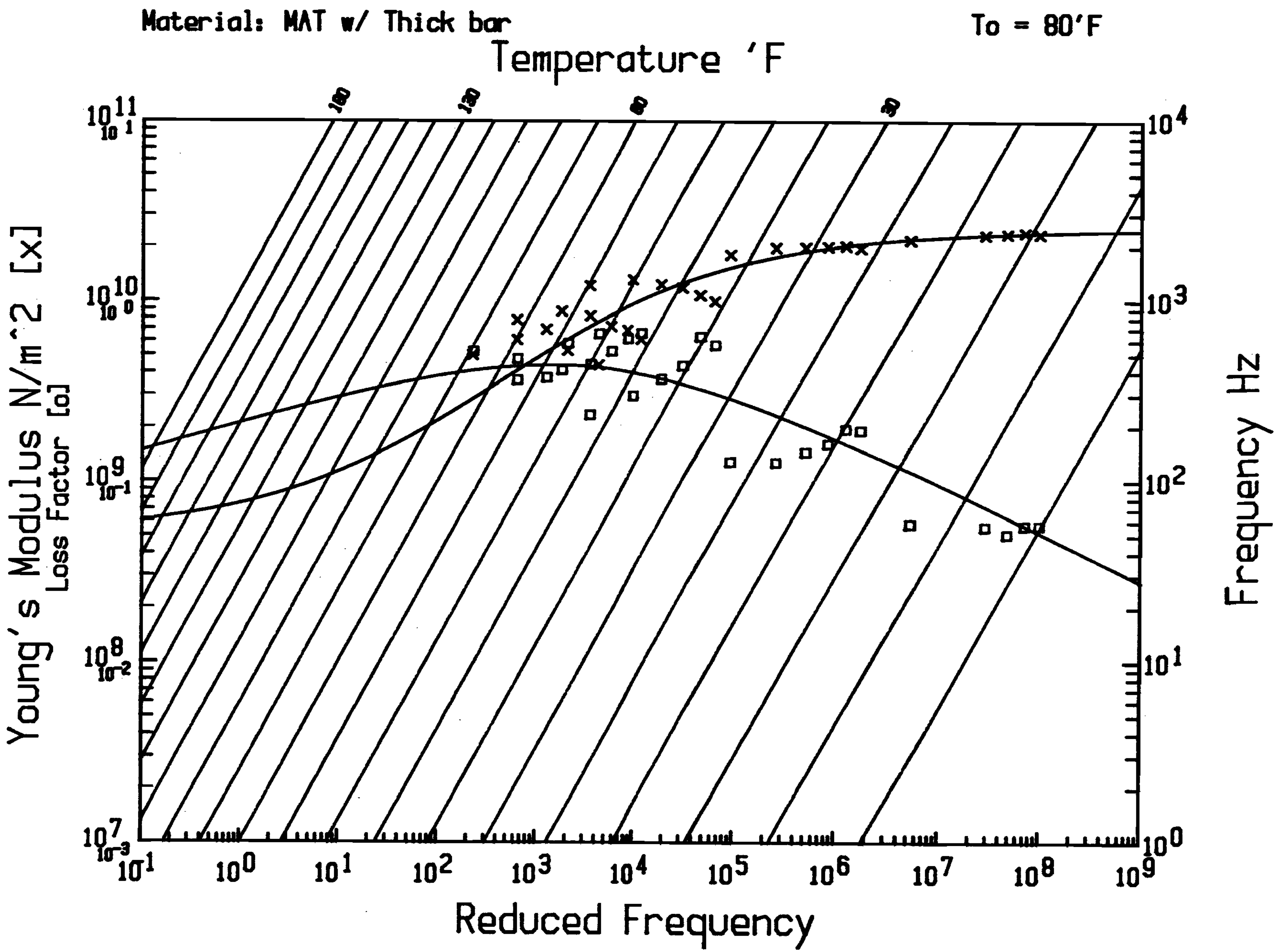

Figure 6 Reduced Frequency Nomogram with Thick Bar