ENGINEERING DESIGN
A GLOBAL VIEW OF DUPONT POLYMERS

Designing For Vibration

By Peter A. Tuschak

> MATERIAL SELECTION, GEOMETRY PLAY SIGNIFICANT ROLES IN VIBRATIONS RESPONSE

Plastic components, especially those in home appliances. sporting goods and automotive applications. are frequently subjected to dynamic loads, i.e. vibrations and impacts. Steady state vibrations, either sinusoidal or random, can cause deformations and stresses beyond that of comparable static loads, and require special approaches in design.

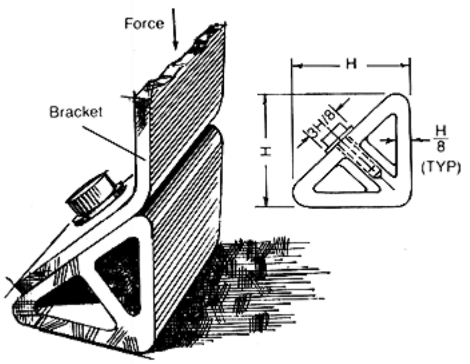
In the ribbed beam of Rynite® 530 thermoplastic polyester in Figure 1. a 89 newton (20 lb) load at the free end deflects the beam 1.5 mm (0.059 n). In service, there is a steady state. sinusoidal oscillation of the load. In other words, the force at the end of the beam becomes a periodic function of time:

$$F = F_{max} \sin 2 \pi f t$$

where F_{max} equals 89 N (20 lb), f is the frequency of vibrations in hertz (cycles/second), and t is time.

The frequencies at which the maximum oscillations occur are called the natural frequencies. or resonances. The effect of "driving" a structure at a natural frequency is demonstrated for the ribbed beam in Figure 2. In the range of 1 - 100 hertz, the deflection shows three peaks in line A of Figure 4—at 5.73, 32.72, and 81.66 hertz—which are the natural frequencies of the beam in the given range. The amplitude of deflections at 5.73 hertz is 88.4 mm (3.48 in), which would cause a maximum elongation in the beam of 5.2 percent. Since the elongation at break for Rynite® 530 at 23°C (73°F). is 2.7 percent, it is clear that the beam could not survive the vibrations. Contrast this with the static deflection of 1.5 mm under an 89 N load (0.059 in under a 20 lb load), where the corresponding static elongation is 0.08 percent.

One way to deal with vibrations is to isolate the structure from the load via a vibration absorber. In Figure 3, the triangular spring at the end of the beam model is given the properties of Hytrel® 4056 polyester elastomer. As one can see in line B of Figure 4, the natural frequency shifts from 5.73 to 5.4 hertz and the amplitude drops from 88.4 mm (3.48 in) to 41.4 mm (1.63 in). This corresponds to a maximum elongation of 2.4 percent—below the failure limit.



A triangular spring of Hytrel® 4056 polyester elastomer—a wall thickness of 1/8th the spring's height (H) is recommended—is one way to absorb vibrations.

Figure 1. Static deflection of ribbed contilever beam of Rynite® 530.

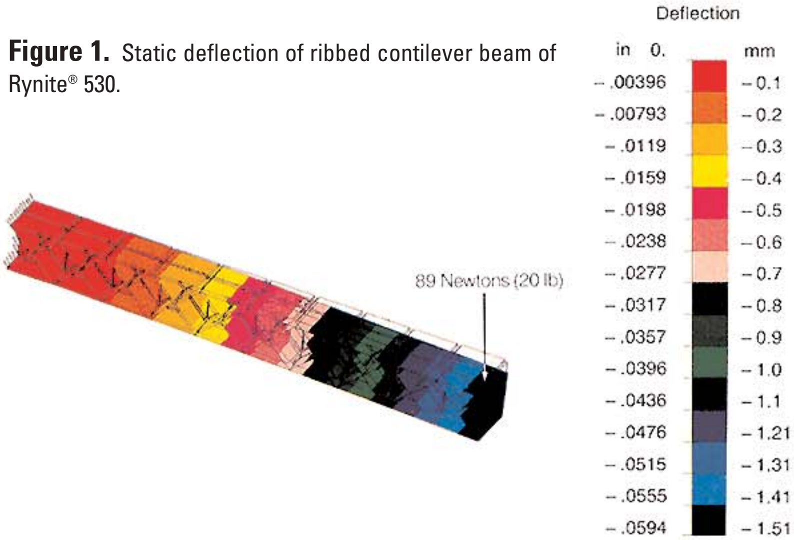


Figure 4. Comparison of beam response with and without vibration absorber.

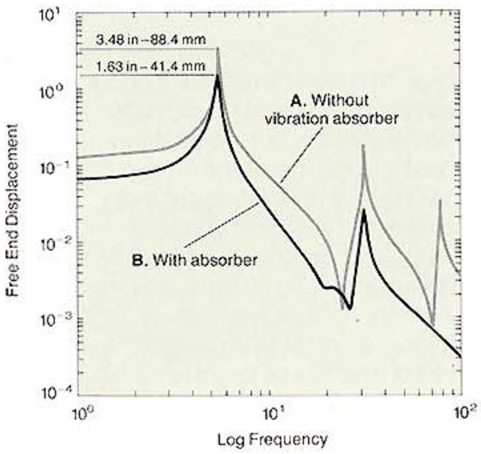
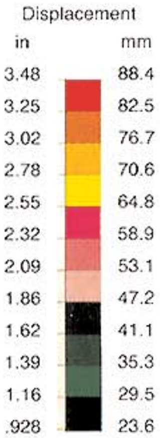


Figure 2. Displaced geometry at 5.73 hertz (cycles/second).



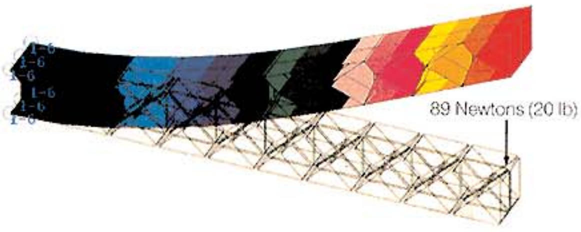
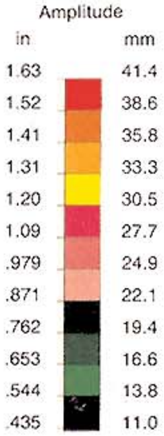


Figure 3. Displacement contours with vibration absorber at 5.4 hertz (cycles/second).

Beam Material: Rynite® 530
Vibration Absorber Hytrel® 4056



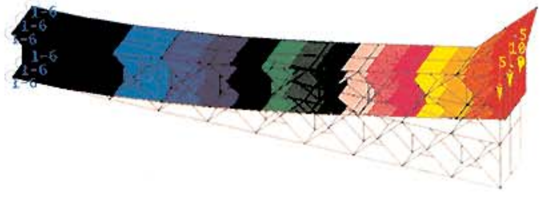


Figure 5. Washing Machine Spin Tub.

N-600 – 1000 RPM

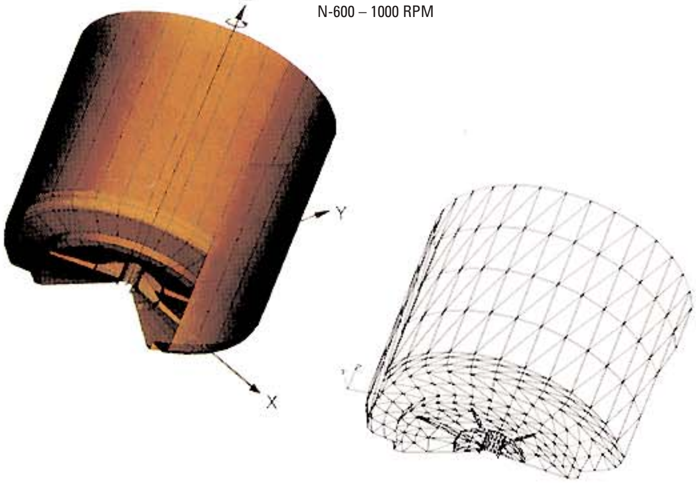
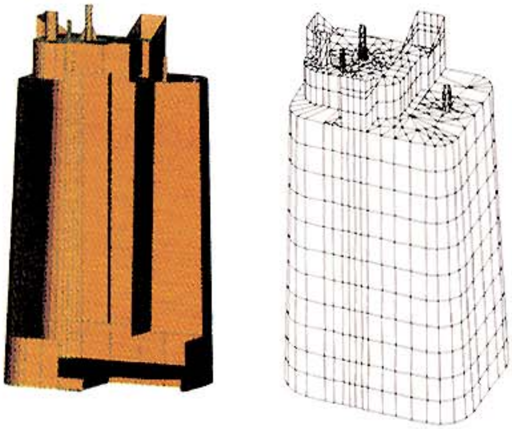


Figure 6. Vapor Canister.



If further reduction in amplitude is desired, vibration absorbers at the base of the beam and/or additional supports can be used. Changes in flexural modulus and specific weight will also lead to different response characteristics since the stiffer a structure is, the higher its first natural frequency. Conversely. the higher the specific weight, the lower the first natural frequency Thus, material selection and geometrical design play significant roles in the vibrational response of plastic components.

Frequency response analysis should be employed in the design of items such as the spin tubs of washing machines (Figure 5), where an unbalanced load of clothes will apply periodic forcing to the tub and the whole drive system. In under-the-hood or under-the-chassis automotive components, such as plastic vapor emission canisters (Figure 6), intake manifolds, or fuel lines, periodic or random forces can cause premature fatigue failure The design objective in both of these cases must be to:

a) Design resonant frequencies out of the input frequency range, and

b) Use vibration isolation whenever needed to reduce the deflection peaks that occur at resonances.

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