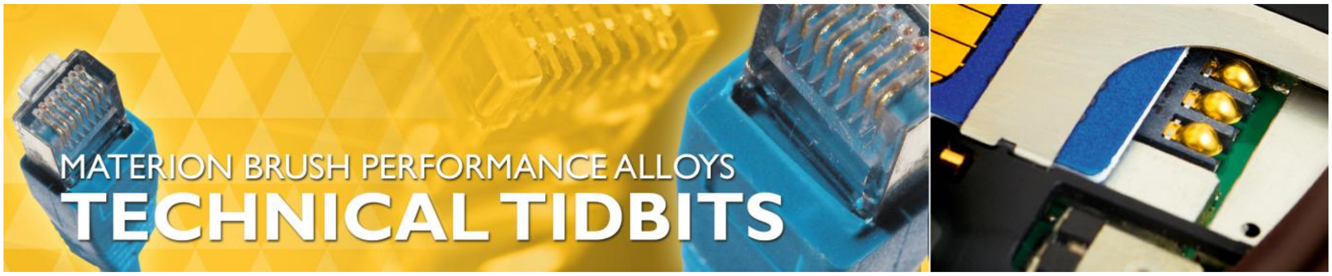


**Issue No. 84 – December 2015** **New Publication**

**Define "Good" –** A discussion of the particular spring performance advantages provided by various material properties.

- **Spring Rate**
- **Peak Force**
- **Stroke**
- **Resilience**
- **Modulus of Resilience**
- **Impact Resistance**
- **Operating Cycles**
- **Operating Life**
- **Wear Resistance**
- **Vibration Resistance**
- **Resonant Frequency**

*The next issue of Technical Tidbits will compare one piece vs. two piece terminal contacts.*

# What Makes a Good Spring Material?

After spending the last 8 months learning about various spring types, it is time to find out about the material properties that separate good springs from OK springs from bad springs.

Over the years I have received many questions. One that comes up quite often is "Does this make a good spring material?" Alternatively, I may hear "My current material is not working. How do I make it springier?" The answer, of course is "It depends on what you are trying to do with the spring." There is a difference depending on whether you need more force, less force, more deflection, less deflection, etc. So, in order to select a material that meets your requirements, you will have to focus on different material properties, depending on the different desired outcomes below.

- **Maximizing Spring Rate/Stiffness** – Spring rate is the ratio of the reaction force to the applied deflection. In order to increase it, you need to use a material with a higher modulus, or you need to modify the geometry. In beam contacts, you do this by increasing width/radius, thickness, or decreasing length. Stiffness is the opposite of flexibility.

- **Maximizing Peak Force** – For this you would need a higher modulus material to increase the spring rate, and perhaps a higher yield strength material to allow the stress to build up to a sufficient level to provide the needed force. If the spring force is too low because the material is yielding, then CuBe or other age hardenable alloys can be heat treated to increase the yield strength and achieve a greater force before the material yields. However, if the peak force is too low and the material has not yet yielded, it is impossible to heat treat greater stiffness into the material. In the latter case, you would need to increase the spring rate by changing the geometry or using a material with a higher elastic modulus, as discussed above.

- **Maximizing Stroke/Flexibility** – In order to get the most deflection out the material, you need good flexibility and/or high elastic **resilience**, the ratio of yield strength to elastic modulus. Reducing the stiffness would increase the maximum allowable deflection, but at a penalty of reduced contact force See Technical Tidbits Issues #6 for more information on why low force is bad and #22 for more information on elastic resilience.

- **Maximizing Impact Resistance/Energy Absorption/Surviving Drops** – For this you would need a high **modulus of resilience** (yield strength$^2$/ elastic modulus). High resilience is important to maximize the deflection and high strength is important to maximize the allowable stress. Together, as the modulus of resilience, they maximize the amount of energy that the spring can absorb before failure. See Technical Tidbits Issues #1 and 22 for more information.

- **Maximizing Operating Cycles** – In order to increase the number of operating cycles until fatigue failure, choose a material with a high fatigue strength or modify the geometry to reduce the stress.

- **Minimizing Wear** – Use a material with a high hardness to decrease contact friction and minimize abrasive wear.

- **Maximizing Operating Life** – In order to ensure the maximum life, you need to ensure consistent contact force over the life of the connector. For this you would need high conductivity to minimize temperature rise, good stress relaxation resistance to keep the force above the minimum required, and good fatigue strength if the part is highly cycled.

- **Minimizing Vibration** – In order to minimize the amplitude of vibration, it is important to increase the stiffness of the spring, similarly to maximizing peak force. Also, verify that the geometry does not have a **resonant frequency** near the expected frequency of vibration, or you will end up with a rapid and unexpected fatigue failure.

- **Maximizing Current-Carrying Capacity** – For this you would need to increase the electrican and thermal conductivity, increase the spring's cross-sectional area, or decrease the length of the conducting path. See Technical Tidbits Issue #24 for more information.

## Miscellaneous Springs (continued)

Table 1 below summarizes the effect of various material properties and geometric variables on the performance of cantilever beam springs. Similar logic holds true for the other spring types, as long as you understand which variables are in the numerator and denominator of the force or torque vs deflection and stress vs defection curves.

| Design Goal | Material Properties | Geometry |
|---|---|---|
| Maximize Spring Rate | Increased Elastic Modulus | Shorter Beam Length, Greater Beam Width, Greater Beam Thickness |
| Maximize Peak Force | Increased Elastic Modulus Increased Yield Strength | Greater Beam Width |
| Maximize Stroke/Deflection | Increased Resilience: Higher Ratio of Yield Strength to Elastic Modulus | Greater Beam Length, Reduced Beam Thickness |
| Maximize Energy Absorption/Survive Drops | Increased Modulus of Resilience: Higher Ratio of Square of Yield Strength to Elastic Modulus | Greater Beam Length, Greater Beam Width, Greater Beam Thickness |
| Maximize Number of Operating Cycles | Increased Fatigue Strength | Greater Beam Length, Reduced Beam Thickness, Eliminate Stress Risers |
| Maximize Current Carrying Capacity | Increased Electrical & Thermal Conductivity | Shorter Beam Length, Increased Beam Cross Section |
| Maximize Operating Time at Elevated Temperatures | Increased Electrical & Thermal Conductivity, Increased Stress Relaxation Resistance | Shorter Beam Length, Increased Beam Cross Section |
| Minimize Vibration Amplitude | Increased Elastic Modulus | Shorter Beam Length, Greater Beam Width, Greater Beam Thickness |

**Table 1. Summary of Design Tips to Improve Spring Behavior.** Note that the recommendations for changing the geometry sometimes are in direct conflict with each other. Furthermore, they are also in conflict with the trend toward miniaturization of all components.

When you are looking to improve the performance of a design, perhaps so you can use it in a harsher environment, to make it smaller, to carry more current, or to just increase one of the parameters above, you will need to either change the geometry or change the material. A higher yield strength helps a number of these design parameters, as does high electrical & thermal conductivity, increased resistance to stress relaxation, and greater fatigue strength. Increasing the elastic modulus also helps, as long as the yield strength is increased by an equal or greater amount. No spring performance parameter is improved with a reduction in these properties.

*Written by Mike Gedeon of Materion Performance Alloys Marketing Department. Mr. Gedeon's primary focus is on electronic strip for the automotive, telecom, and computer markets with emphasis on application development.*

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Materion Performance Alloys
6070 Parkland Blvd.
Mayfield Heights, OH 44124

Sales +1.216.383.6800 800.321.2076 BrushAlloys@Materion.com
Technical Service +1.216.692.3108 800.375.4205 BrushAlloys-Info@Materion.com


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