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MATERION

TECHNICALTIDBITS

MATERION PERFORMANCE ALLOYS

Home on the Range –
A brief discussion of how typical material properties may vary and how it can lead the design engineer into trouble.

- **Histogram**
- **Normal Distribution**
- **Standard Deviation**
- **Six Sigma**
- **Specification Limits**

The next issue of Technical Tidbits will discuss issues with tuning and trying to customize material properties.

MATERIAL PROPERTY **RANGES AND STATISTICS**

(Note: the following discussion assumes that the reader is familiar with basic statistical concepts such as normal distribution and standard deviation.)

If you look at the data sheet for any material, you will notice that you will rarely find a single value for any given property, unless it is accompanied by the word minimum, maximum, nominal or typical. Most often, a range of expected values is provided, along with a note that the published data is for reference only and not for design purposes.

The design engineer would prefer that every piece of metal that they purchase under a given specification to be perfectly identical. However, this is as likely as having identical twins born several years apart. Material suppliers do everything in their power to minimize variation, but entropy and sensitive dependence on initial conditions (also known as chaos theory or the butterfly effect) are impossible to overcome.

Many older specifications would call out a minimum value and a maximum value for any given property. More recently, specifications would call out only minimum values (or only maximum values if a lower number is better.) The latter practice is far more logical. If a particular piece of metal falls outside the specification range, it will be scrapped out. This is fine for a piece of metal where a measured property is worse than the specification range. Now, imagine a particular piece of metal that is a statistical outlier, and its properties are better than the specification range. Under the former system, it would fail to meet the specification, even though it is actually better than required and it would illogically need to be scrapped. Under the latter system, there would be no problem since it would exceed the minimum.

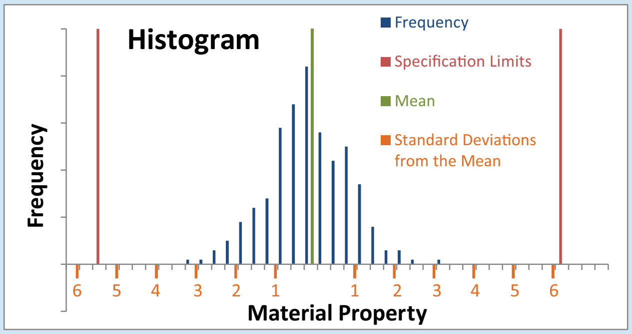

Figure 1. Typical Distribution of a Material Property.
The majority of the measurements fit within 3 standard deviations, and all the measurements are within 4 standard deviations of nominal. Five standard deviations fit comfortably within the specification limits, so the probability of missing the specification is very low.

Properties will typically show a **normal distribution** around a nominal value. (See the **histogram** in Figure 1 above). For any given property, some pieces of material will be higher than nominal and some will be lower. Ideally, the specification range would be wider than the ±3 sigma variation. This would suggest that 97% of material would fall within the specification range. If 6 **standard deviations** fall between the nominal and the **specification limits** (**6 sigma** capability, Cpk=2.0), then only 3.4 out of 1 million pieces of material would be expected to fall outside the limits of this particular property. Process capability will be discussed in more detail in a future issue.

MATERIAL PROPERTY **RANGES AND STATISTICS** (CONTINUED)

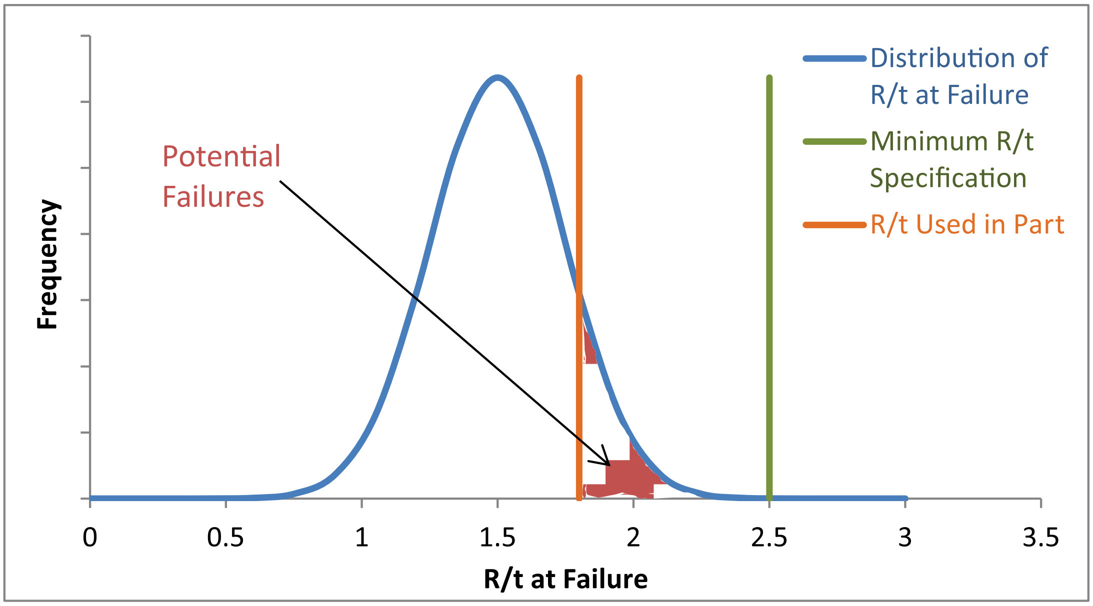

Figure 2. Potential Problems with Normal Variation in Properties. The blue line shows a hypothetical histogram of the minimum bend radius required to avoid fracturing in a particular alloy and temper. The specification minimum would be set where virtually all material would be guaranteed to pass. If a part is designed to be stamped with a bend that has an R/t ratio is less than the specification limit, metal that falls on the left of the orange line can be formed successfully, while metal on the right side would likely crack during forming, even though there is nothing at all wrong with the metal.

Figure 2 above shows an example where the standard variation of a material property can create an issue. Bend formability is a good example that shows how exceeding the specification can result in a complete failure. (Formability is a much better example than yield strength. If a part yields in service, it may or may not be bad, depending on the situation. However, if a part cracks during forming, it is most likely useless.) Say that you make a tool that bends a part with a minimum R/t ratio of 1.8 and you use a material with a minimum R/t specification of 2.5. You may get some sample material for trial that forms a lot better than the specification and you may even get production runs of several coils that show no problem. Suddenly, you receive a coil that falls on the right side of the distribution and it cracks during the forming operation. There is nothing wrong with the coil, it is fully within specification. This is why it is important to pay attention to all material property specifications and to design your parts and fabrication tooling appropriately.

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Handling copper beryllium in solid form poses no special health risk. Like many industrial materials, beryllium-containing materials may pose a health risk if recommended safe handling practices are not followed. Inhalation of airborne beryllium may cause a serious lung disorder in susceptible individuals. The Occupational Safety and Health Administration (OSHA) has set mandatory limits on occupational respiratory exposures. Read and follow the guidance in the Material Safety Data Sheet (MSDS) before working with this material. For additional information on safe handling practices or technical data on copper beryllium, contact Materion Performance Alloys or your local representative.

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