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MATERION

# TECHNICALTIDBITS

MATERION BRUSH PERFORMANCE ALLOYS

**It *is* as bad as it sounds! –** A brief discussion on the ability of materials to withstand high temperatures while under stress.

- Creep
- Primary Creep
- Secondary Creep
- Tertiary Creep
- Creep Rupture/ Stress Rupture
- Strain Hardening
- Recovery
- Ductility Minimum Temperature
- Ductile-Brittle Transition Temperature
- Notch Sensitivity

*The next issue of Technical Tidbits will discuss the dielectric constant of an electrical insulator material.*

## STRESS RUPTURING/**CREEP RUPTURING**

**Creep** is a gradual increase in plastic strain at constant stress, at elevated temperatures. In other words, it is an increase in permanent deformation of a material when it is held at a high temperature for a long period of time, with no change in applied load.

Creep is measured similarly to a tensile test. In a tensile test, the material is pulled apart at a continuously increasing load. In a creep test, the material is held at a specific temperature, and then loaded to a desired stress level, which remains the same throughout the test. In both tests, strain is measured throughout the process. However, in a tensile test, the output is load (stress) vs. strain, while in a creep test, the output is strain vs. time.

A good description of the process can be found in Mechanical Metallurgy, by George Dieter. Creep typically occurs in 3 stages, although not all materials will show all 3 behaviors. In the first stage, (**primary creep**) the creep rate initially starts high, and then gradually decreases, as **strain hardening** occurs and fewer dislocations are available for movement.

During **secondary creep** (the second stage) the creep rate is constant. This is due to a balance between strain hardening and **recovery** (a tendency of the metal to want to return to a lower energy, lower stress state.) Recovery essentially undoes strain hardening. It accounts for softening of cold worked material during solution annealing. Eventually, recovery wins out, and the material begins to neck, effectively increasing the stress. This results in a rapid acceleration of the creep rate in the third stage (**tertiary creep**).

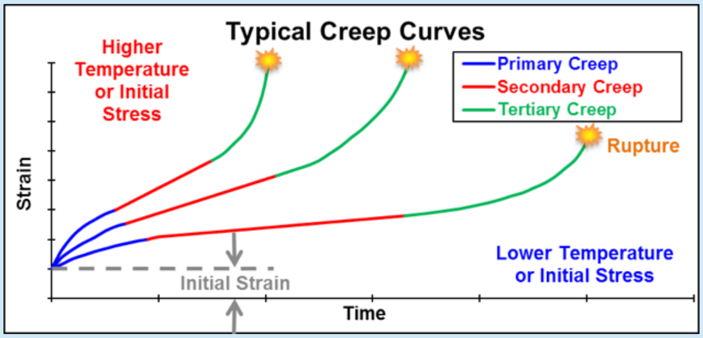


**Figure 1. Typical Creep Curves.** Note that as the exposure temperature or the initial stress level increases, the material deforms more quickly and the time to failure becomes much shorter. Like in a tensile test, the material continuously deforms and ultimately fractures. However, unlike in a tensile test, the stress level stays the same through the entire process.

**Stress rupture** or **creep rupture** is the term for the abrupt failure at the end of the creep process. Sometimes, the time to failure is of more interest than the overall creep behavior itself. Figure 2 shows creep rupture data for a copper alloy. As expected, higher temperatures and greater initial stress levels accelerate the failure, while lower temperatures and lower stress levels increase the time to rupture. The failure will occur at stresses below tensile strength at that particular temperature, and far below the room temperature tensile strength.

Copper alloys also may experience another temperature-related problem. Ductility of these alloys typically falls with temperature until it reaches a minimum value, then the ductility increases again as temperature continues to increase. While the material may have plenty of ductility at room temperature, at the **ductility minimum temperature** it may experience brittle behavior.

## STRESS RUPTURING/**CREEP RUPTURING** (CONTINUED)

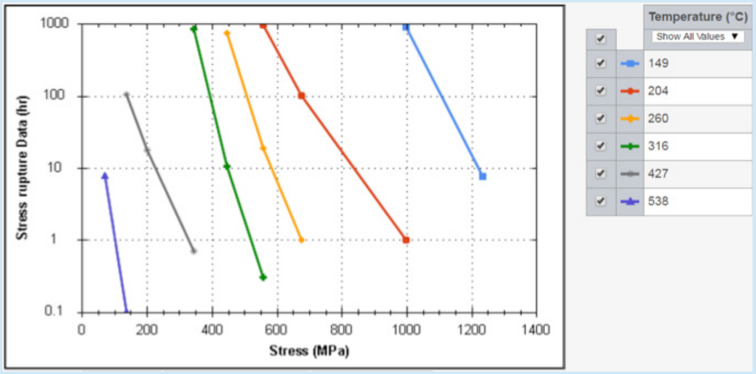


**Figure 2. Typical Stress Rupture Data for a Single Material**
Note that the temperatures get progressively higher as the curves proceed from right to left. As temperature increases, the material fails in less time and at lower stress levels. At high enough temperatures, failure occurs in minutes even at very low stress levels. This particular material has a room temperature tensile strength range of 1140 to 1380 MPa.

This is another important distinction between copper alloys and steel alloys. Steel alloys lose ductility and become brittle at cryogenic temperatures, when they pass through their **ductile-brittle transition temperatures.** Copper alloys retain their full strength and ductility at these temperatures, and may even experience slight increases in both. Conversely, copper alloys will lose ductility and become brittle at elevated temperatures, while steel alloys will retain their ductility. This is why knowing the expected temperature swings in the environment is a critical factor for selecting materials for given applications.

With reduced ductility, materials may also experience increased **notch sensitivity** as well. As a reminder, a notch sensitive material will experience a greater amount of the theoretical stress concentration of stress risers, while materials that are not notch sensitive will experience less of a stress concentration effect. This means that sharp radii, changes in cross section, notches, etc. that would be relatively innocuous at room temperature could suddenly become failure initiation points at temperatures where notch sensitivity occurs.

This concludes the Technical Tidbits series on thermal properties. Next month we will move on to a few more electrical properties, followed by magnetic properties.

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**References:**

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