Back to basics: Martempering to reduce distortion

This process is more expensive than normal quenching, but benefits of reduced distortion and reduction of rework make it worthwhile.

In the previous article, we discussed the principle of quench and temper, which is arguably the most common type of steel heat-treating. In this article, we will discuss the principles of martempering.

Martempering [1] is a specialized process that is only used when distortion and high-residual stresses are an issue. In this process, parts are quenched from the austenitizing temperature into hot oil or molten salt at the approximate martensite start temperature (100°-200°C). The part is held at this temperature until the surface and center temperatures of the part are nearly the same. Once the center of the part has reached the quenchant temperature, the part is removed from the quenchant and allowed to cool in any convenient manner (usually air cooling). This prevents the formation of thermal stresses due to unequal cooling between the center and surface (Figure 1) and uniform transformation of austenite to martensite.

If complete hardening is to occur, the austenite must cool sufficiently fast to prevent the center cooling rate to miss the “nose” of the TTT diagram. Since the TTT diagram shows the martensite start temperature, Ms, the TTT diagram is useful for selecting the optimal quenchant temperature, and estimating the time the part must be held at temperature to prevent the formation of bainite.

The primary advantage of martempering is that parts will have lower distortion and reduced residual stress. This is from reduced thermal gradients during quenching and relatively uniform transformation of martensite. Martempering can be accomplished in either oil or molten salt. Typical temperatures for martempering, some through hardening and carburized grades, are shown in Table 1.

As indicated above, the part is held at approximately the martensite start temperature (Ms) for a period of time, to minimize the thermal gradients from center to surface. The maximum time for this thermal hold is dependent on the bainite start time on the TTT diagram. The part is withdrawn from the bath before bainite is allowed to form.

Martempering is most likely used for parts that have been carburized. The carburized case of the part has a greater carbon content than the core. Since the case has a greater carbon content, the Ms temperature is lower in the case than in the core. The part is quenched into oil or molten salt at temperatures just above the Ms temperature of the carburized case. This means that the core will often transform earlier than the case, resulting in the beneficial compressive residual stresses at the surface of carburized parts.

Martempering is especially appropriate for bearings, gears, and shafts, where the parts are costlier to fabricate and are made to closer dimensions. This is illustrated in Figure 2, where the distortion is shown as a function of martempering temperature.

The limitations of section thickness must also be considered for suitability for martempering. With a given severity of quench, there is a limit in section thickness, where the steel will no longer harden fully or transform to martensite (Figure 3). However, depending on the application, it may be acceptable for the center of the part not to be completely transformed to martensite. Often times it is acceptable that the core hardness is less than the surface hardness. If this is the case, then the size for martempering can be increased (Figure 4). The effect of the resulting mixed microstructure on the mechanical

Figure 1. Schematic representation of martempering.

Figure 2. Distortion of SAE 52100 bearing races as a function of martempering temperature. [2]

Table 1. Typical martempering temperatures in oil and molten salt [3].
properties would have to be evaluated for each application.

As a general rule, distortion decreases with increasing temperature. This is due to the reduction of thermal gradients during quenching.

A manufacturer of small parts was exhibiting extremely high distortion of SAE 1075 parts. They were martempering the parts at 250°F (121°C) and seeing upwards of 80 percent scrap on certain parts. This led to high rework and material costs. The recommendation was made to increase the martempering temperature. A trial was initiated to increase the martempering temperature up to 176°C (350°F). The results (Figure 5) showed substantial improvement in the percent scrap due to heat treating distortion. Upwards of 80 percent improvement in the scrap generated was achieved [4].

Since martempering uses elevated temperatures of typically 225°-325°F (105°-160°C), the quench oils used must be specially formulated from quality-base stocks and extensive anti-oxidants.

CONCLUSIONS
In this short article, we have discussed the benefits of martempering to reduce the distortion and residual stresses of gears, shafting, and bearings. Martempering is a more expensive process than normal quenching, but the benefits of reduced distortion and reduction of rework more than pay for the additional cost.

In the next article, we will discuss the process of austempering. Should you have any questions regarding this, or any other article, please do not hesitate to contact the author.

REFERENCES

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