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Innovations in Aluminum Heat Treatment

The heat treater is always looking to improve his processing techniques, shorten cycle times and lower costs without sacrificing production quality. Recent innovations in aluminum heat treating suggest this is possible. Let's learn more.

Double Aging (DA)

Double aging (Fig. 1) is a technique used for reducing total aging time for various aluminum alloys. The effects of double aging and thermomechanical double aging (i.e. a combination of work hardening and heat treatment) on enhanced mechanical properties of a 7075 aluminum alloy have recently been reported.[1] Results illustrate the effects of accelerating the kinetics of precipitation on hardness and strength (via tensile testing). By applying the appropriate heat-treatment cycle, the time to peak aging can be reduced by a factor of up to 36 without a substantial decrease in hardness or tensile properties.

As heat treaters we know age-hardenable aluminum alloys can be hardened or strengthened by natural or artificial aging. The science tells us that a supersaturated solid solution is formed after the solution heat treatment. Aging at temperatures well below the solutionizing temperature produces Guinier-Preston (GP) zones and metastable coherent precipitates that harden the alloy up to the peak condition. However, stable and incoherent precipitates start forming in the overaged condition. The type of precipitation varies with alloy composition.

For example, the most important factor influencing the DA treatment in an Al-Zn-Mg alloy such as 7075 is the time of first aging. Test results on 7075 show positive effects of the DA treatment, with the ductility being higher with slightly less than a 6% decrease in yield and tensile strength. Double aging this alloy to peak hardness results in a significantly reduced processing time – from 48 hours to 2 hours – and such processing can lead to reduced energy usage and reduced production costs resulting from the accelerated kinetics of precipitation.

Again, there is an optimum time, which varies with both the composition of the alloy and temperature of first aging treatment. A higher second aging temperature accelerates the precipitation in 7075, but it cannot be so high as to cause significant reduction in volume fraction of precipitates or dissolution of GP-zones.

Thermomechanical double aging (Fig. 2) causes further acceleration of precipitation, reducing the total heat-treatment time to only 80 minutes. This results in an increase in hardness and strength in 7075 alloy beyond the conventional aging procedure, but the ductility is reduced relative to conventional single age or the double-aging heat treatments.

Rapid Heat Treatment (RHT)[2,3]

When cast components for structural applications such as alloy wheels are manufactured using Al-Si-Mg-based casting alloys (typically A356 and A357), T6 heat treatment is in most cases an essential step in the manufacturing process. The T6 heat treatment provides two beneficial effects: an improved ductility and fracture toughness through spheroidization of the eutectic silicon particles in the microstructure and a higher alloy yield strength (YS) through the formation of a large number of fine precipitates that strengthen the soft aluminum matrix. The first benefit is realized through the solution treatment, normally at a temperature around 1005°F (540°C), while the second benefit is achieved through the combination of solution treatment, quenching and artificial aging in the temperature range of 285-340°F (140-170°C).

In the casting industry, it is often specified that a cast component should be solution treated for six hours at 1005°F (540°C).

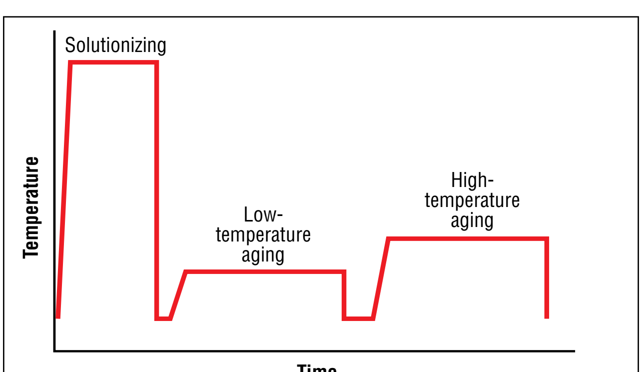

Fig. 1. Double-aging heat-treatment process cycle

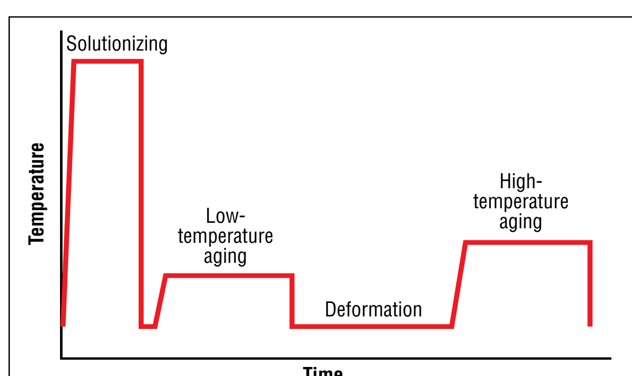

Fig. 2. Double aging and thermomechanical heat-treatment process cycle

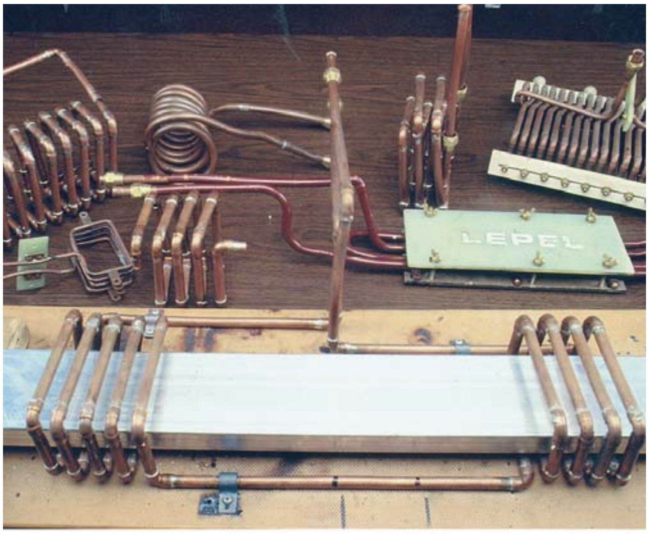

Fig. 3. Typical induction coils used in the RHT process

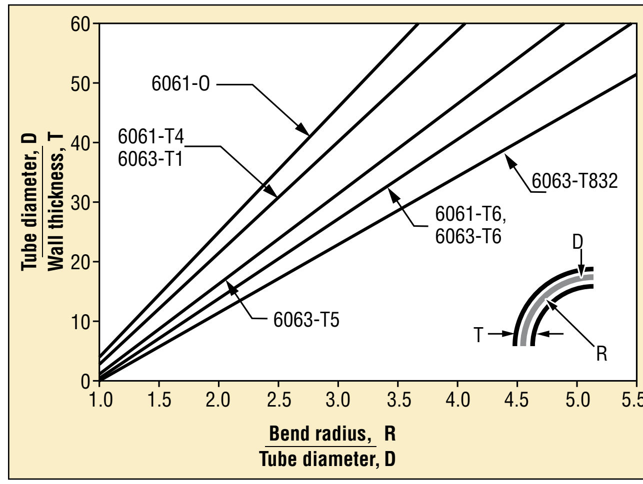

Fig. 4. Bending relationship *Note: In the above figure, if the tube diameter to wall thickness ratio lies above the respective lines for the given tempers, the tube generally cracks during bending.*

While the benefit of T6 heat treatment is accepted, the additional cost and production time associated with such a treatment is also substantial. Positive results have been reported for permanent mold-cast test bars of a modified A356 alloy where a solution treatment of 50 minutes at 1005°F (540°C) is sufficient to attain more than 90% of the maximum YS, more than 95% of the ultimate tensile strength (UTS) and nearly 90% of the maximum elongation for a given aging condition.

Other studies have investigated the effect of even shorter (0-30 minute) solution-treatment time at 1005°F (540°C) or 1020°F (550°C) on the microstructure and properties of fully modified Al-7wt.%Si-0.3wt.%Mg alloys. In addition, it has recently been demonstrated that common high-pressure diecasting (HPDC) alloys, such as those based on the Al-Si-Cu and Al-Si-Mg-(Cu) systems, may be successfully heat treated without causing surface blistering or dimensional instability. The potential exists therefore to develop and evaluate secondary HPDC alloys designed specifically for rapid heat treatment while still displaying high castability.

Significant improvements in the tensile properties for HPDC alloys may be achieved by a truncated solution treatment of 15 minutes at 915-940°F (490-505°C), quenching and then artificial aging at temperatures in the range of 300-425°F (150-220°C).

Retrogression Heat Treatment (RHT)[4]

Retrogression heat treatment (Fig. 3) is used for improving formability of aluminum extrusions. It is defined as a means of rapidly heat treating 6xxx and 7xxx aluminum alloy extrusions in various tempers, either locally or throughout their length, in order to return to or approach their highly ductile state in their solutionized and freshly quenched state.

For these extrusions in some tempers – such as T4, T5, T6, and even T7, T8, and T9 – RHT involves heating into the solvus temperature range and quenching. Unlike conventional solutionizing heat treatments that involve long times, RHT can be conducted within a matter of seconds and synchronized with a given forming operation. Several commercial applications of the RHT process have already been demonstrated, including forming of aluminum extrusions (Fig. 4) and the forming of heat-treated automotive sheet.

The localized heating and quenching in RHT is applied to materials in high-strength tempers only in regions that will subsequently experience heavy deformation during forming, thus maintaining high strength elsewhere. Although the method of heating in RHT can vary, induction heating has been found to be most reliable and consistent in applying the RHT process to aluminum alloys.

Summing Up

While most heat-treatment processes for aluminum alloys are dictated by specifications (e.g., AMS 2770 or AMS 2771) it is important to understand that ongoing research is looking into ways of reducing cycle times and minimizing costs. Stay tuned. **IH**

References

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