High-strength aluminium material for light weight heat exchanger applications

With the use of conventional brazing materials the request of automotive manufacturers for lightweight materials for applications in high-performance heat exchangers with reduced volume and mass cannot be achieved. As a result of the increase in operating pressures, cooler manufacturers require higher mechanical strength after brazing, good and reproducible processing and forming characteristics of the delivered semi product, as well as excellent brazing results. Aluminium brazing sheet typically consists of a core alloy either of the AA3xxx- or of the AA6xxx- series and a filler layer of an AA4xxx alloy, which has a significantly lower melting range than the core alloy. Alloys of the AA2xxx-series and high strength materials such as AA7050 or AA7075 have not been used as core material for brazing sheets since their solidus/liquidus temperatures are too low. In the early 1980s LongLife alloys based on AA3xxx were developed in order to meet the demands for higher strength and improved corrosion resistance prevailing at that time [1]. In the early 1990s a multilayer material compound was presented to enhance mechanical strength and corrosion resistance of brazing sheet. The sacrificial anode material enriched in magnesium and zinc increases the strength of the 3xxx core alloy by diffusion phenomena [2].

In Figure 1 typical mechanical properties of currently available brazing materials in pre- and post braze condition are compared. The post brazed yield strengths $R_{p0,2}$ for standard non-heat treatable 3xxx materials range from 35 to 55 MPa; the values for LongLife alloys vary from 55 to 65 MPa. Depending on the cooling rate after brazing heat treatable 6xxx series alloys achieve post brazed yield strengths $R_{p0,2}$ of 70 to 85 MPa in naturally aged condition. The mechanical characteristics of these materials are often insufficient for the future stipulations of the automotive industry. This article is based on the development of a high-strength, heat treatable brazing sheet with an AA7020 core alloy [3].

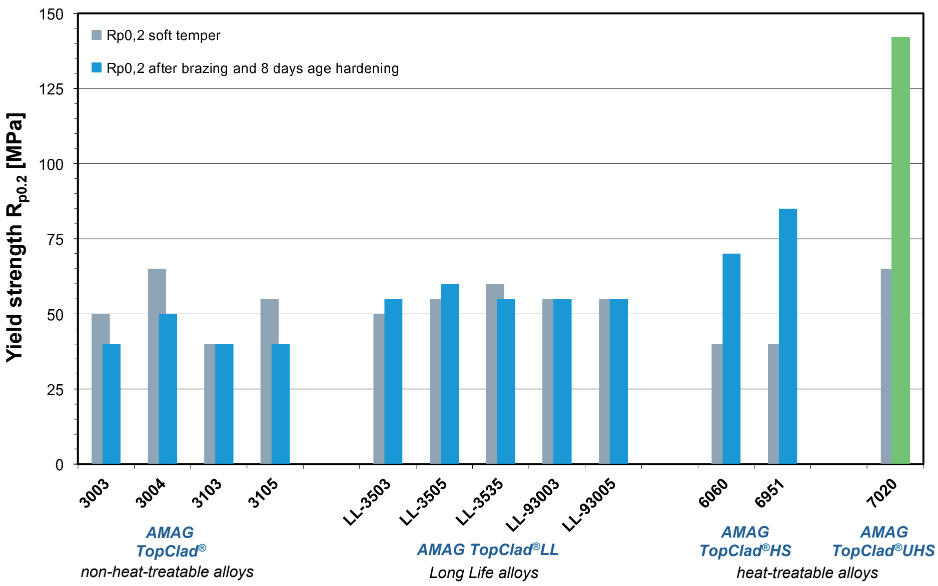

Figure 1: Yield strength $R_{p0.2}$ of AMAG TopClad® products

Characterization of AA7020 brazing sheet

The AA7020 alloy belongs to the heat treatable Al-alloys and is characterized by high static strength. The combination of zinc and magnesium results in age hardening and thus in strength levels which exceed those of standard brazing alloys by far. The strength is mainly a function of Zn and Mg; the aging effect depends on the Zn/Mg ratio.

The chemical composition of AA7020 is given in Table 1 [4, 5]. To prevent a detrimental diffusion of Mg into the clad filler during brazing on an additional cladding of an interlayer is required. In this paper results with AA1050 interlayer are described.

Table 1: Chemical compositions of AA7020 and AA1050

designation	%Si	%Fe	%Cu	%Mn	%Mg	%Zn	%Ti
AA7020	0.35	0.40	0.20	0.05 – 0.50	1.0 – 1.4	4.0 – 5.0	0.05
AA1050	0.25	0.40	0.05	0.05	0.05	0.07	0.05

Post-braze strength

Alloy AA7020 gains its high strength after brazing due to solution heat treatment and natural aging. Parallel to joining during the brazing process solution annealing also occurs at brazing temperature. Precipitates are formed by nucleation and growth from a supersaturated solid solution during room temperature aging. In order to achieve optimum strength characteristics, the majority of heat treatable aluminium alloys have to be subjected to solution annealing in a relatively narrow temperature range, however, this does not apply to AA7020. This favorable behavior allows optimized process control for both solution heat treatment and brazing in a single heating operation. As the quenching sensitivity of AA7020 is low, the cooling speed after brazing can be varied to a high degree without subsequently affecting natural room temperature age hardening.

As shown in Figure 2, the AA7020 material achieves a yield strength $R_{p0.2}$ of 65 MPa in soft temper, which after brazing can rise to over 140 MPa with ongoing room temperature aging. Higher strengths and improved corrosion resistance are obtained by artificial aging at 115 to 130 °C.

Mechanical properties at elevated temperatures

After brazing (i.e. after solution heat treatment) heat exchangers are exposed to temperatures up to 160 °C in service. To simulate the material characteristics at operating temperatures artificial aging of AA7020 brazing sheet was initiated after 8 days of natural aging. These aging curves are shown in Figure 3. At the very beginning of artificial aging the strength drops due to a reversion process [4, 5]. Higher temperatures and longer aging times lead to a loss of strength due to overaging.

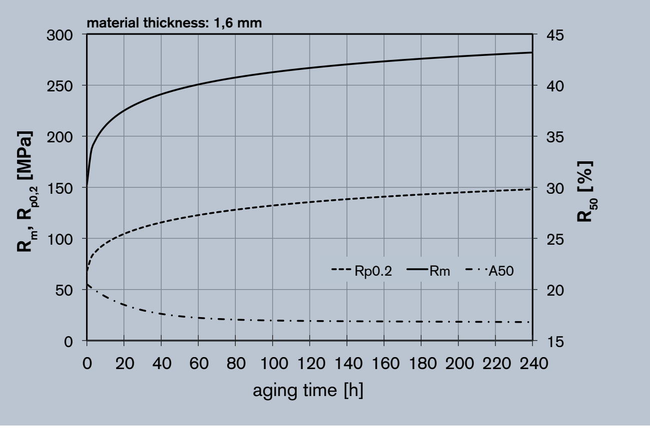

Figure 2: Natural age hardening process AA7020 brazing sheet

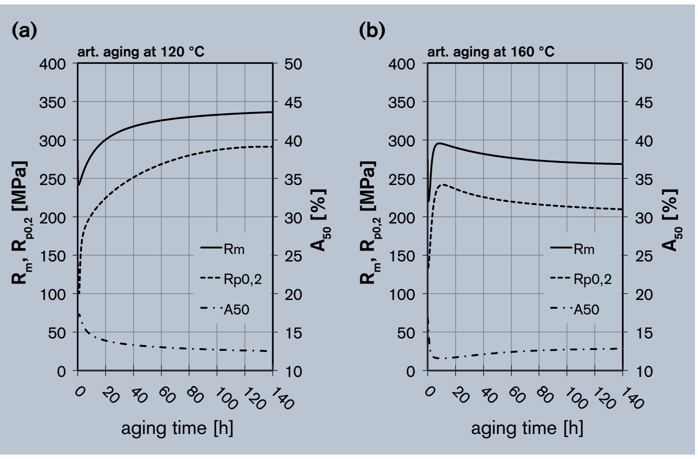

Figure 3: Artificial age hardening of 1,6 mm AA7020 brazing sheet at 120°C (a) and 160 °C (b)

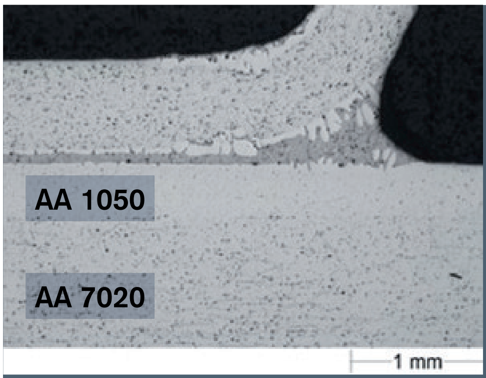

Figure 4: Proper brazing results due to sufficient AA1050 diffusion barrier

Customer benefits of AA7020 clad brazing sheet for base plates

Alloy AA7020 exhibits proper shearing and stamping characteristics and is hence a premium option for plate-type heat exchangers. Oil coolers use planar base plates of AA3xxx-, AA5xxx- or AA6xxx-alloys in a thickness range of typically 2.5 to 6.5 mm which could be reduced significantly by use of high strength AA7020 brazing sheet. Due to the high hardness of ~55 HB in soft temper the high strength material shows excellent scratch resistance against mechanical defects. This property is advantageous especially in the sealing area between the engine block and the oil cooler, an area which is critical with respect to leakages (Figure 4).

All standard Al-Si filler alloys for vacuum and flux agent based brazing processes can be cladded as long as the working temperature does not exceed 600 °C. As demonstrated in Figure 4 the diffusion barrier avoids the diffusion of Zn and Mg and also the melting of low melting phases. The corrosion resistance of AA7020 brazing sheet for base plates is sufficient since the diffusion barrier made from AA1050 with more than 150 µm thickness also acts as a corrosion protection layer.

Literature:
[1] Gray, A.; Aluminium in automotive heat exchangers – closing the technology gap, 8th international brazing seminar, 2004.
[2] Yamauchi, S., et al; Clad aluminum allay material having high strength and corrosion resistance for heat exchanger, US 5292595A, 1993.
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[4] Aluminium-properties and physical metallurgy, AMS, 2005, pp. 175-185.
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