The Growth of Aluminium in Automotive Heat Exchangers

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Since the introduction of long-life alloys back in the early 1980's, suppliers of aluminium brazing sheet products have embarked on a process of continuous improvement and new developments to keep pace with increasing challenges set by the OEM's. In particular the need to downsize and lightweight. While alloys like AA3003 and AA3005 are still used for many applications in automotive heat exchangers, long-life alloys have now become 'the norm' for the majority of radiator tube and evaporator plate applications.

1. Market Trends

Since the mid-eighties, when environmental pressures made it clear that light-weighting of passenger cars would be a key factor in reducing greenhouse gas emissions and improving fuel efficiency, the aluminium content per vehicle has nearly doubled.

By 2005, it is estimated that virtually 100% of all radiators, heater cores and evaporators will be manufactured from aluminium. In North America aluminium has already achieved 100% penetration. It has been calculated that a saving of some 20 kg of CO_2 emissions can be achieved for each kilogram of weight saved in the vehicle. Currently, of the approximately 130 kg of aluminium in the vehicle, the heat exchanger components account for about 14 kg.

2. Key Property Requirements

With industry drivers such as light-weighting, reducing the envelope size and cost reduction, there has been a clear need for higher strength alloys. However, as down-gauging of materials increases, in particular tubestock, the need for an improvement in corrosion performance is required. Therefore, improving the corrosion resistance of Al-Mn based alloys became the focus of many alloy development programs back in the late seventies and early eighties and is still continuing.

3. Alloy Developments

It is well known that aluminium alloys can be strengthened by a number of mechanisms, namely: particle dispersion hardening; solute hardening; age hardening precipitates; and grain size reduction.

Summarised in Table 1 are the post-brazed (CAB) strength ranges that can be achieved with the generic alloy options discussed earlier.

4. Manufacturing Developments

In addition to extensive alloy development programs, some suppliers have developed novel methods for cladding onto continuously cast core alloys and producing clad ingots in-situ. As far back as 1984, Alcan had patented a system for cladding in-line on their belt caster (FlexCaster®), and this was followed by Reynolds and Alcoa who utilised a twin roll caster (TRC) approach to produce clad products. As with all TRC products, there are still some outstanding issues with products where formability is a key requirement. In addition to the cladding on-line developments, Corus and Alcoa have developed modified casting processes to produce clad in-situ ingots.

5. Future Challenges

Overall, the response of the material suppliers to the challenges presented by the new designs of heat exchanger components/systems and government legislation - ‘closing the technology gap’ – has been good. Without the strength increases and improvements in corrosion resistance, the down-gauging achievements would not have been attainable.

However, there still remains a ‘technology gap’ between the needs of the industry and current materials performance availability. OEMs will continue to encourage suppliers to produce multi-functional alloys that are stronger and have better fatigue resistance. Yet, irrespective of materials performance, there will always be the pressure to reduce the manufacturing and raw materials costs. It is easy to foresee some conflict when the pressure for the recycleability/re-use of heat exchanger units increases at the vehicle ‘end-of-life’. One major challenge for the industry, which could have a major impact on material costs, is progress in the standardisation of brazing sheet products used in automotive heat exchangers.

Alloy Type	Post-brazed yield MPa & (ksi)
AA3003 & AA3005	35 - 45 (5.1 – 6.5)
Long-life mkI (sacrificial band)	50 – 55 (7.2 – 8.0)
Long-life mkII (sacrificial band)	65 –70 (9.4 – 10.1)
Ultra long-life (sacrificial band + Ti)	55 – 60 (7.2 – 8.7)
Long-life (Ti layering)	55 – 65 (8.0 – 9.4)
Multiclad	70 – 75 (10.1 – 10.9)
Heat treatables (6xxx series)	75 - >85 (10.9 - >12.3)

Table 1 Post-brazed yield strengths of brazing sheet alloy variants

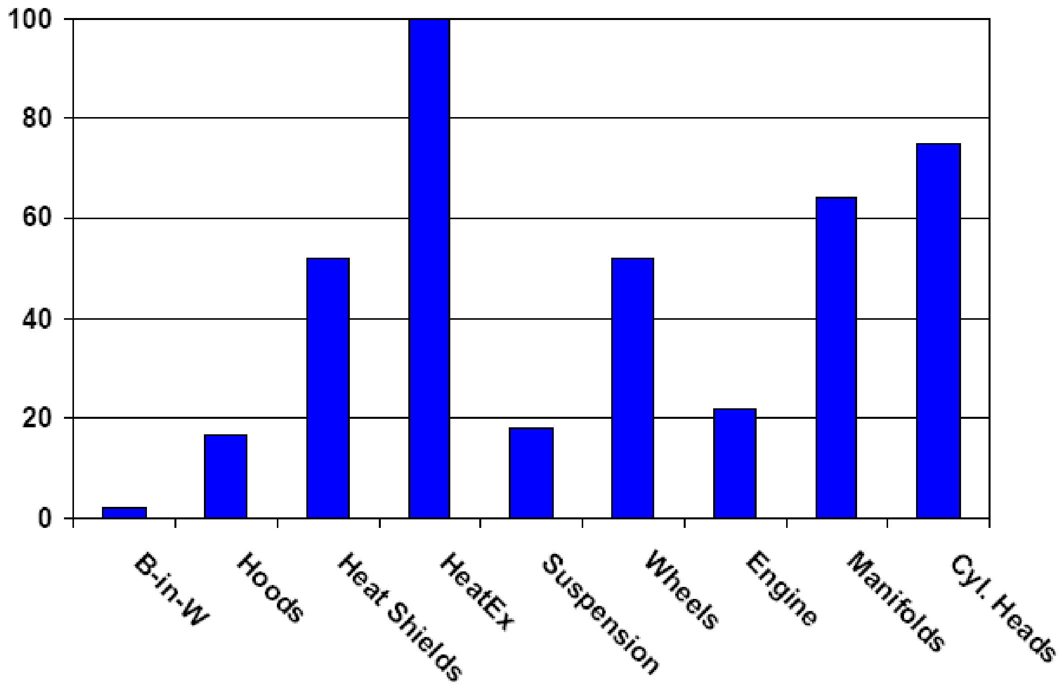

Figure 1 Aluminium Component Penetration % (US): source: Ducker Research

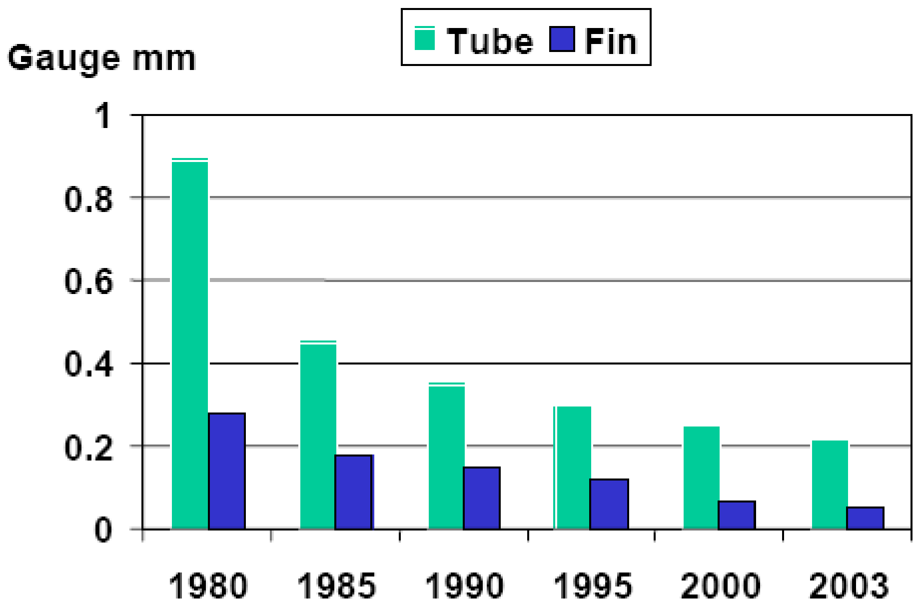

Figure 1 Downgauging trends in tube and finstock alloys