Overview: Brazing With (NiCoCr)-B-Si Amorphous Brazing Filler Metals: Alloys, Processing, Joint Structure, Properties, Applications•

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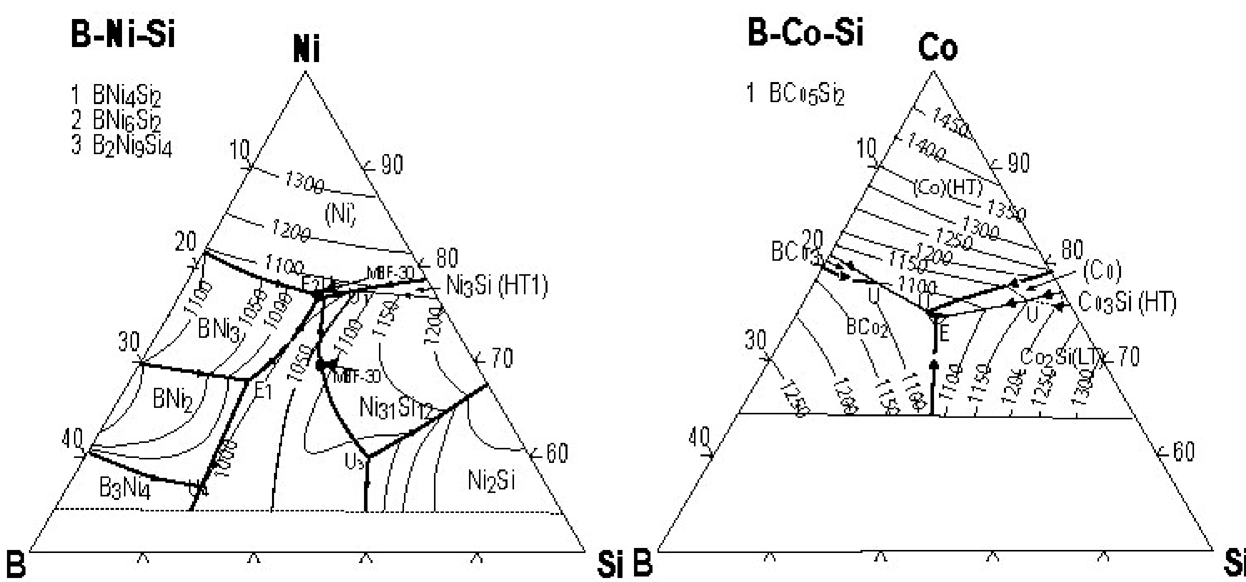
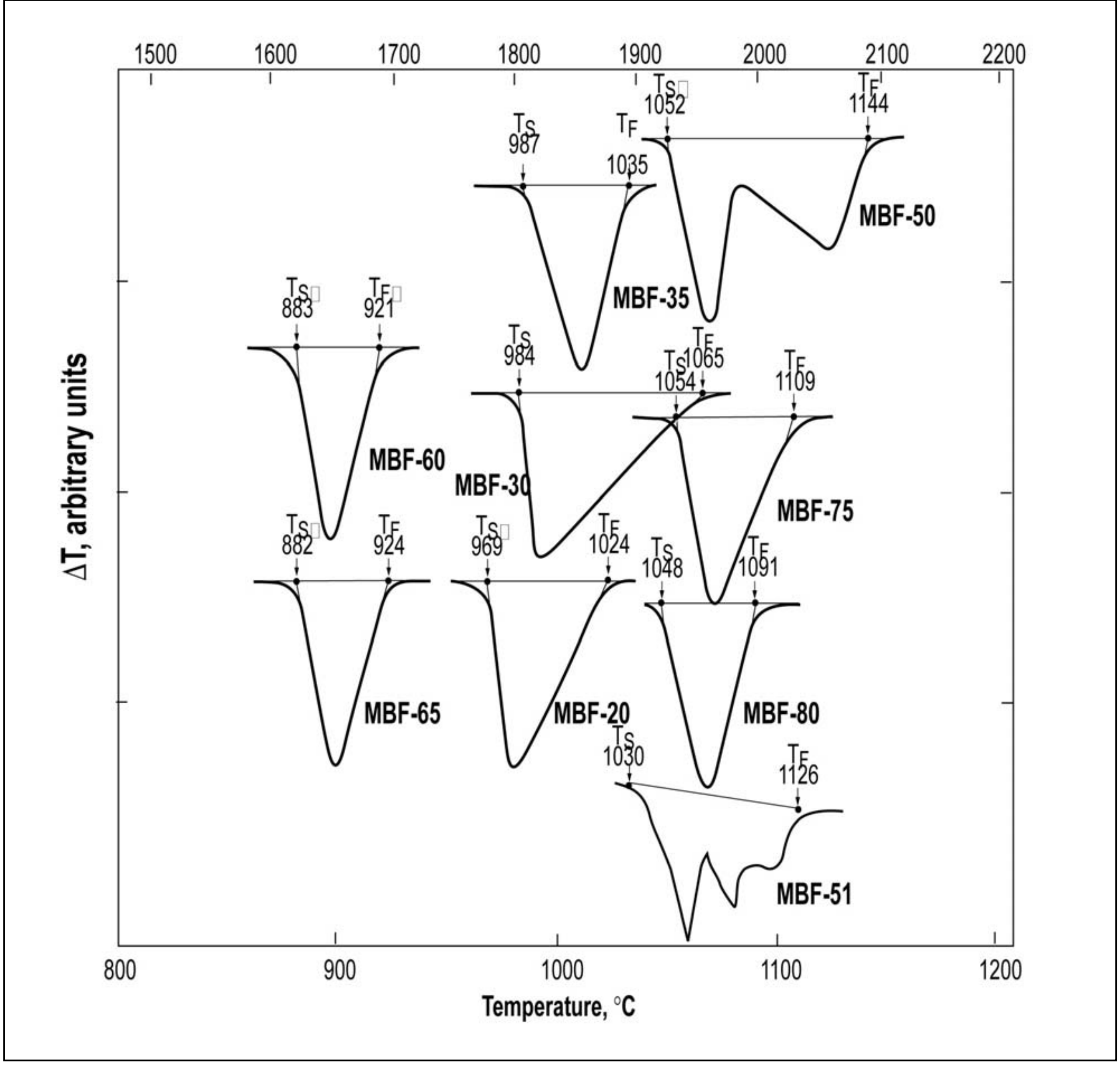
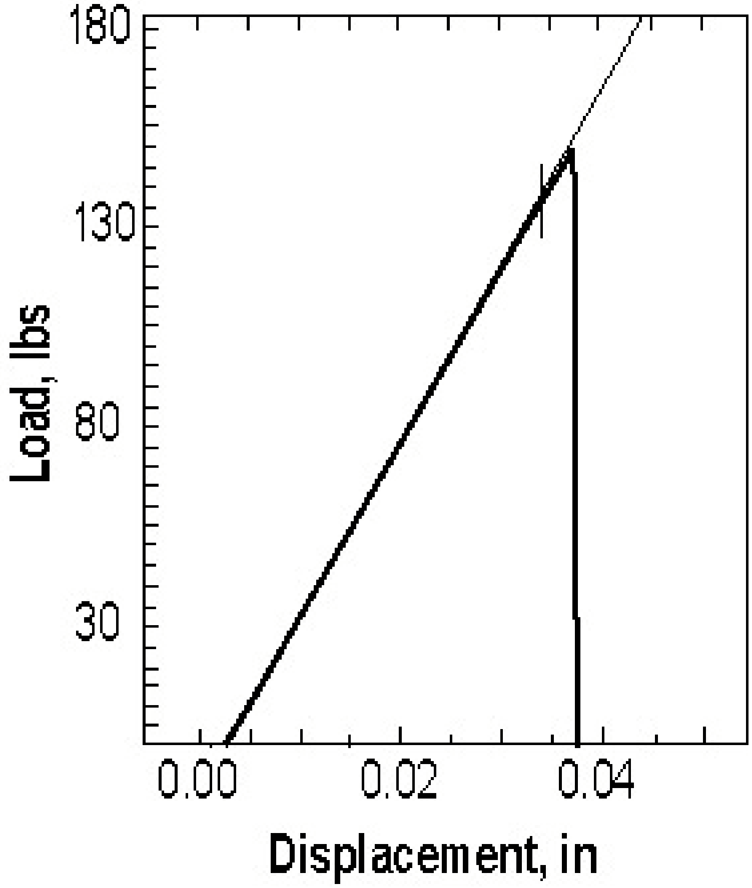
Appendix



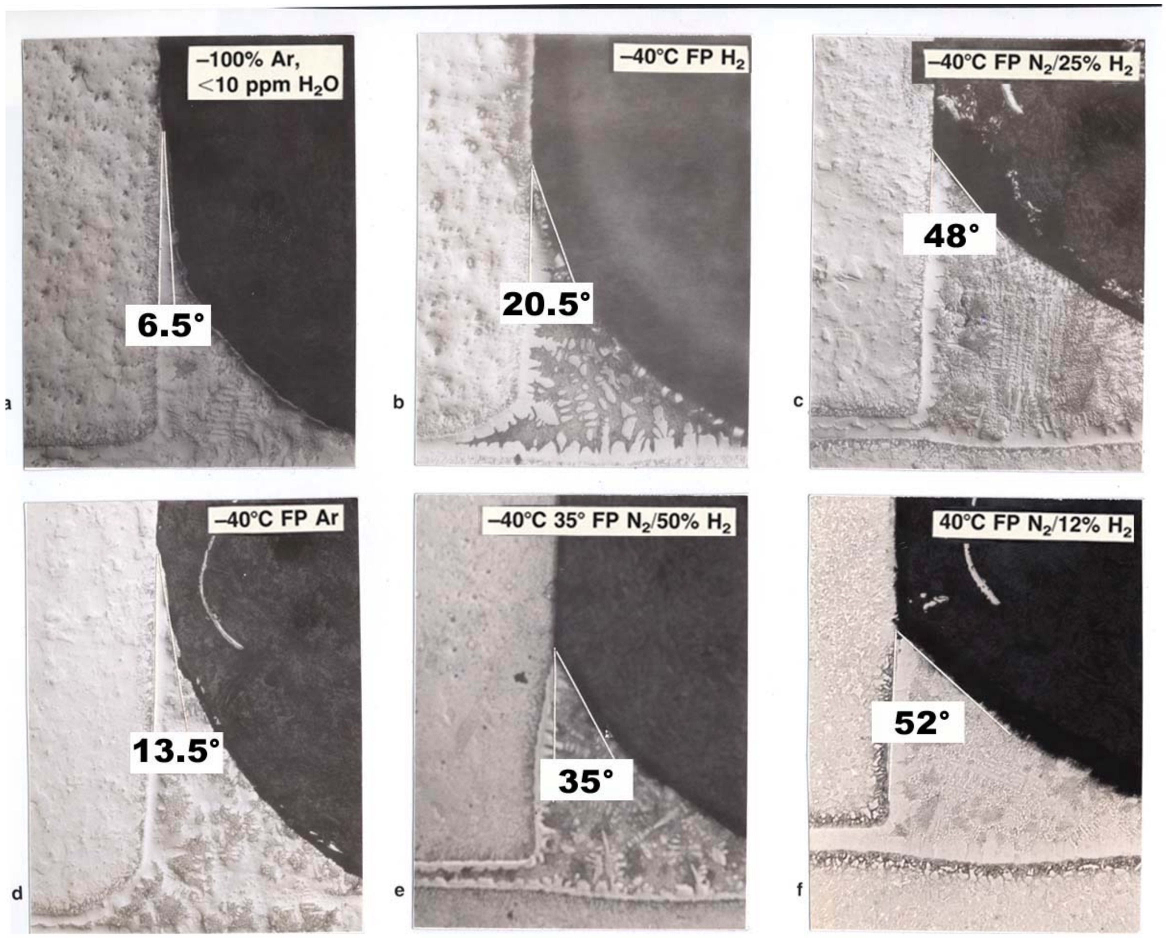
1. Liquidus projections of Ni-B-Si and Co-B-Si phase diagrams[11] and locations of MBF-30 and –35 alloy compositions.



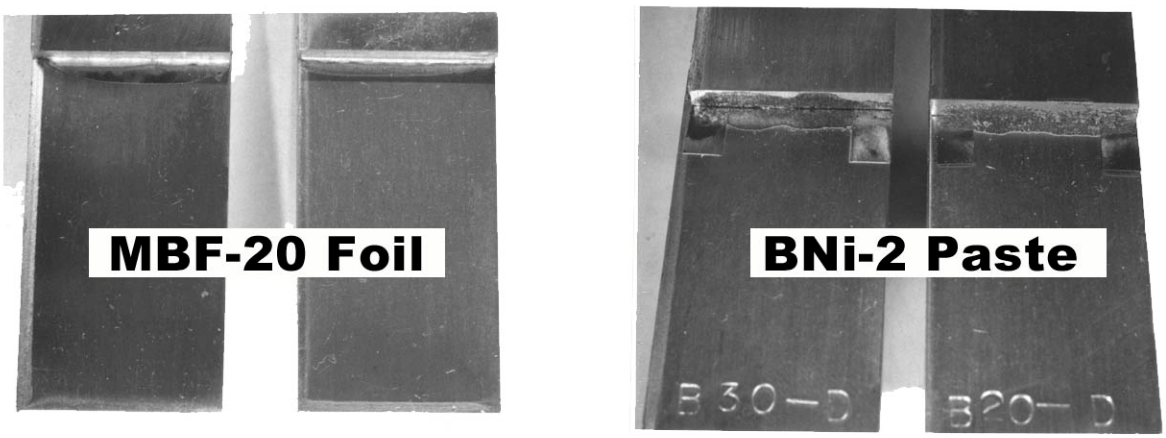
2. DTA melting troughs of some MBF alloys.



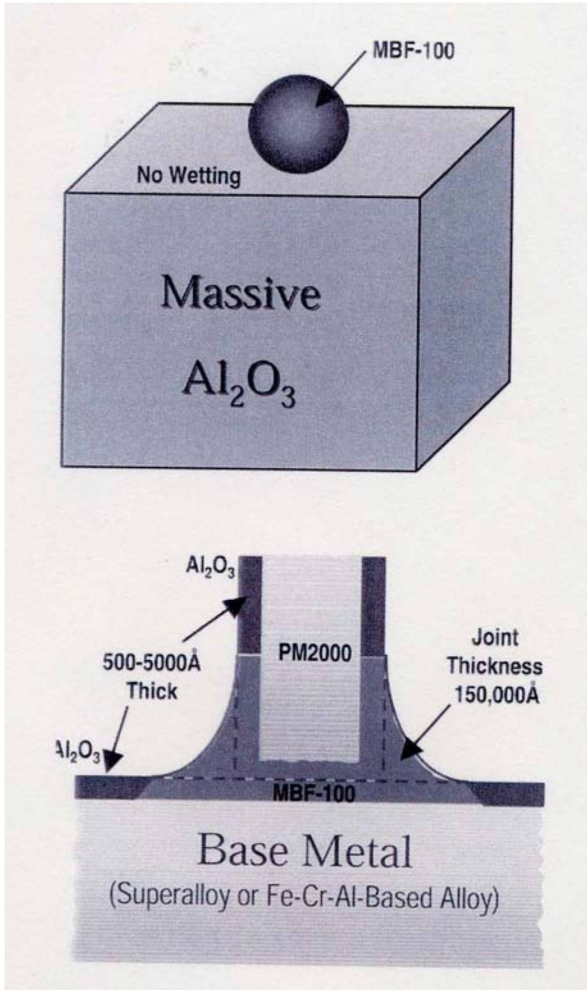
3. Typical load/displacement graph of an MBF-51 specimen in the as-cast state that was mechanically tested with 2.5 mm/min loading rate at 25 °C.



4. Contact angles formed by MBF-20 alloy on the vertical part of the T-type 409 stainless steel joints brazed under various atmospheres at 1115°C for 10 min. (100X).[20]

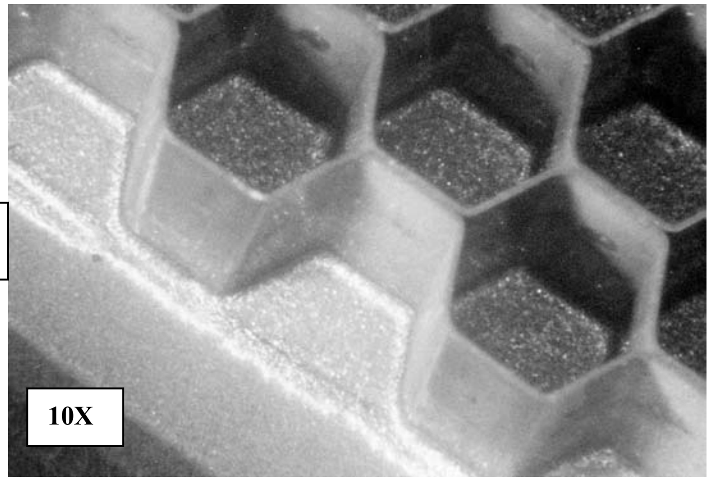


5. Fillets formed by MBF-20 foil and BNi-2 paste on 409 stainless steel joints brazed under -40°C FP 50:50 N_2: H_2 atmosphere at 1115°C for 10 min. Note incomplete flow and crevices formed on a sample brazed with the paste.

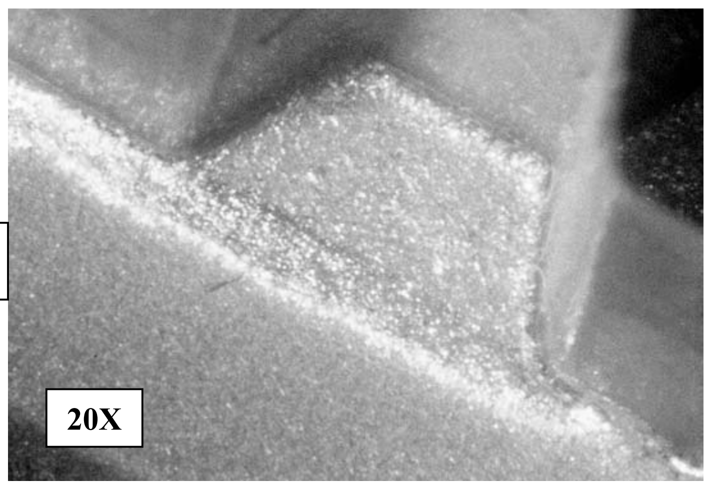


6. Schematics of wetting mechanisms acting during MBF interaction with a massive alumina sample and a base metal part covered by an inherent alumina/titania oxide film.

a

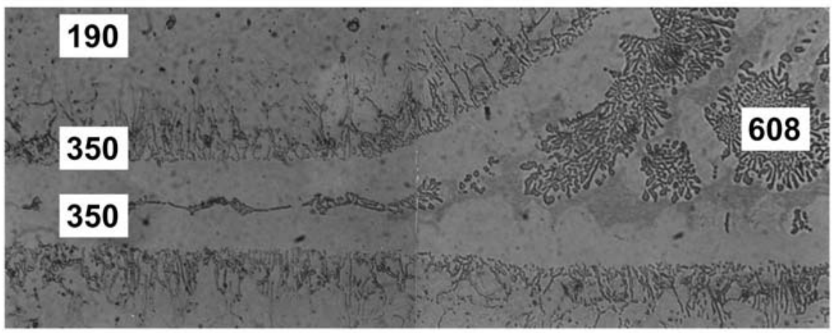


b

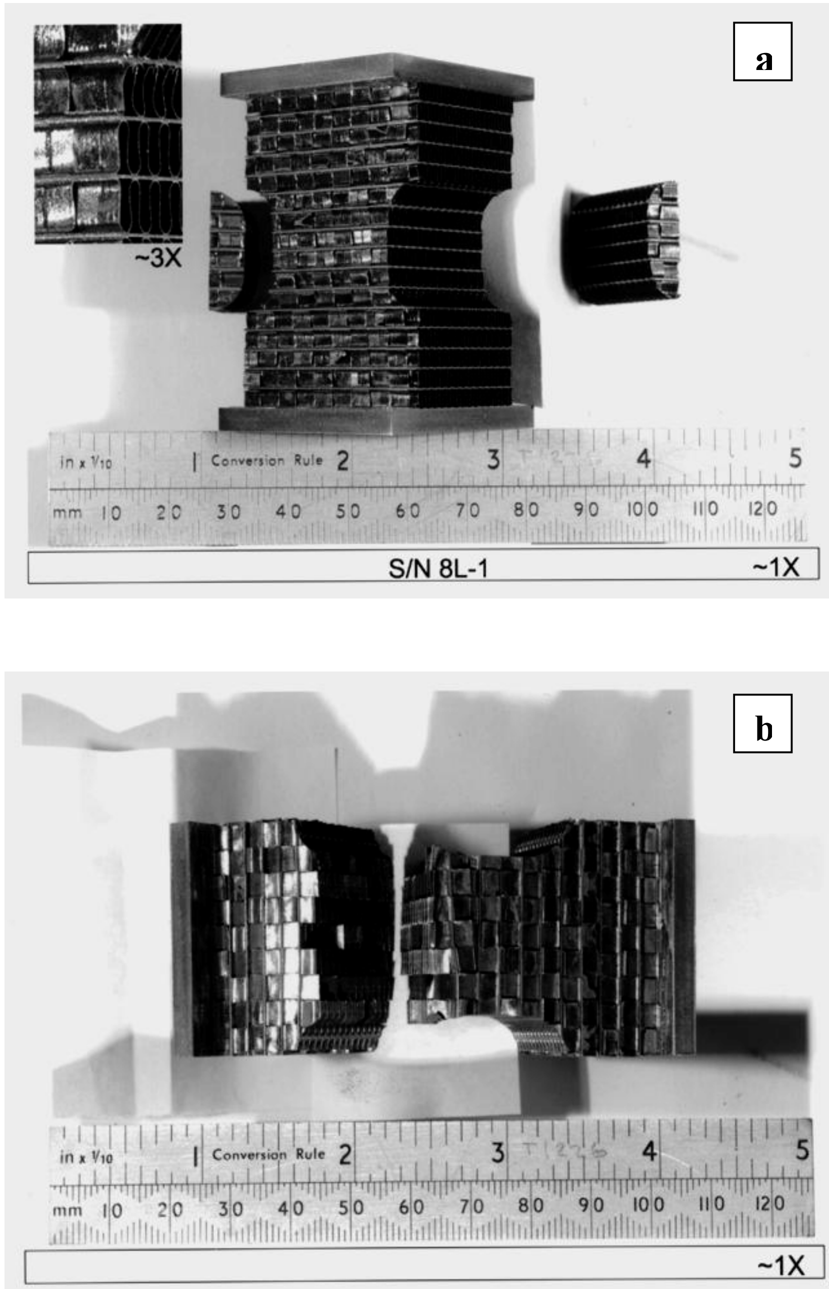


7. IN-738/MBF-100/PM2000 brazed honeycomb turbine seal as viewed for the top (a) and from the side (b). Complete wetting of flat IN-738 surface and formation of very good fillets at PM2000 cell is observed.

8. Various preforms from MBF ribbons stamped into intricate shapes (white arrow) and photoetched to form multiple small holes or sophisticated profiles (black arrows).

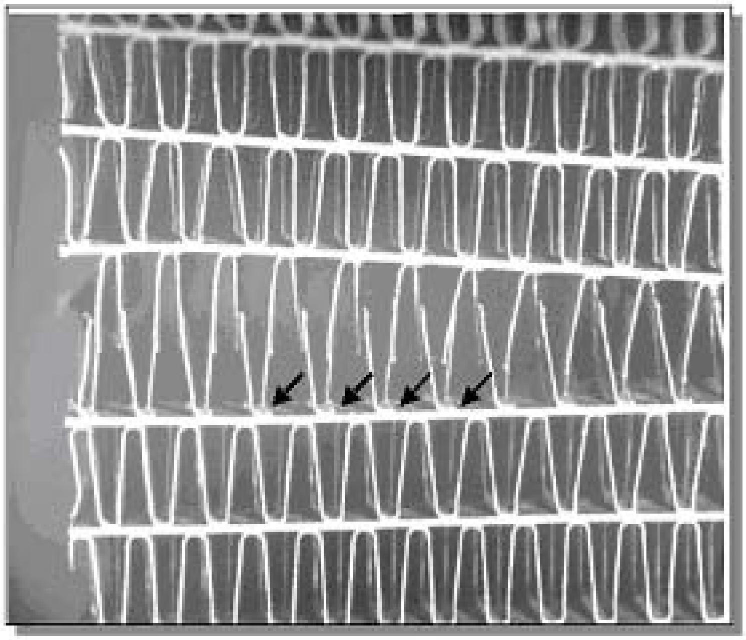


9. Micrograph of a 409/MBF-20/409 joint brazed at 1055°C for 10 min under 50:50 N_2/H_2 atmosphere having -40°C FP. Numbers indicate Vickers microhardness, kg/mm^2 of some joint area.



10. Samples of brazed plate/fin 436 stainless steel structures: (a) In the as-brazed state after electroerosion cutting; (b) After failure under mechanical testing in the tensile mode at 650°C.

a



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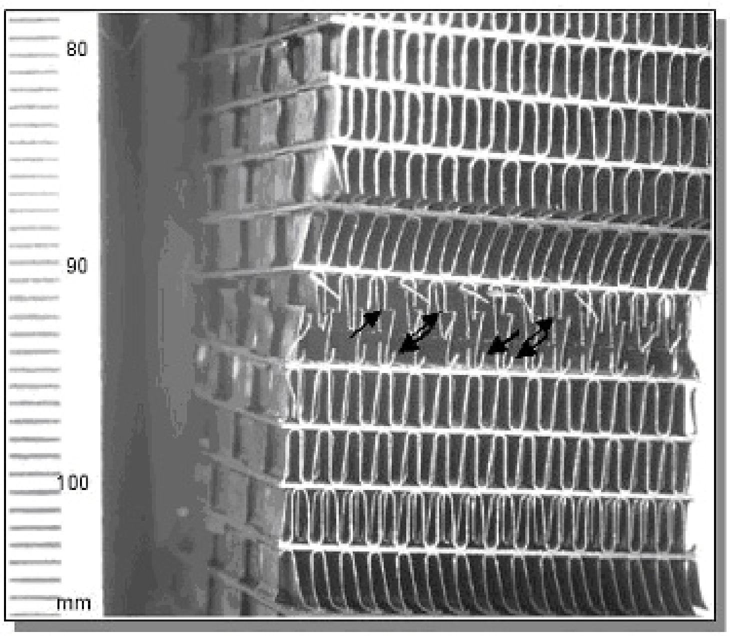
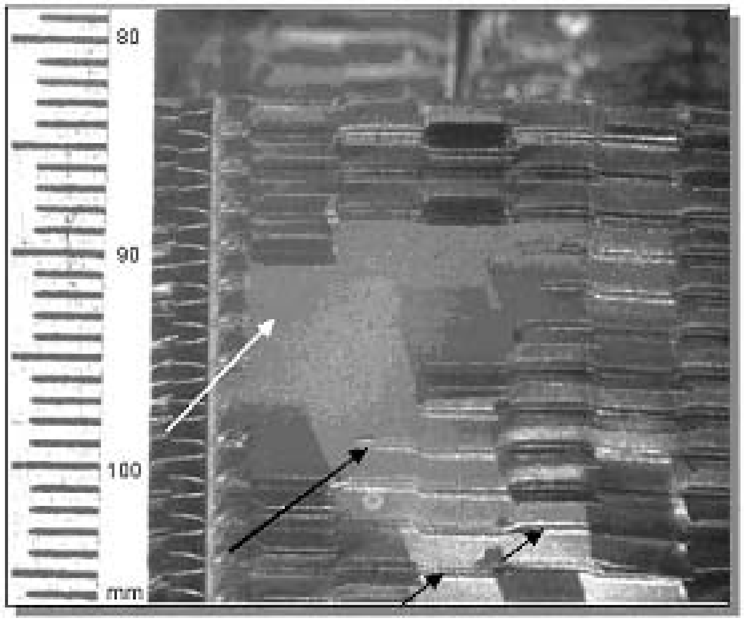


11. Samples of 436 stainless steel plate/fin structure after failure under tensile mechanical testing at 25°C. (a) 25-μm thick MBF-20 foil: Failure occurred in the lean fillets (arrows) formed due to too thin foil used. (b) 50-μm thick MBF-20 foil: Failure occurred in the middle of the fin base metal (arrows) due to large and sufficiently strong joint cross-sections formed using thick brazing foil.[13]

a



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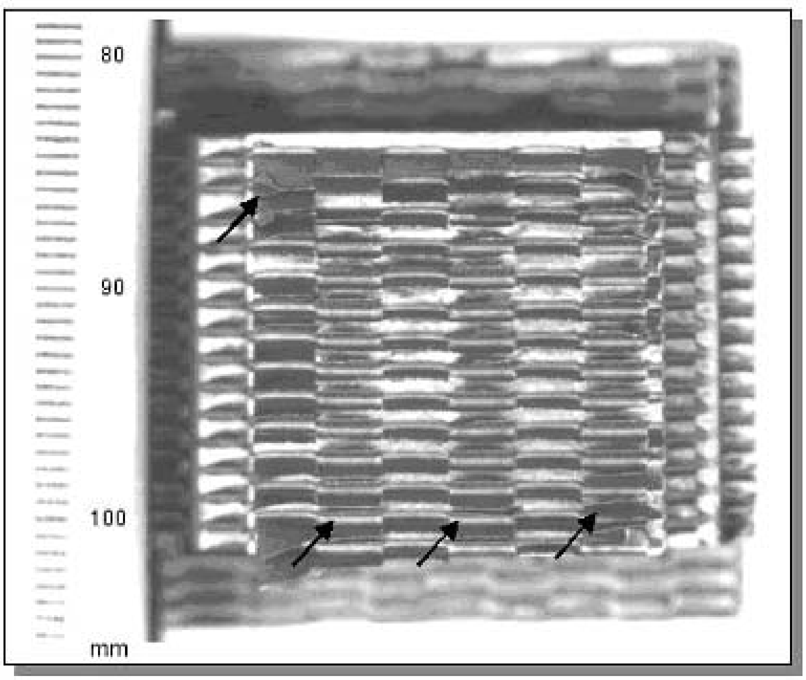
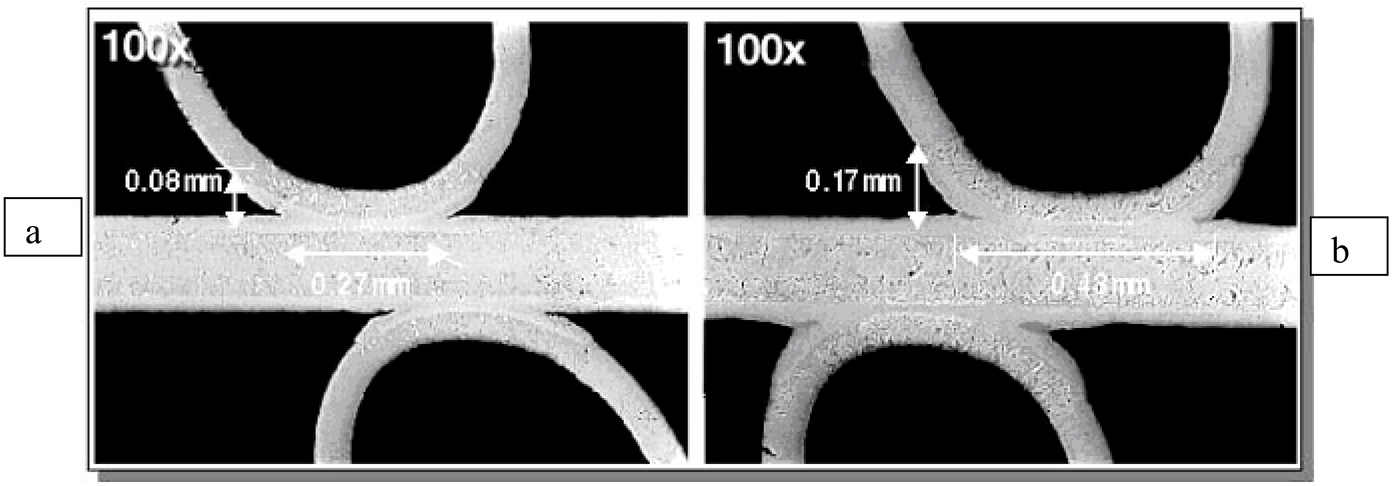
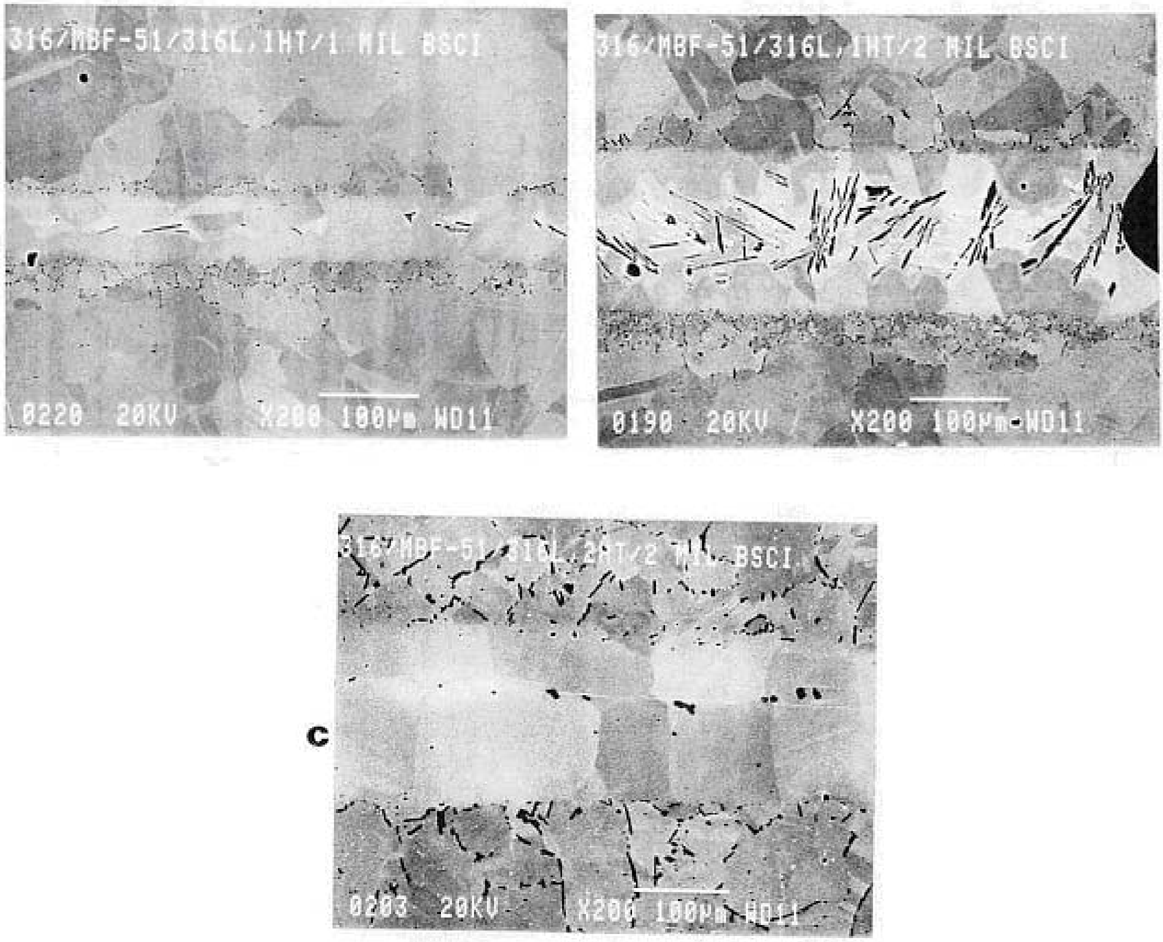


12. Samples of 436 stainless steel plate/fin samples after tensile testing: (a) 25-µm thick MBF-20 foil. Unbrazed area is seen (white arrow). Note that failure occurred in the lean fillets (black arrows). (b) 50µm MBF-20 foil: Failure occurred in the middle of the fin base metal (arrows) due to a large cross-section formed using sufficiently thick brazing foil.



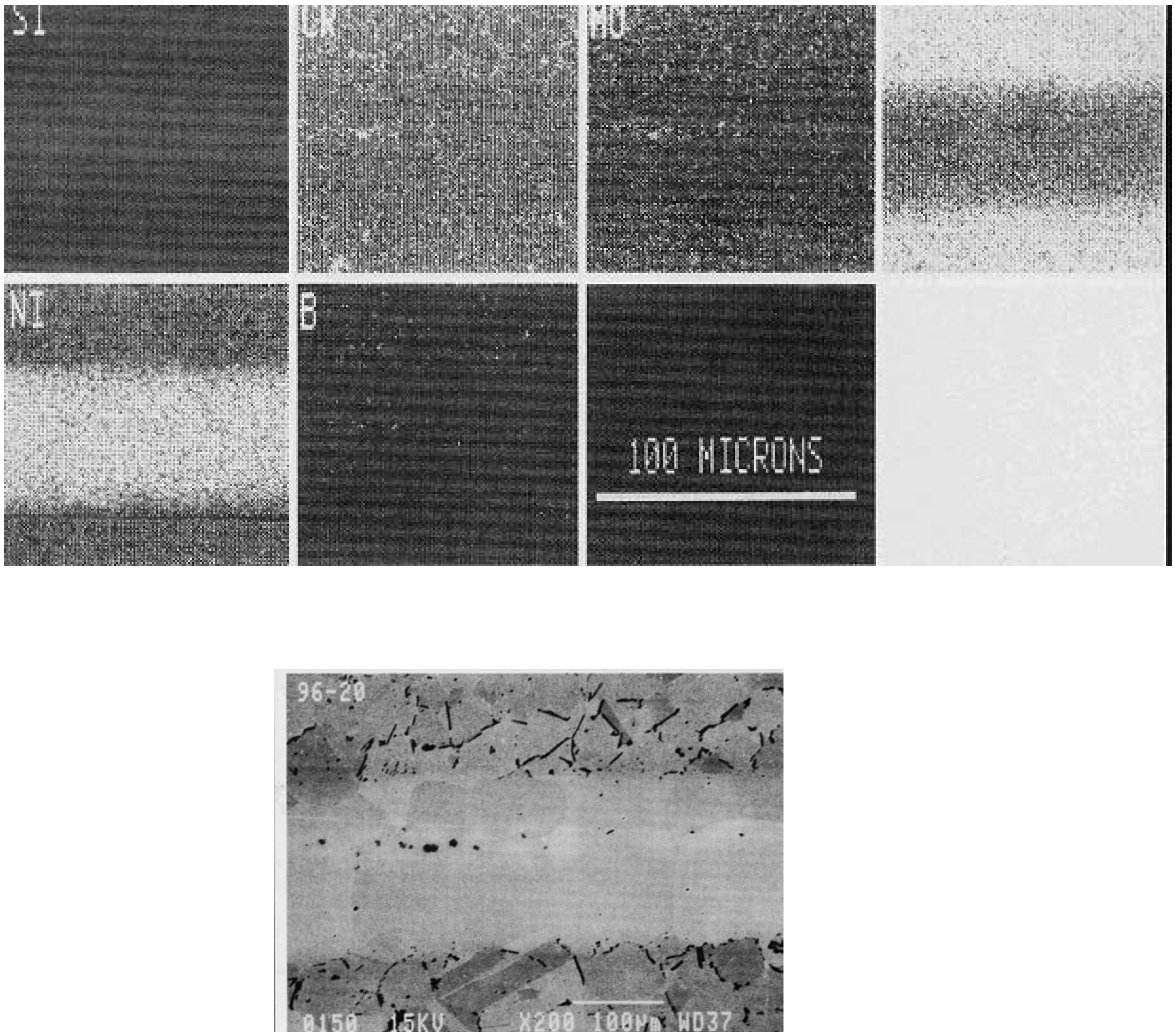
13. Microstructure of two 436 stainless steel plate/fin samples brazed using 25 μm thick (a) and 50-μm thick (b) MBF-20 foil. Note that while inside of the brazes the joint thickness is the same, the cross-section of the 50-μm joint is larger than that of the 25-μm joint. The former is wider and the fillet height is higher. Therefore, the 50-μm joint is substantially stronger.[13]

a b



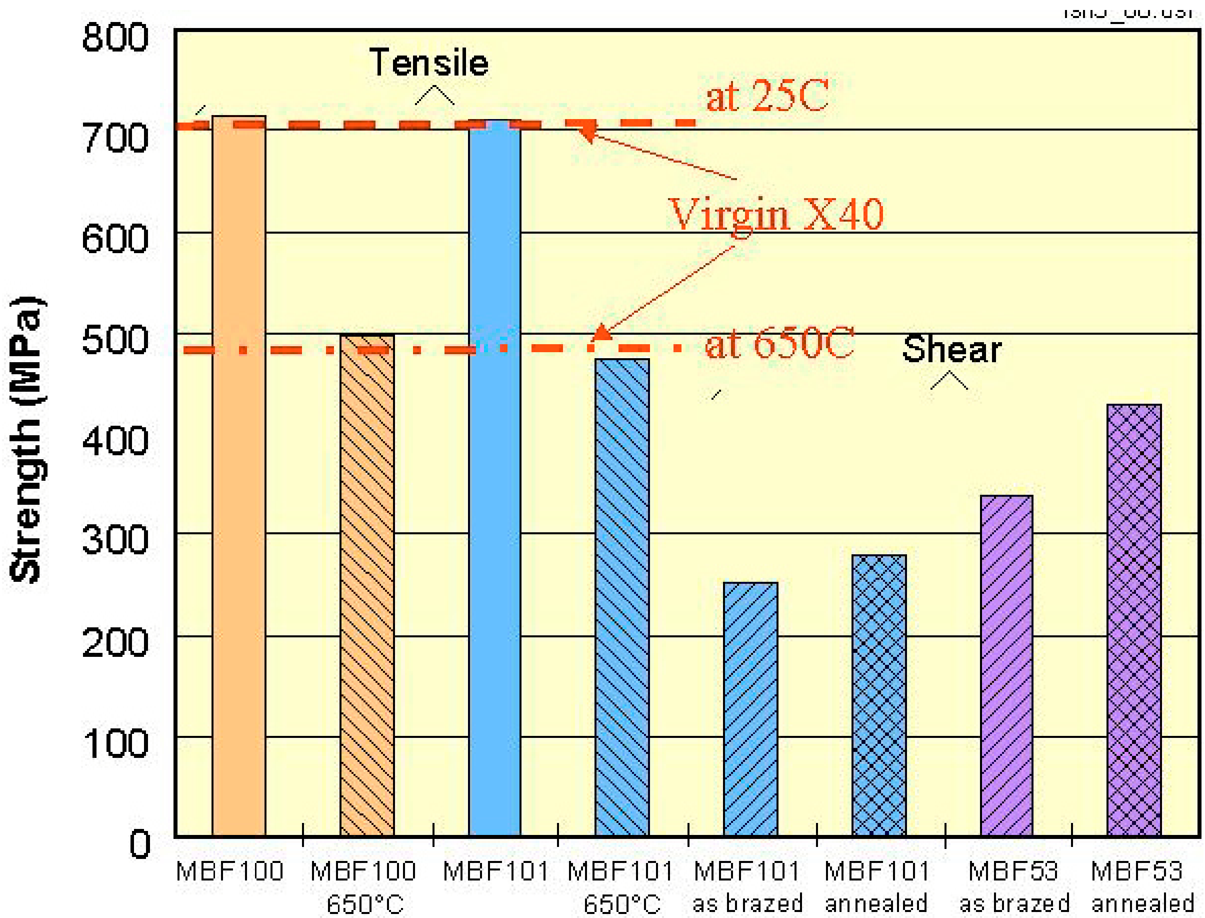
c

14. SEM micrograph of 316/MBSF-51/316 joints brazed using 25 (a) and 50 μm (b) thick MBF-51 ribbon and a short brazing cycle; 50 μm foil and a long brazing/annealing cycle were used in joint shown in (c). Note that a strong ductile single phase braze was formed when there was a small amount of boron in the joint and/or a long brazing time is used.[17]

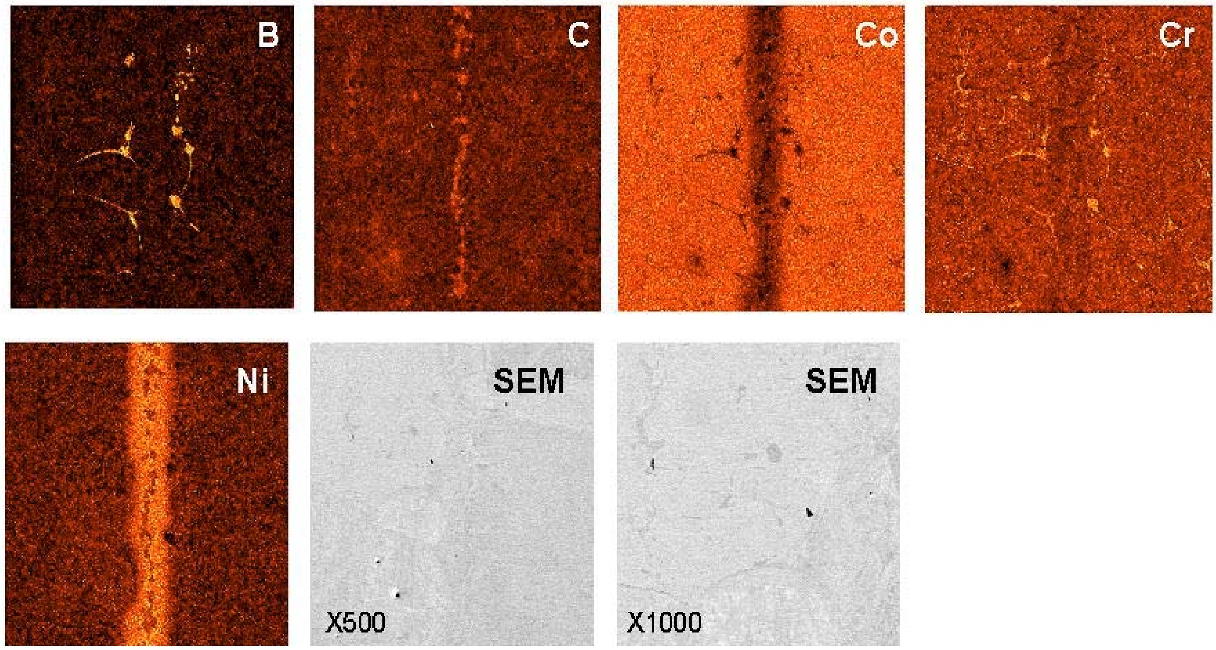


15. SEM micrograph and corresponding x-ray elemental maps of a 316L/MBF-51/316L joint brazed with 2-mil thick foil using a long term brazing cycle. The braze has practically a single-phase (NiCrFeSi) solid solution structure. Boron is diffused into the base metal interface area forming segregated Cr_xB_y intermetallic crystals at the grain boundaries.[17]

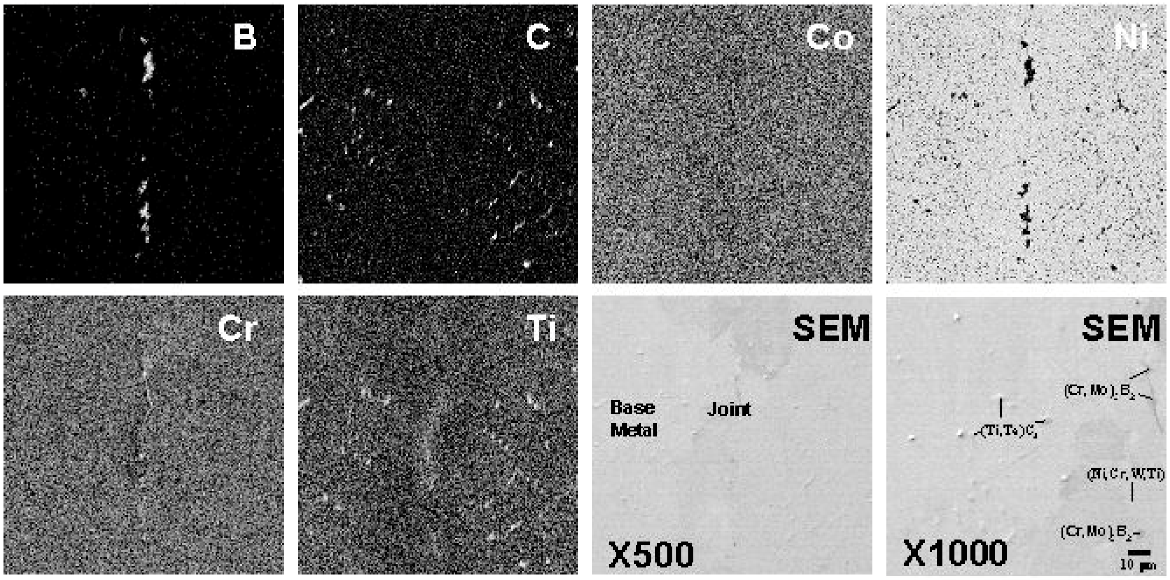
16. SEM micrograph of an IN625/MBF-51 joint after a 90-min brazing cycle at 1155°C in vacuum with slow heating and cooling stages to avoid cracking induced by thermal stresses.



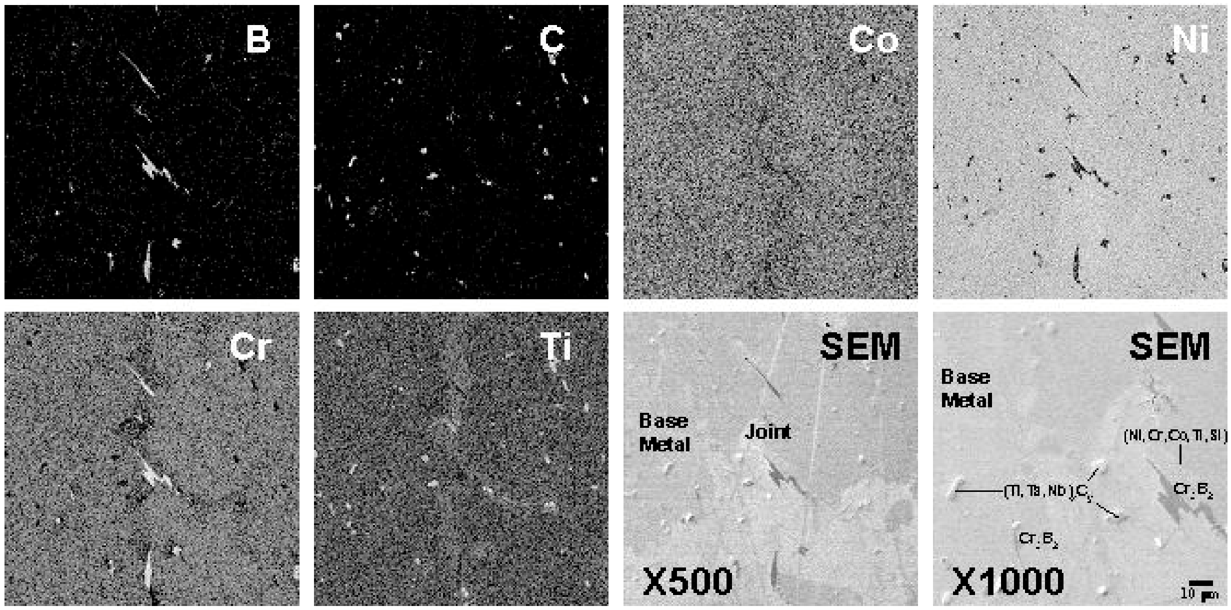
17. Tensile and shear strength of X40/MBF-series alloy joints at 25 and 650°C.[26]



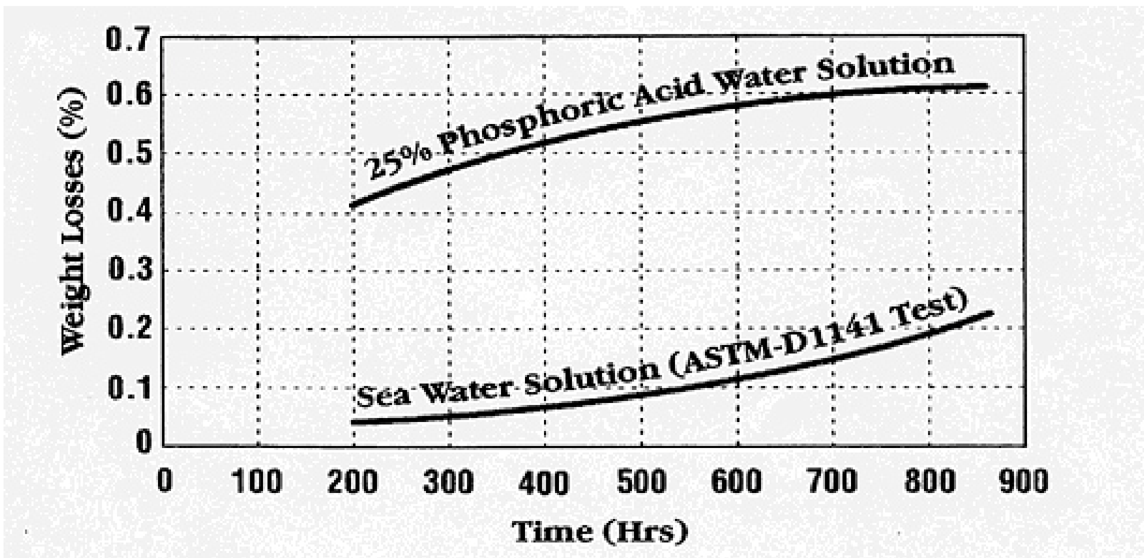
18. Microstructure of and elemental distribution in a X45/MBF-53/X45 joint brazed at 1170°C for 15 min and annealed at 1070°C for 6 hours.



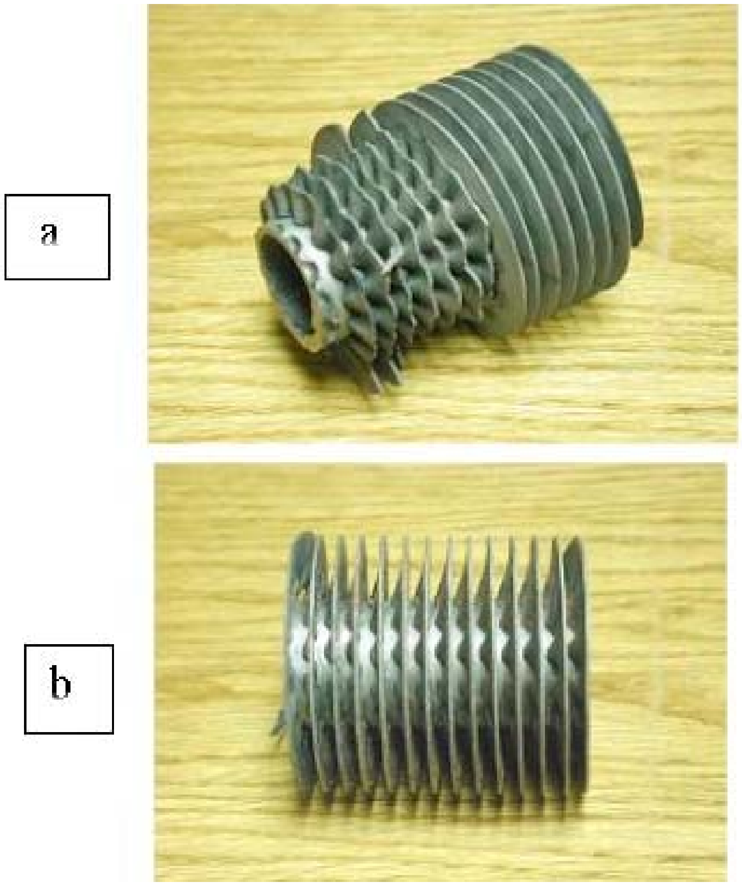
19. Microstructure of and elemental distribution in IN738/MBF-53/IN738 joints brazed at 1170°C for 15 min and annealed at 1070°C for 6 hours.



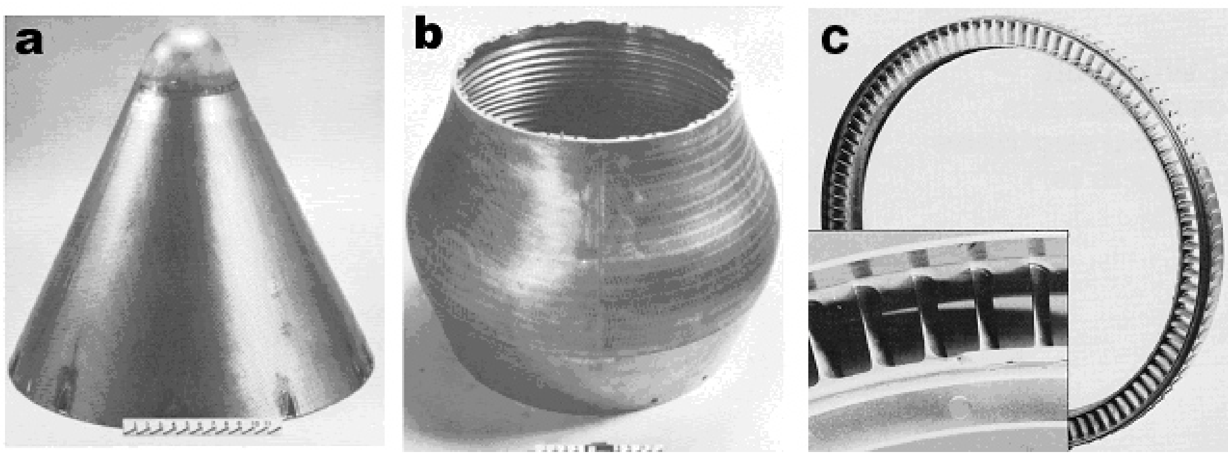
20. Microstructure of and elemental distribution in IN939/MBF-53/IN939 joints brazed at 1170°C for 15 min and annealed at 1070°C for 6 hours.



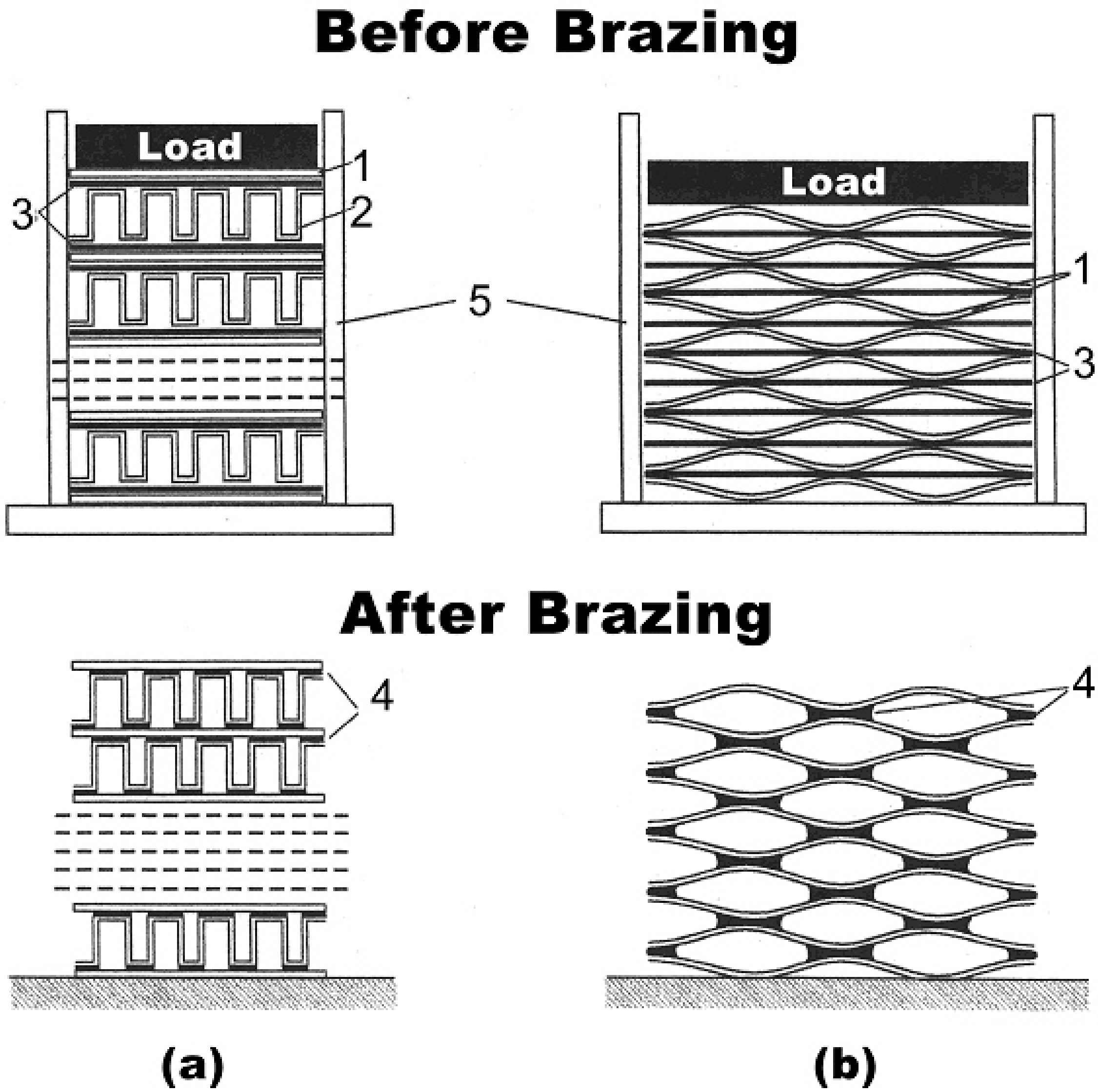
21. Weight losses of 316/MBF-51/316 Joints in a 25% water solution of phosphoric acid and sea water[17].



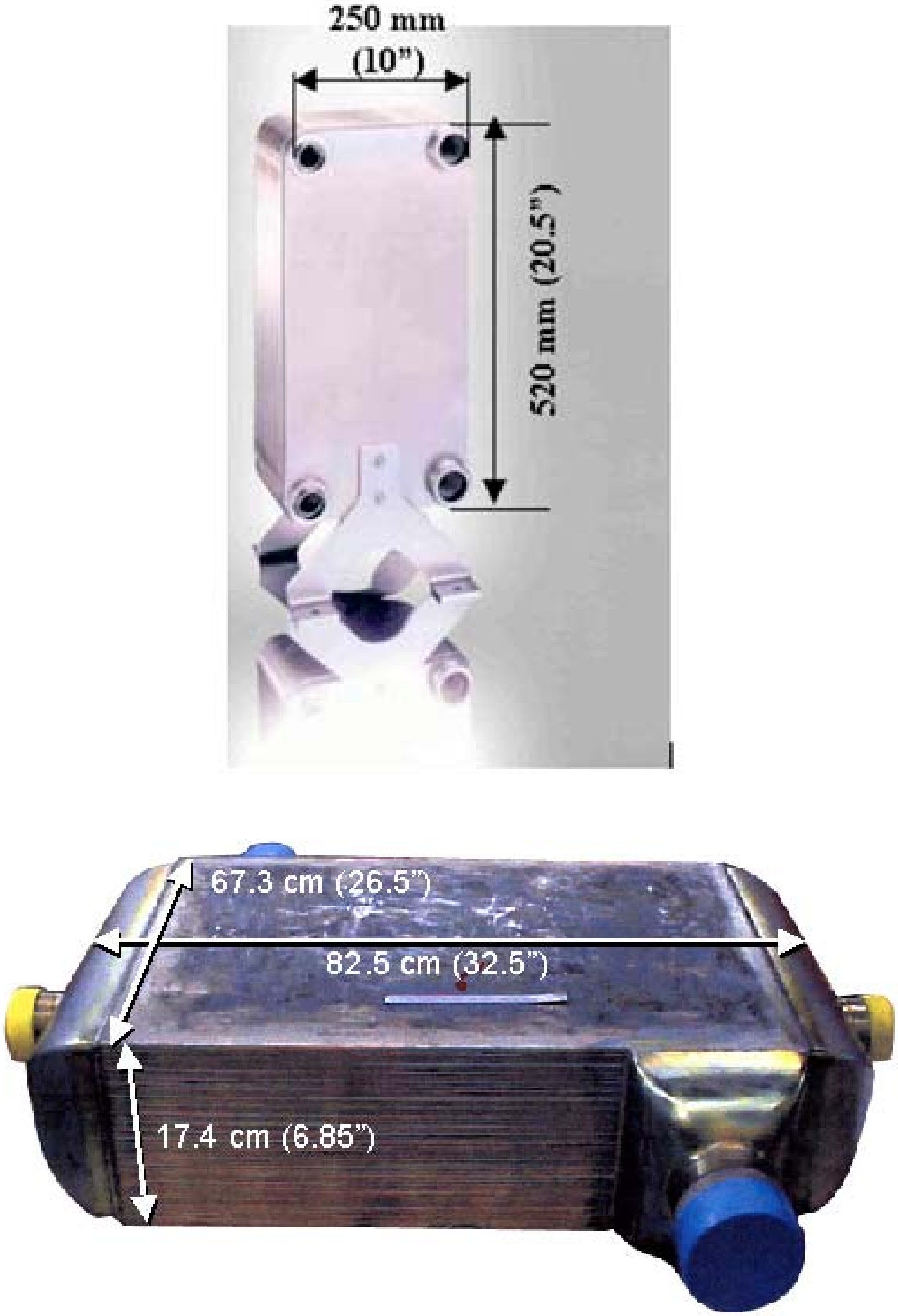
22. Two samples of SB423 tubes brazed using MBF-20 (a) and MBF-53 (b) after 1126 hours corrosion testing according to ASM G28-97 standard procedure.



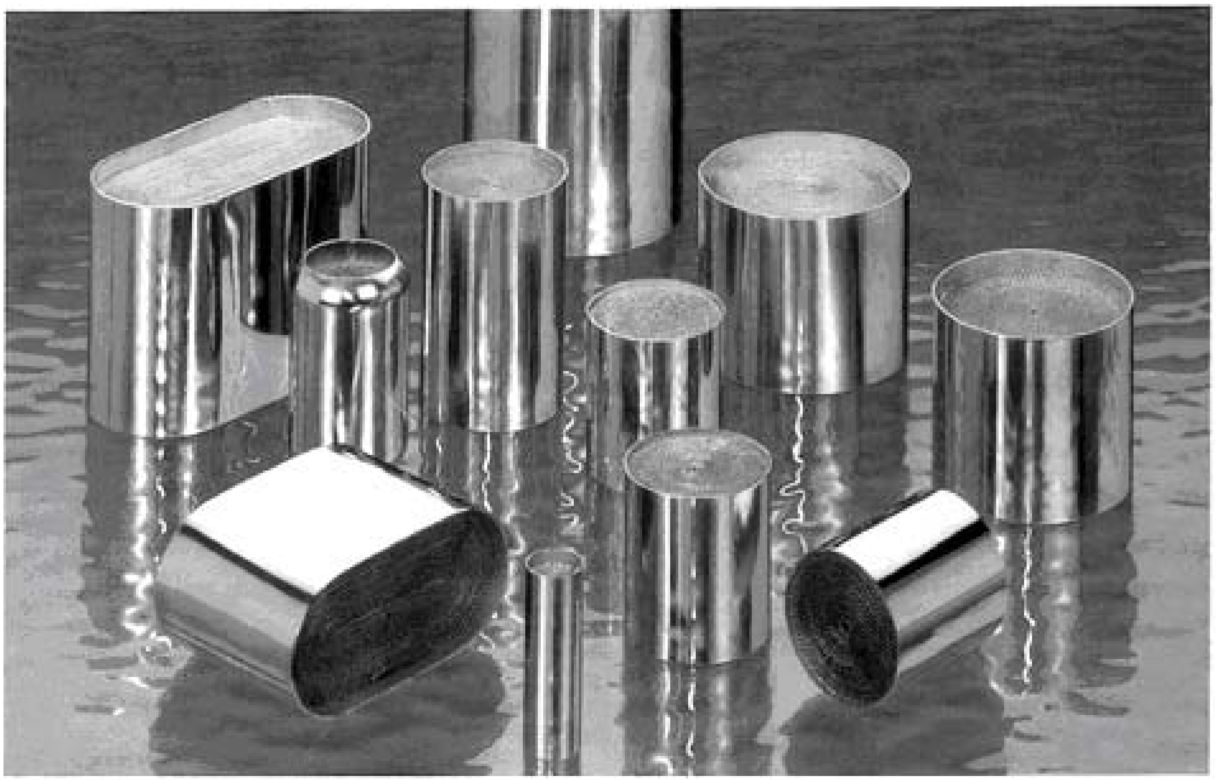
23. Typical aerospace engine parts fabricated using MBF: (a) Exhaust plug for P&W JT9D jet engine[37]; (b) Exhaust plug for GE CF6-80 jet engine[37]; (c) P&W jet engine compressor stator. [36]



24. Schematics of plate/fin/plate (a) and plate/plate metallic heat exchangers brazed using MBF.



25. Two large heat exchangers brazed using side-by-side preplaced MBF-51 200 mm wide preforms.



26. Various car and motorbike metallic catalytic converters brazed with MBF-50.