Diode Laser Brazing of AZ31B to Steel Sheet Using a Ni Interlayer

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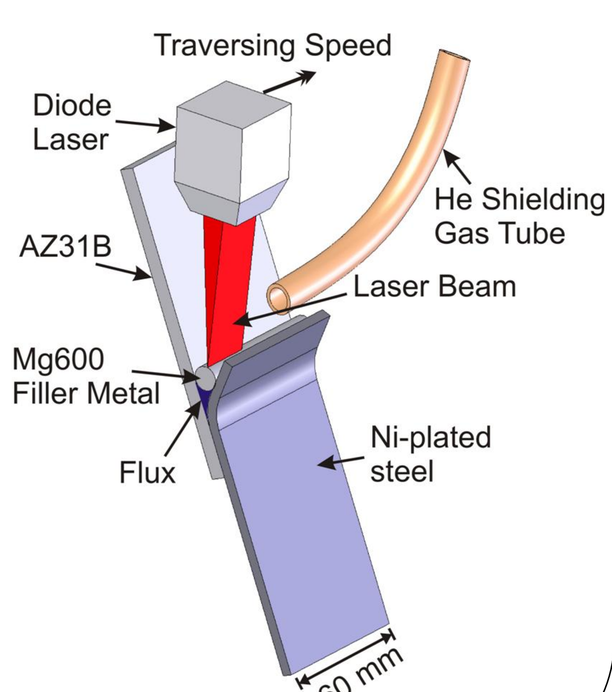
The Problem and Objective

There is much interest in joining light-weight magnesium alloys to steel sheet for automotive and other applications. However, Mg does not wet or bond to steel and has a low boiling point well below the melting temperature of steel. Diode laser brazing is a potentially viable joining process provided an appropriate interlayer is used for improved wetting and the magnesium is kept below its boiling point. The objective of this study, therefore, was to investigate the brazability of AZ31B-H24 Mg alloy to steel sheet with electro-plated Ni on the steel as an interlayer when using a laser as a heat source.

Process Overview

Single flare-bevel joints were made between 1.0 mm thick AZ31B-H24 Mg and plain carbon steel sheet. The steel sheet was electro-plated with a 5.5 µm thick layer of Ni. A 2.4 mm diameter TiBraze Mg 600 (Mg-Al-Zn alloy) filler wire and flux was placed in the joint as shown. A 4 kW Nuvonyx diode laser system and a Panasonic 6-axis robot were used to heat and melt the filler wire and joint.



The intensity distribution of the laser beam at the focal point was rectangular in shape (1 mm×12 mm) with a uniform intensity profile. The range of process parameters used were 1.8 to 2.4 kW laser power, 5 to 10 mm/s travel speed, and -0.2 to 0.4 mm beam offset relative to the steel.

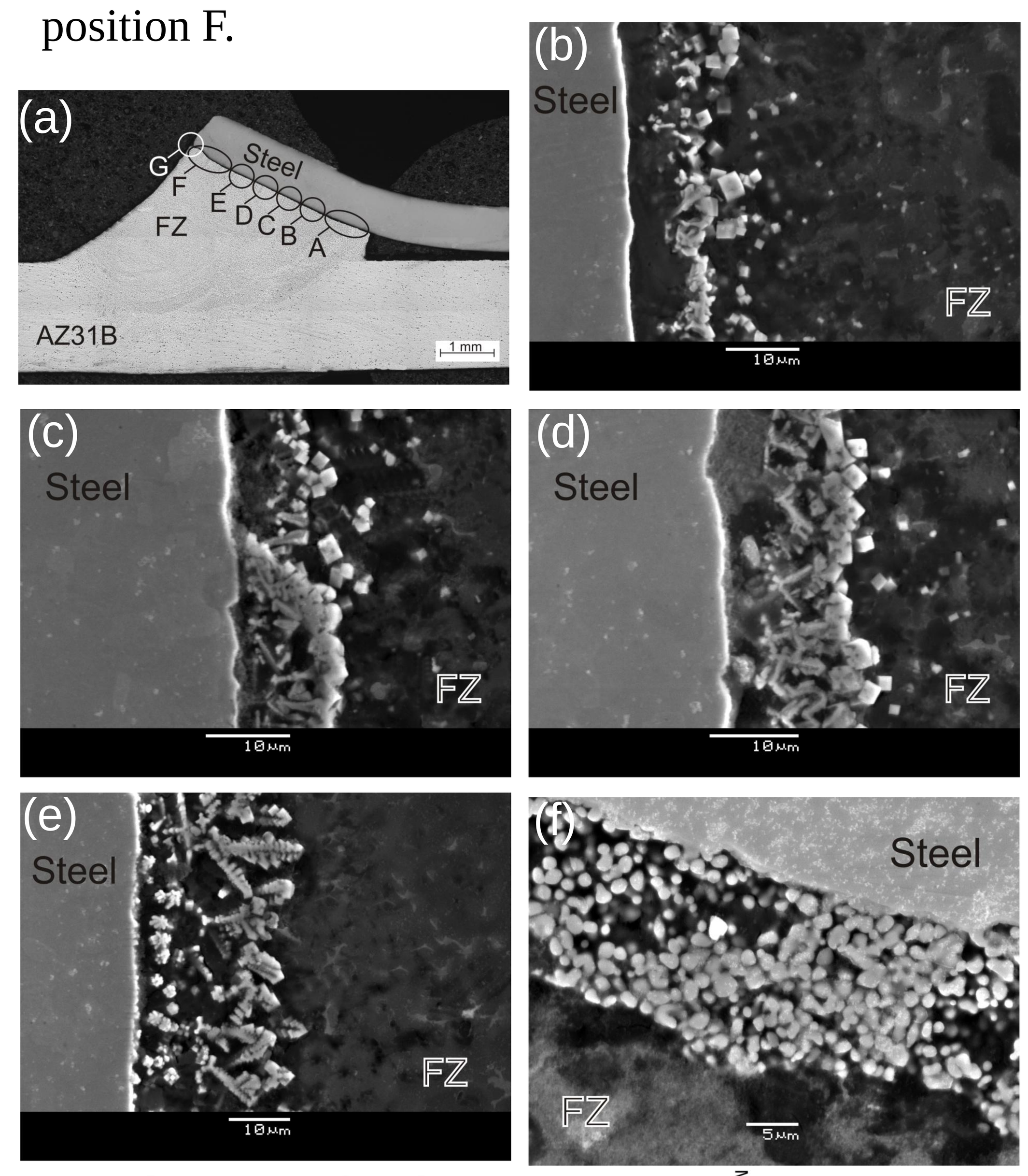
Laser Brazed Mg to Steel Joints

There was no wetting or bonding between the uncoated steel and the Mg braze alloy fusion zone (FZ).

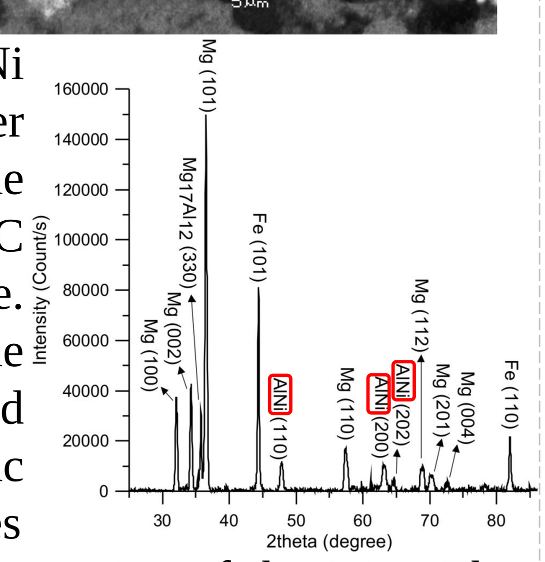
The 5.5 µm thick Ni electro-deposited layer on the surface of the steel significantly improved the wetting and bonding of the steel by the molten Mg-Al filler metal. Acceptable brazed joints with good wetting of both base materials and some partial melting of the AZ31B base metal were obtained when using 2.2 kW laser power, 8 mm/s travel speed, and 0.2 mm beam offset to the steel side.

Interfacial Microstructure

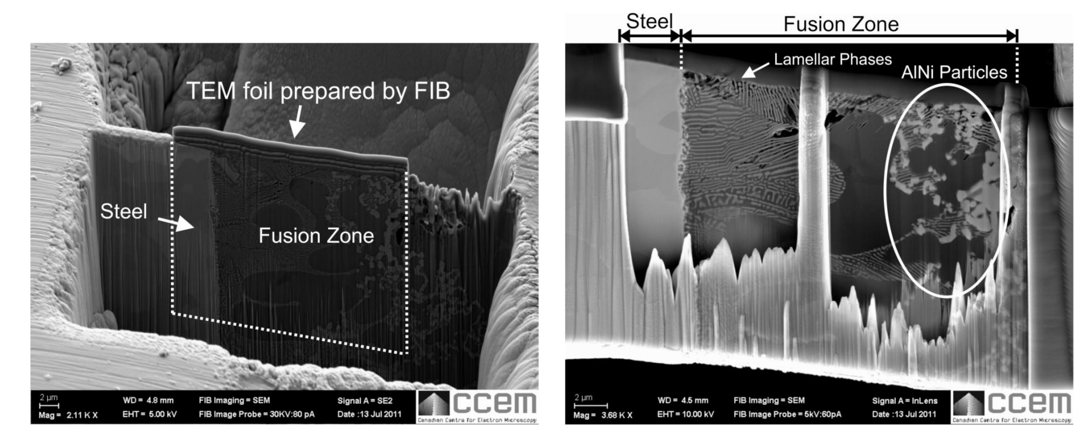
SEM images in different positions of steel-FZ interface shown in (a): (b) position A, (c) position B, (d) position C, (e) position D, (f) position E, and (g) position F.



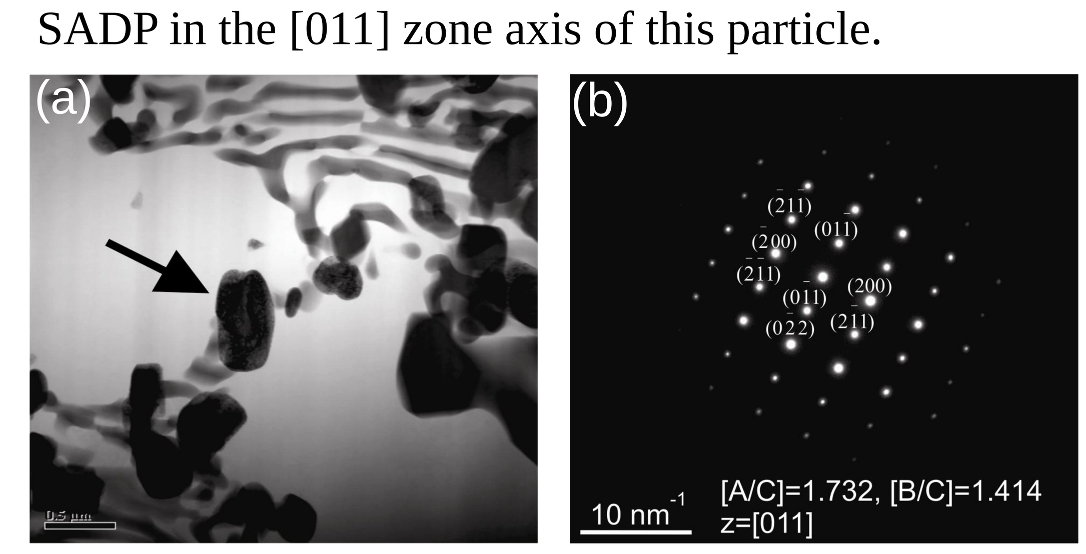
Dissolution of the Ni coating layer during laser brazing process led to the formation of new IMC phases along the interface. These phases formed in the sequence of diamond shaped particles, dendritic phase, and nodules particles from the bottom to the top portion of the joint. The XRD result confirmed the formation of AlNi intermetallic phase at the steel-FZ interface.



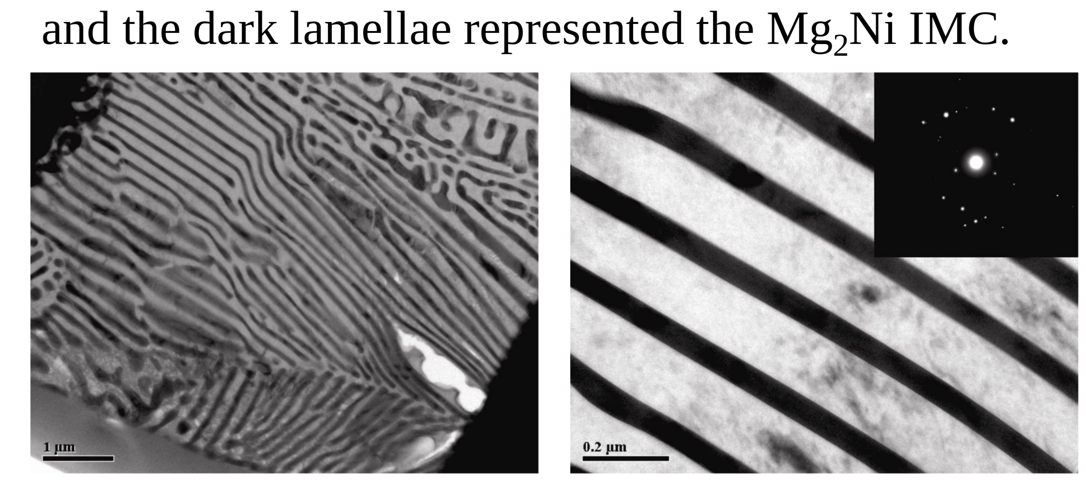
TEM foil attached to a copper grid from Steel-FZ interface prepared by Focus Ion Beam technique.



AlNi particle characterization: (a) TEM image, (b) SADP in the [011] zone axis of this particle.

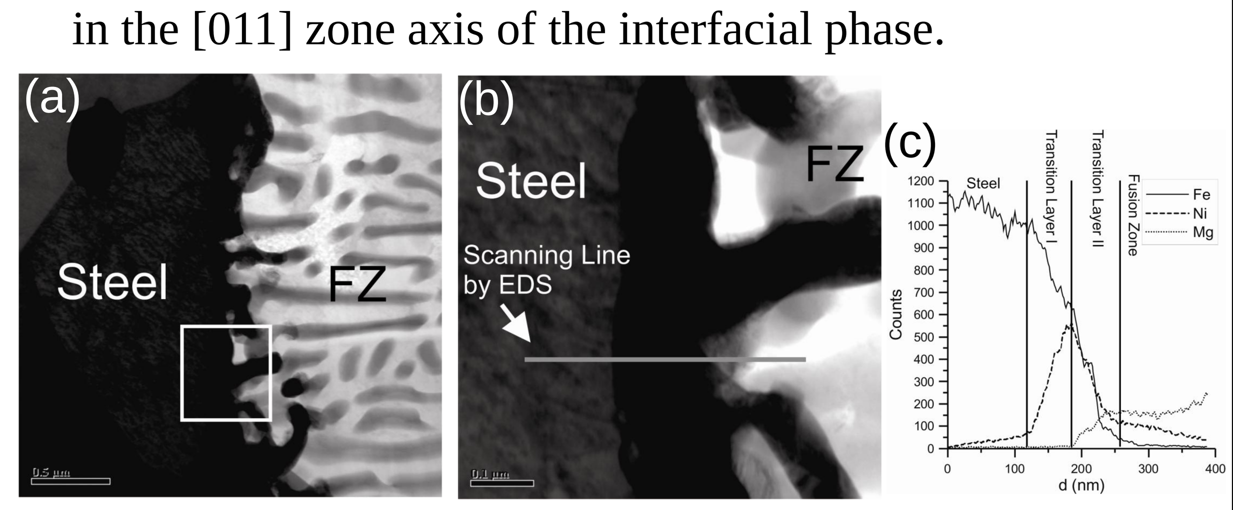


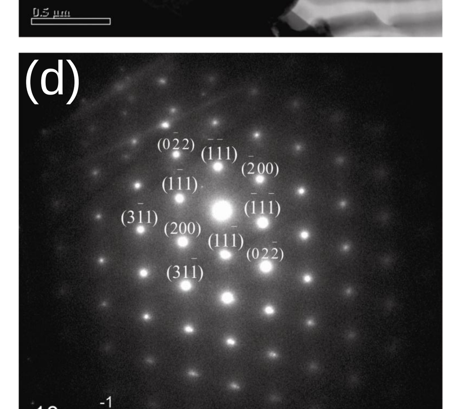
TEM images of the lamellar phases formed along the steel-FZ interface show Mg-Mg_2Ni lamellar eutectic phases. The white lamellae corresponded to α-Mg and the dark lamellae represented the Mg_2Ni IMC.



Transition Layer

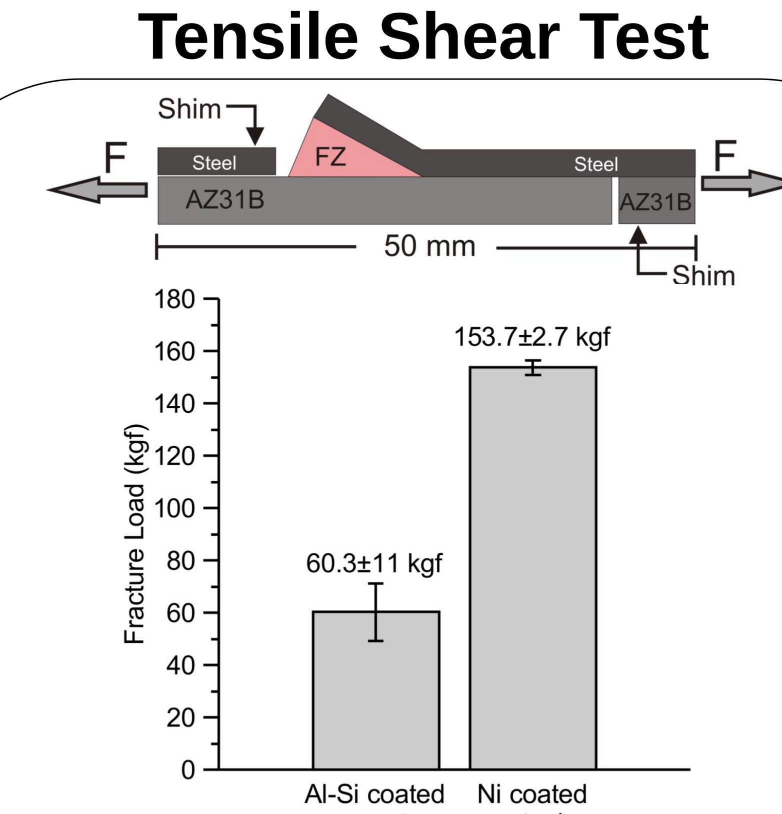
(a) TEM image of the steel-FZ interface, (b) higher magnification of the selected area by square in (a), (c) EDS line scan analysis of the interface, and (d) SADP in the [011] zone axis of the interfacial phase.





Formation of the Fe(Ni) solid solution transition layer on the steel was key to the formation of a metallurgical bond between the steel and the Mg alloy fusion zone. Layer 1 was Fe(Ni) solid solution and layer 2 corresponded to Fe(Ni,Mg) solid solution.

Tensile Shear Test



The average tensile shear strength of 5 mm wide laser brazed steel-Ni-AZ31B joints was 153.7 kgf for a joint efficiency of 60% relative to the AZ31B-Mg alloy sheet. This is over 150% higher than tensile shear strength of the laser brazed Al coated steel-AZ31B Mg alloy (A.M. Nasiri *et al. Weld. J., 2011, 11, pp. 211s-219s*).

Conclusions

The results of this study suggest that successful laser brazing of the steel sheet to the Mg alloy sheet depends strongly on the Ni electro-deposited interlayer layer on the steel sheet. The formation of Fe(Ni) transition layer, AlNi IMC with different morphologies, and Mg_2Ni eutectic phase proved the occurring of metallurgical bonding between the steel and Mg alloy. The Ni promotes wetting of the Mg alloy by formation of a thin Fe(Ni) transition layer on the steel and AlNi in the FZ.

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