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TRANSITION JOINTS BETWEEN DISSIMILAR MATERIALS

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1. INTRODUCTION

Dissimilar metal and composite-to-metal transition joints present difficult design challenges if there is a requirement to achieve high levels of integrity. Traditionally, this has meant that designers have been reluctant to incorporate such joints in their designs, unless extremely conservative measures are taken or where there are no alternatives.

1.1. DISSIMILAR METAL JOINTS USING STIR-LOCK™

Currently, there is great interest in joining magnesium, steel, titanium and copper to aluminium alloys. The joining of aluminium superstructures to steel-hulled ships, automotive components, for instance steel to aluminium tailor-welded blanks, as well as many aerospace applications require improved solutions to dissimilar metal joints.

The following describes preliminary studies being carried out on dissimilar metal and composite-to-metal transition joints at TWI. The Stir-lock™ technique presented has the capability of producing transition joints from sheet and plate material between a number of dissimilar materials by the use of discreet through-holes that have re-entrant features.

Stir-lock™ is an 'in-process' forge/forming seam joining technique. One side of the Stir-lock™ joint can be compared with riveting, whereby a rivet head is formed into a countersunk hole, for example, to provide a mechanical interlock between two or more plates. The countersunk holes are made in the comparatively harder sheet or plate material. However, the material that forms the interlock or 'rivet head', remains integrally part of the comparatively softer, more easily formable sheet or plate material. The Stir-lock™ technique can also be applied to any perforated material. Figure 1 shows a possible application for steel-to-aluminium joining in a T-joint configuration.

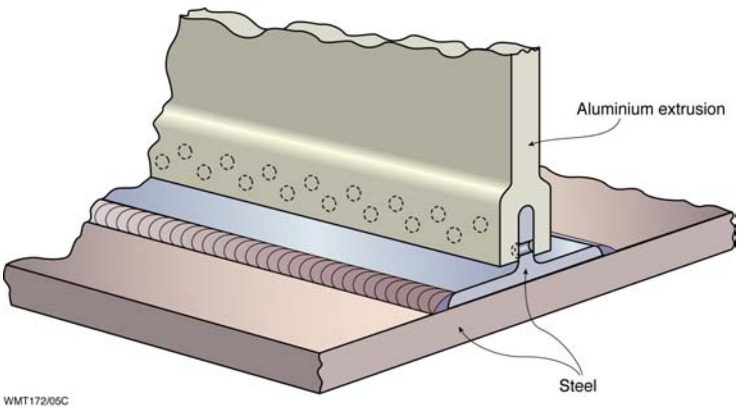


Fig.1 Stir-lock™ technique for joining dissimilar metals

Demonstration examples of steel to aluminium transition joints are shown in Figures 2 and 3.

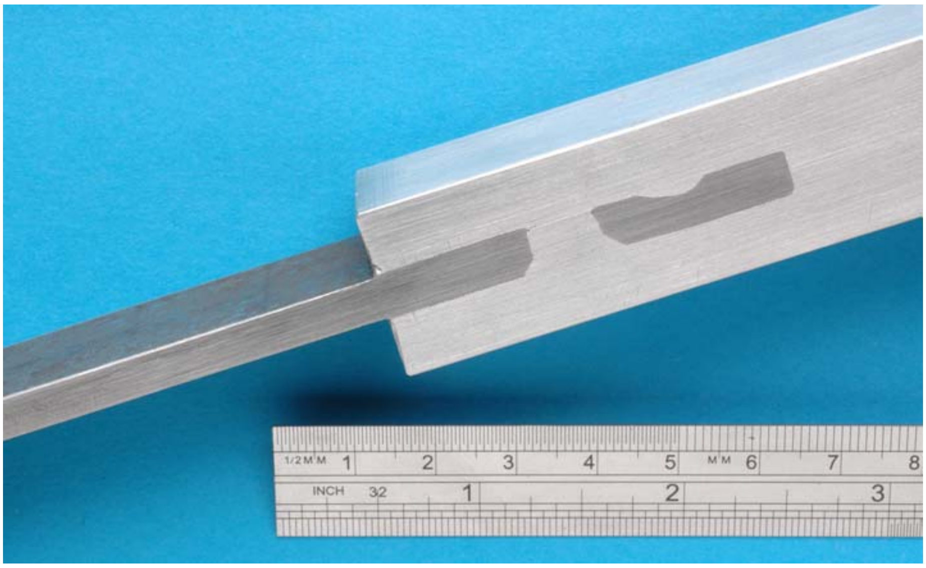
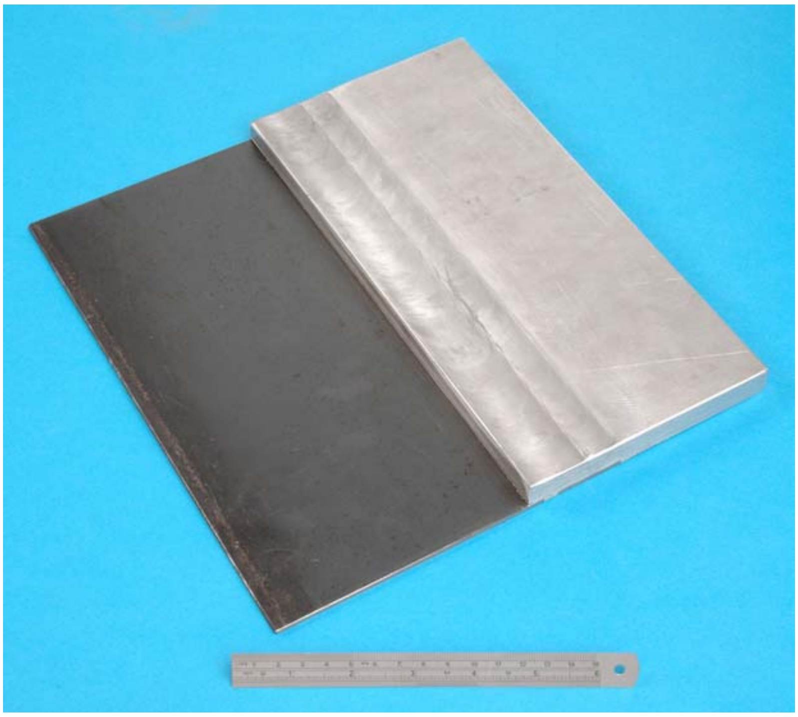


Fig.2 Double sided transition joint showing hole cross-section



a)

b)

Fig.3 Single sided, Stir-lock™ aluminium-to-steel transition joint.
a) Friction treated near-side, continuous weld track;
b) Far-side showing aluminium extruded into re-entrant holes.

A simple tensile test on initial samples showed promising results and failed in the steel along the line of holes. In this respect, the joint can be designed to fail in the steel or in the aluminium material, depending on the hole pattern.

1.2. COMPOSITE TRANSITION JOINTS USING STIR-LOCK™

Transition joints between metals and composite materials are also becoming increasingly important in the aerospace, marine and automotive industries. Using the Stir-lock™ technique, reinforcement transition joints can also be produced for composite/metal applications. Figure 4 shows a stainless steel mesh joined to aluminium sheets by friction. The mesh provides a skeleton reinforcement for the application of resin based, polymer or rubber materials. This technique differs from other transition jointing techniques in that the reinforcement itself can provide a degree of flexibility, which can be important for certain applications eg for polyurethane or rubber-to-metal composite applications, where appropriate compliance and flexibility is required.

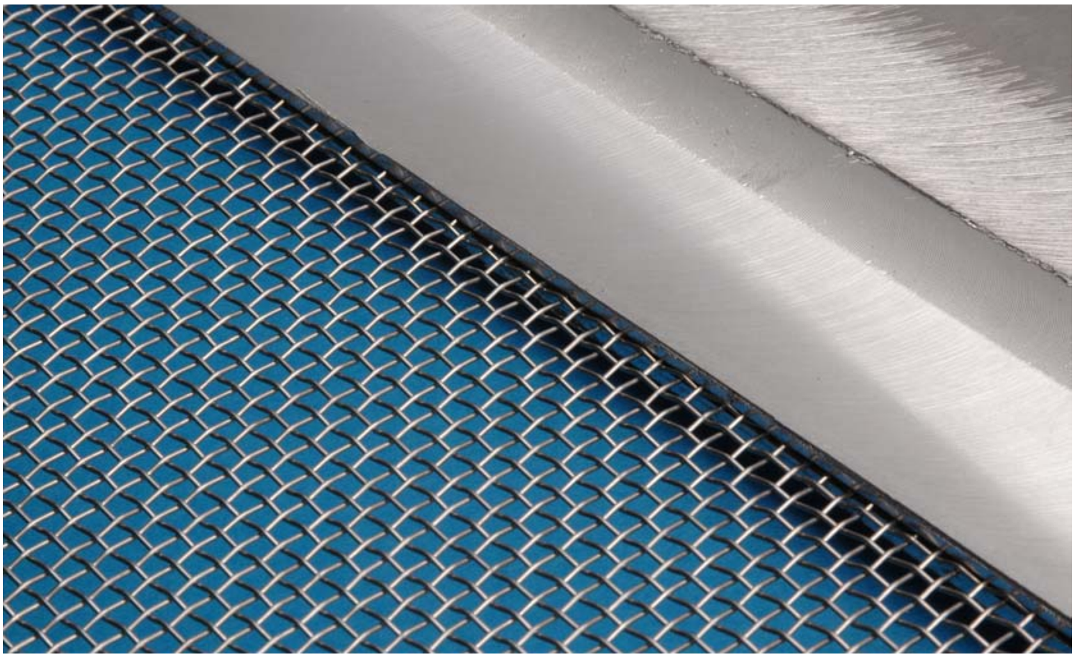
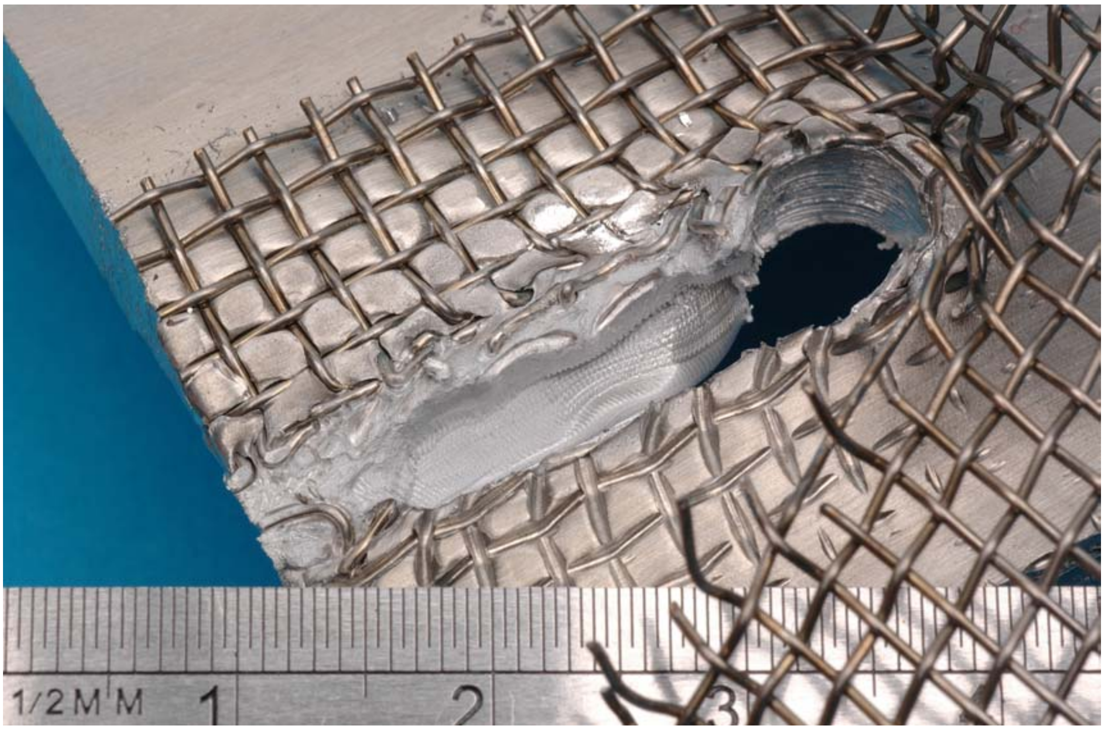


Fig.4 Stainless steel mesh reinforcement joined to aluminium sheets by the Stir-lock™ technique

Peel tests were carried out on initial welded samples, which showed that the mesh was substantially joined to the aluminium sheet material. Figures 5a and b show the mode of failure of the peel tested sample in which both the aluminium sheet material and stainless steel mesh have undergone significant deformation prior to joint failure. The results of test show that the weld region remained attached to one side of the sheet, and pulled material out of the other sheet.



a)

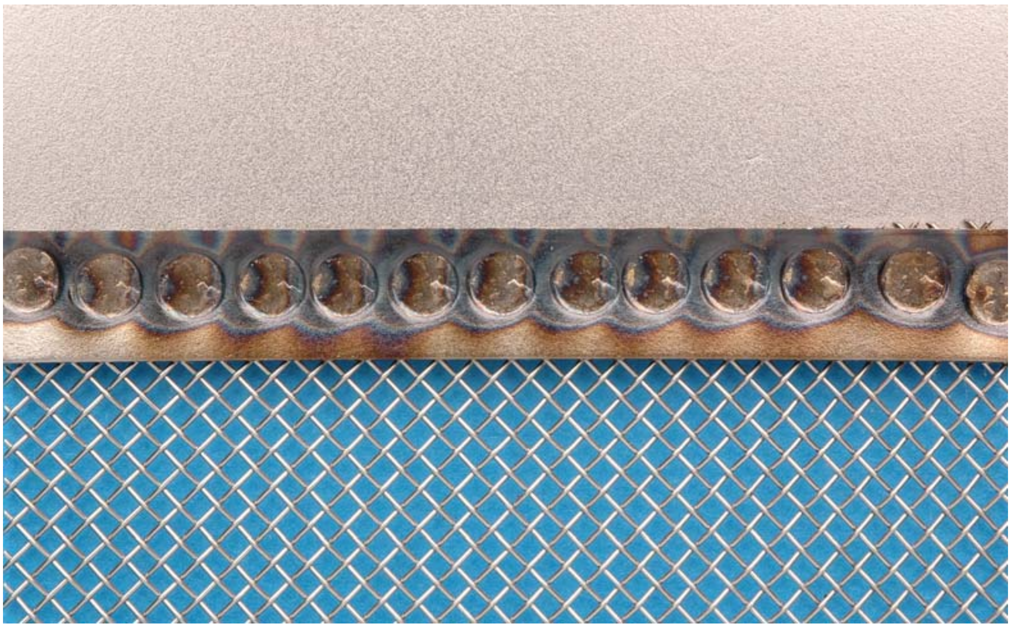
b)

Fig. 5 Transition joint between stainless steel mesh and aluminium sheets

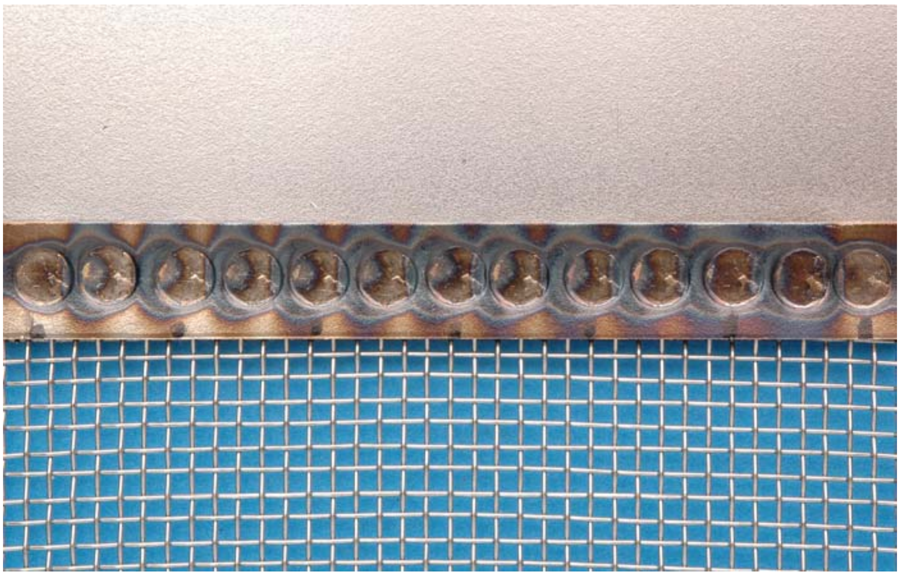
a) Weld region pull-out with embedded and part ruptured mesh
b) Weld region attached with some embedded mesh

1.3. RESISTANCE WELDED COMPOSITE REINFORCEMENT

Resistance welding processes can also be used to join sheet to mesh and this is a common method for joining filter or sieve meshes, for example. Spot seam or projection welding can be used, depending on the size and form of the component to be made. Although the mesh can be welded directly to sheet or other solid forms, there is a tendency to cause some damage to the mesh with this approach, and electrode wear can be severe. Consequently, the best way to join mesh is often to use a cover sheet and encapsulate the mesh. Figure 6 shows examples of stainless steel mesh welded to 1mm low carbon steel sheet with a 12mm wide cover strip.



a)



b)

Fig 6 Skeletal reinforcement transition joint produced by resistance welding, viewed from cover strip side.

a) Diagonal mesh alignment;
b) Square mesh alignment.

Spot welds were used in this case and a fused nugget is formed between the sheet and cover strip, fusing-in the mesh at the same time. It is possible to weld the sheet to two meshes using two cover strips in one operation. An example is shown in Fig. 7.

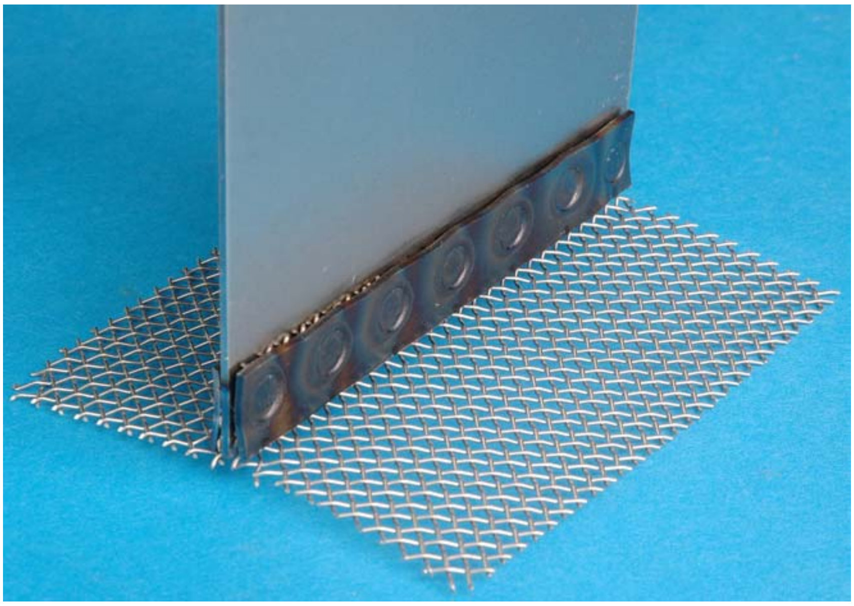


Fig.7 Skeletal reinforcement transition joint produced by resistance welding for a composite-to-metal T joint

Different forms of material, such as perforated metal or other non-solid forms, could be welded as an alternative to mesh. Furthermore, different steels, uncoated and coated could be welded, depending on the application and other weldable materials could also be considered. Resistance welding processes are ideally placed to produce skeletal reinforcement structures for composite/metal transition joints.

2. DISCUSSION AND CONCLUDING REMARKS

In-process forging, forming, embossing and mechanical joining of seam joints by friction techniques are well known (1,2,3,4 and 5). More recently a friction stir spot welding method has been used to fill individual holes by a series of one-by-one separate FSW spot welds in order to provide a series of mechanical locks (4). The Stir-lock™ technique differs from the latter because it can fill individual holes along a common seam in a continuous and uninterrupted manner.

Transition joints between dissimilar materials and composite materials are frequently required in a range of demanding engineering structures and are of growing importance for many applications. The use of structural composites provide the opportunity for reduction in the weight of structures provided that the transition joints are able to transfer stresses homogeneously and in such a manner as to achieve the required design life

Initial investigation of transition joints has demonstrated the potential of using friction techniques for producing mechanical joints between dissimilar metals and skeletal reinforcement for composite materials. In addition, resistance welding provides a useful method of joining mesh to sheet to form a transition and skeletal reinforcement that would allow the joining of polymer, rubber or composites to metals.

Further work at TWI is being undertaken to investigate the following:

- The advantage of the Stir-lock™ technique for composite/metal and dissimilar metal joining
- The development of the resistance welding and other fusion welding techniques for manufacture of skeleton reinforcement for composite/metal joining
- The development of suitable skeleton reinforcement for substantially flexible rubber/metal joints

3. ACKNOWLEDGEMENTS

P J Oakley, F C Smith, P L Bryant and C Spence

4. REFERENCES

1. Thomas W M, and Nicholas E D: ‘Friction surfacing advances’ TWI Connect, March 1991.
2. Thomas W M: Friction Stir Welding and Related Friction Process Characteristics’, INALCO 1998 7th International Conference, Joints in Aluminium, Cambridge, UK 16th April 1998.
3. Kallee W S, Nicholas E D, and Thomas WM: ‘Friction Stir welding – Invention Innovations and Applications’ INALCO 2001 8th International Conference, Joints in Aluminium, Munich, Germany, 28-30 March 2001.
4. Okamoto K, Hirano S, Inagaki M, and Aono Y: ‘Method of joining Metallic Materials’, International patent US 6,843,405 B2, Filed Feb, 5th 2003.
5. Mishiza R S: ‘Friction Stir Processing Technologies’, Advanced Materials & Processes, pp.43-45, October 2003.