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Published in:
71th Annual Assembly of International Institute of Welding

Published: 15/07/2018

Document Version
Publisher's PDF, also known as Version of record

Please cite the original version:
Karvinen, H., Nordal, D., & Santos Vilaca da Silva, P. (2018). From Conventional to Hybrid Friction Stir Channeling: Milestones and Characterization. In *71th Annual Assembly of International Institute of Welding* [IX-NF-005-18]

IIW2018 Annual Assembly - Sub-Commission IX-NF (Indonesia, Bali, July 15th, 2018)

Document IX-NF-005-18

From Conventional to Hybrid Friction Stir Channeling: Milestones and Characterization

Heikki Karvinen, Daniel Nordal, Pedro Vilaça

Department of Mechanical Engineering, School of Engineering, Aalto University, Espoo, Finland.

Abstract

The Hybrid Friction Stir Channeling (HFSC) is a recently developed manufacturing method [1,2] for producing free-path internal, closed channels and welding of multiple metal components in a single action. The concept of HFSC is to join multiple components while simultaneously creating a closed channel within the processed volume. The channels are formed by continuous extraction into external flash of part of the processed material from the stirred zone. This way the size of the channels can be variable in a quite wide range. The channels have an overall quadrilateral shape prescribed by the geometry of the tool and processing parameters. One significant incremental benefits of using HFSC, is the fact that the channel can be produced in component systems involving thin workpieces, made of similar or dissimilar materials such as copper (Cu) and aluminum (Al) and different material thicknesses, instead of the thick monolithic preforms required in the FSC concepts. The Cu and Al are important materials in many industrial applications due to their high conductivity and corrosion resistance. Cu has excellent electric and thermal conductivity and corrosion resistance and Al provides good electric and thermal conductivity with good corrosion resistance. Al enables also production of lightweight applications. Structures combining the properties of Cu and Al are attractive to for example thermal management solutions for electric vehicles and power electronics [3], which require high electric or thermal conductivity with minimized mass.

Historically, the Friction Stir Channeling (FSC) was firstly proposed in 2005 [4], based on reversing the material flow pattern from Friction Stir Processing, which enabled production of internally closed channel within a monolithic plate. In this original concept all material extracted in the process is laid on a small clearance between the tool shoulder and workpiece. Therefore, the final surface is higher than the original surface, and the channels are limited to small sizes because the material is kept in the processing domain, and the gap with the tool have to be small in order to form a complete ceiling layer and thus keep the channel closed. In 2013, an important evolution of the original FSC of monolithic components was presented [5], with a distinct material flow where part of the processed material is extracted from the processed zone as self-detaching flash. In this concept, the tool shoulder is kept in contact with the surface of the workpiece, and thus the processed surface is planar and at the same quota as the initial surface of the component being processed. By adjusting process parameters, and tool features it is now possible to produce channels with a wide range of dimensions. Some other works present different options for FSC of monolithic components, namely based on controlling the tilt angle [6] and using static shoulder [7].

In this study, the HFSC processing of multimaterial components is characterized with internal pressure test, helium leak test, protocols to evaluate the channel path stability, microstructural analysis, microhardness field measurements and assessment of roughness features in all the channel surfaces.

Keywords: Hybrid Friction Stir Channeling; Mechanical Characterization; Metallurgical Characterization; Aluminum; Copper.

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