Mašinski fakultet Univerziteta u Nišu
Faculty of Mechanical Engineering University of Niš

ZBORNIK RADOVA

NAUČNO-STRUČNA KONFERENCIJA O ŽELEZNICI

XIV ŽELKON '10 RAILCON '10

2010

SCIENTIFIC-EXPERT CONFERENCE ON RAILWAYS

PROCEEDINGS

Niš, Srbija, 07. - 08. Oktobar 2010.

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XIV SCIENTIFIC-EXPERT CONFERENCE ON RAILWAYS
RAILCON '10

AN OVERVIEW ON FSW AND ITS APPLICATION IN RAILWAY VEHICLE INDUSTRY

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Dragan J. MITIĆ [4]

Abstract *– Friction Stir Welding (FSW) as a promising new welding technology has been adopted by various industries and it has been implemented into their manufacturing procedures. Railway companies throughout the world use FSW in development processes of different kinds: for speed trains, rail stock, tanks, containers etc. Serbia's scientific society is familiar with abilities and advantages of the FSW and there is enthusiasm for its application. Several Serbian scientific institutions work on development of FSW and its use in industry. Serbian Railways are in the phase of reconstruction and deal with numerous difficulties. FSW is still considered as "exotic" welding procedure" and has never been massively implemented into the Serbian railway industry.*

Keywords – Friction Stir Welding, Railway

1. INTRODUCTION

Friction stir welding (FSW) is a solid – state welding process (metal of the welding pieces and/or filler metal are not melted during the welding process), and is used mostly for applications on sheet or plate shaped parts, usually on large parts which cannot be easily heat treated post weld to recover temper characteristics. FSW is used where the nominal metal characteristics should remain unchanged or minimally changed during the welding process.

FSW was invented and experimentally proven by Wayne Thomas and its team at The Welding Institute UK in December 1991 and this institute holds numerous patents on the process [1].

This process is primarily used on:

- 2000, 5000, 6000, 7000 series aluminum,
- Aluminum based metal matrix composites,
- Copper and its alloys,
- Titanium and its alloys,
- Zinc, stainless steel and nickel alloys,
- Lead, Plastic,
- Some combinations on previously mentioned materials (for example, welding of bronze and aluminum).

2. PRINCIPLE, ADVANTAGES AND DISADVATAGES OF THE FSW

During FSW process (Figure 1), a cylindrical – shouldered tool, with a profiled threaded/unthreaded probe (Figure 1, 5) and flat or coned shoulder (Figure 1, 4) is rotated at a constant speed and fed at a constant traverse rate into the start point of the joint line (Figure 1, 7) between two plates (Figure 1, 1 and 2). Welding plates are butted together and clamped rigidly onto a backing plate (Figure 1, 3) in a manner that prevents the abutting joint faces from being forced apart. The height of the probe is slightly less than the weld depth required (height of the welding plates) and the shoulder tip (Figure 1, 6) is in intimate contact with top surfaces of the welding plates.

Friction stir welding uses two types of physical – mechanical processes, that happen with materials, to create weld: friction processes and deformation processes (as the most dominant – stirring). Friction processes result with generation of heat [3]. Frictional heat is generated between the welding tool's active

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surfaces - probe side, probe tip, shoulder tip and the material of the work pieces. This heat generated during sliding and sticking of welding tool and welding material [5, 6], along with the adiabatic heat within the material, cause the stirred materials to soften without reaching the melting point allowing the traversing of the tool along the weld line in a plasticised tubular shaft of metal.

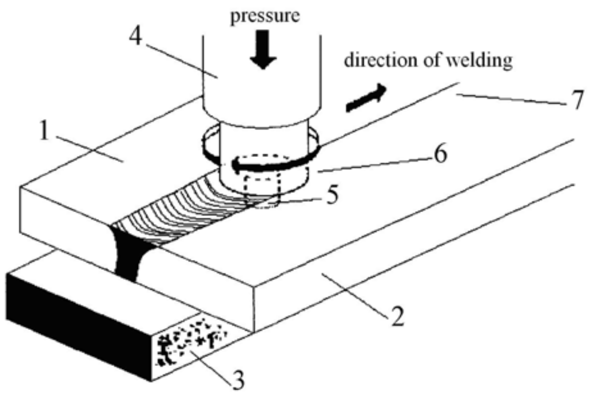

Figure 1 Principle of the FSW: 1 and 2-welding plates; 3-backing plate; 4-shoulder; 5-probe; 6-shoulder tip; 7-weld joint line

FSW is cited as a solid state welding process – process of indirect usage of friction heat generation, where temperature of the welding plates' material can reach at most 80% of the melting point temperature [3, 4]. Terms sticking and sliding are commonly used in FSW terminology, but if FSW is considered as tribological problem, it is more appropriate to describe heat generation within FSW as a product of adhesion and deformation [4, 6]. As the probe is moved in the direction of welding, the leading face of the probe, assisted by a special probe profile (thread), forces plasticised material to the back of the probe while applying a substantial plunging force to consolidate the weld metal. The welding of the material is facilitated by severe plastic deformation in the solid state, involving dynamic recrystallization of the welding (base) material.

Welding process is achieved during five different phases (Figure 2): plunging of the welding tool, first dwelling, welding, second dwelling, pulling out of the welding tool.

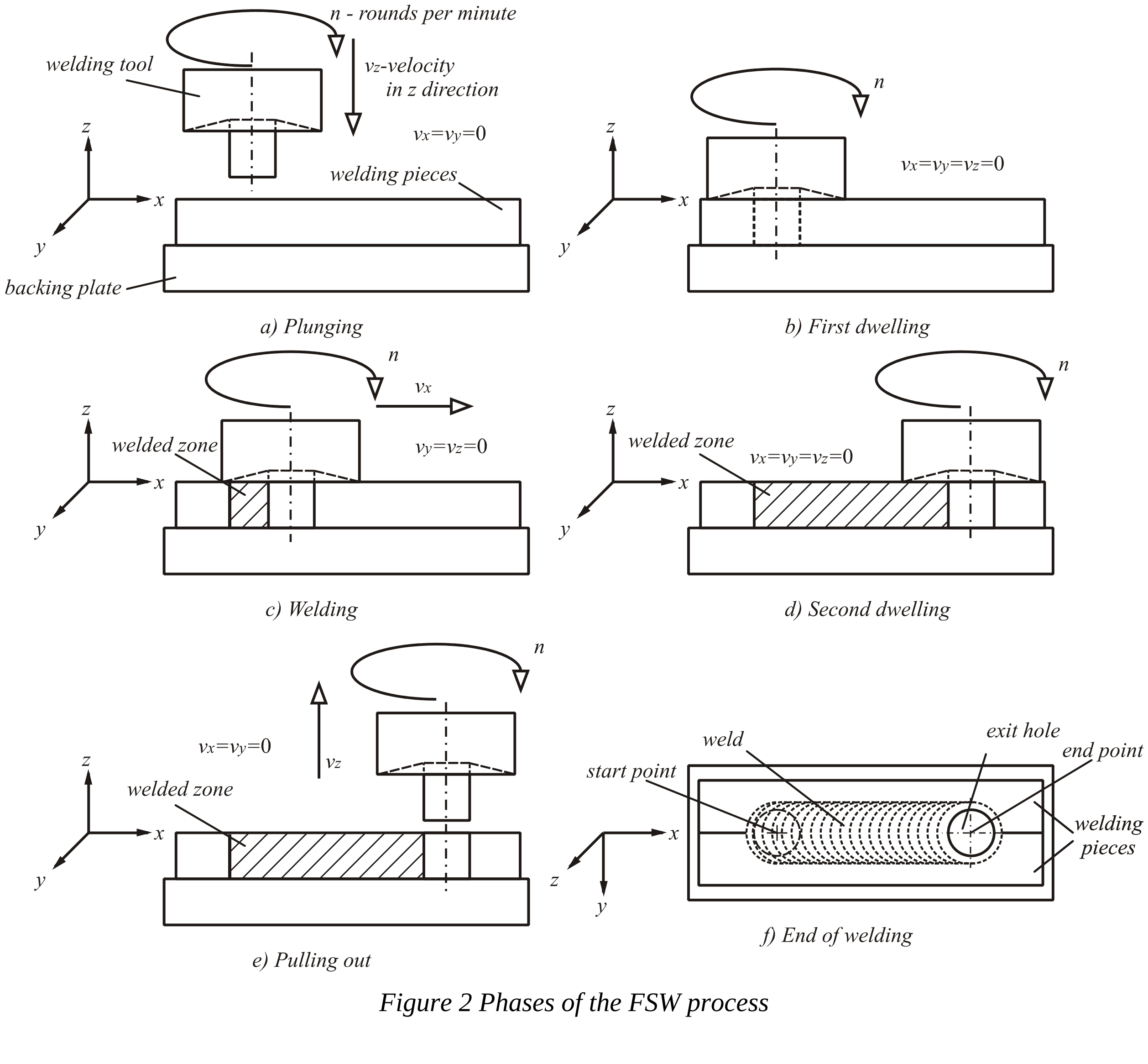

Figure 2 Phases of the FSW process

Advantages of the FSW are numerous:

- Good mechanical properties of the weld – almost the same as for the welding plates
- Low distortion, even in long welds, no spatter and porosity, low shrinkage.
- Excellent mechanical properties.
- Can operate in all positions.
- Non consumable tool and no consumables.
- Can weld Al and Cu of larger than 50mm thickness, in one pass,
- Improved safety of the welding process due to the absence of toxic fumes or the spatter of molten material and low impact on environment.

As any other welding process, FSW has limitations on its application and disadvantages comparing to other welding processes:

- Work pieces must be rigidly clamped,
- Backing plate is required (except for self reacting and directly opposed tools),
- Key holes at the end of each weld,
- Cannot make joints that require metal deposition,
- Less flexible than manual and arc processes,
- Often slower traverse speed than some fusion welding.

3. APPLICATION OF THE FSW IN RAILWAY INDUSTRY

Friction stir welding has showed excellent characteristics in welding and almost the same moment it was invented industry has adopted it as specific but efficient type of welding. FSW is highly applicable for welding of “mild and soft” materials such aluminum is, so it is obvious why first applications of FSW were in shipbuilding, aerospace industry, automobile industry and fabrication.

Common railway industries are oriented to development of steel structures. Significant railway systems – from infrastructure, over vehicles and all other equipment are relatively massive and rigid structures. However, new demands in railway industries point into development of “light, safe and reliable” railway systems. As a process capable to weld light weight materials, FSW has found its application in development of modern railway vehicles. The commercial production of high speed trains made from aluminum extrusions which may be joined by friction stir welding has been published. Applications include [7]: high speed trains, rolling stock of railways, underground carriages, trams, railway tankers and goods wagons, container bodies.

The most popular examples of FSW application onto the railway rolling stock are:

- Roof panels for DSB suburb trains at Hydro Marine Aluminium (Figure 3),
- Side panels for Bombardier's Electrostar and Victoria Line trains at Sapa
- Side panels for Alstom's trains by Sapa
- Commuter, Express and Channel Tunnel Rail Link trains by Hitachi (Figure 4, Figure 5),
- FSSW roof panels by Kawasaki
- Shinkansen floor panels by Sumitomo Light Metal (Figure 6)
- Heat sinks at Sykatek, EBG and Austerlitz Electronics.

Figure 3 Alstom LHB trains for DSB Danish State Railways. FSWed roof panels for these trains are made at Hydro Marine Aluminium [2]

Figure 4 Commuter train - Hitachi with full-length FS welds of double-skin side and roof panels [2]

Figure 5 Express train built by Hitachi containing full-length friction stir welds of double-skin side and roof panels (welded from both sides) [2]

Figure 6 Trainsets with FSW floor panels of Sumitomo Light Metal operate on the Shinkansen in Japan [2]

4. FSW IN SERBIA AND SERBIAN RALWAYS

Friction stir welding is entering the third decade of its existence and becomes more and more applicable in industry. Companies throughout the world recognize its advantages and exploit them hurrying to catch market and technological dominance over concurrent companies. That is the main reason why numerous institutes are working on improvement of the FSW process.

Just like in most of the developing countries, Serbia's scientific labor is recognizing the advantages of the FSW and giving attention to application of this welding process. Until 1990s Serbia had advanced level of industrial development, numerous scientific institutions that were capable to be compared to the leading institutions on the world. Welding in Serbia was developing with the same rate as in any other country of that age.

That happened with the friction welding as well. Heavy industry was interested for application of friction welding, especially in special tools development [3], and many scientific institutions (Universities of Belgrade, Kragujevac, Novi Sad, Niš etc.) worked on numerous projects that had the same goal – improvement of the friction welding. Industrial participants were great companies of those days – Prva Petoletka, GOŠA, 14. Oktobar etc.

During and after the 1990s interest for friction welding has slowly deceased side by side with deceasing Serbian industrial complex. Scientific institutions were in crisis just the same as the industry and friction welding was not interesting anymore. Serbia has lost its primate even in areas where it was dominate – friction welding of weaponry and ammunition. Considering FSW several scientists from University of Belgrade, Faculty of Mechanical Engineering and Faculty of Technology and Metallurgy work on materials used for tool and on weldability of materials. They work on development of mathematical model that will fully describe stress – strain situation of FSW as well. University of Kragujevac, Faculty of Mechanical Engineering with several enthusiastic scientists works on the triblogical aspects of friction welding. One scientist from industrial complex GOŠA FOM, Smederevska Palanka is working on development of geometry of the welding tool and application of various threads on the probe. Few scientists from University of Niš, Faculty of Mechanical Engineering work on development of mathematical model that will describe heat generation processes within FSW [6]. The most of these researches are conducted without patronage of the state, industrial complex or any industry.

Serbian Railways are in the reconstruction phase and this gigantic company is rushing to technologically catch up with the advanced countries and their railways. Due to the lack of funds and every day problems, Serbian industrial complex is focused on pure survival so innovative and advanced welding technologies such FSW is are not applicative under these circumstances. Serbia has no engineering or railway product where FSW has been used widely and massively.

5. CONLUSIONS

FSW has appeared as new, promising welding technology in early 1990s. Until nowadays it has found numerous applications and large number of world's companies have adopted it as conventional welding procedure. Railway manufacturing companies around the globe use it to manufacture speed trains, rolling stock, containers etc. And the most of these companies carry the name of a "brand". It seems that FSW has become a procedure for brand making or privilege of the rich companies. But it only seems, since FSW is practical and easy to use method. Unfortunately, Serbian industrial complex that is working for railways is focused on other issues and massive application of FSW in Serbia's industrial complex will have to wait a little bit more.

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