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JOINING TWO METALS VIA PARTIAL REMELTING METHOD

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ABSTRACT

A new process of joining semisolid AISI D2 tool steel and 304 stainless steel using partial remelting method is proposed. The results obtained from investigating the basic geometries proved a good joining quality differs from the conventional process of welding or mechanical joining with screws or nails. Metallographic analyses along joint interface between semi-solid AISI D2 and stainless steel showed that a smooth transition from one to the other and neither oxides nor microcracking are observed. The current work successfully confirmed that, avoidance of dendritic microstructure of the semi-solid joined zone and high bonding quality components can be achieved. Based on this, a new type of non-equilibrium diffusion interfacial structure was constructed at the joint interface.

Key Words: Thixo-joining, Non-equilibrium diffusion, Direct partial remelting, JMatPro software.

INTRODUCTION

Due to the emergence of the thixotropic materials, many diverse techniques have been created for the purpose of utilizing the possibilities that come out from the characteristic benefits or advantages of this technology (Fan 2002 and Atkinson 2005). Thixo-joining process is a one part of forming operations in thixoforming family. This technique has shown various advantages where compared with conventional joining methods such as: the possibility of producing a functional components

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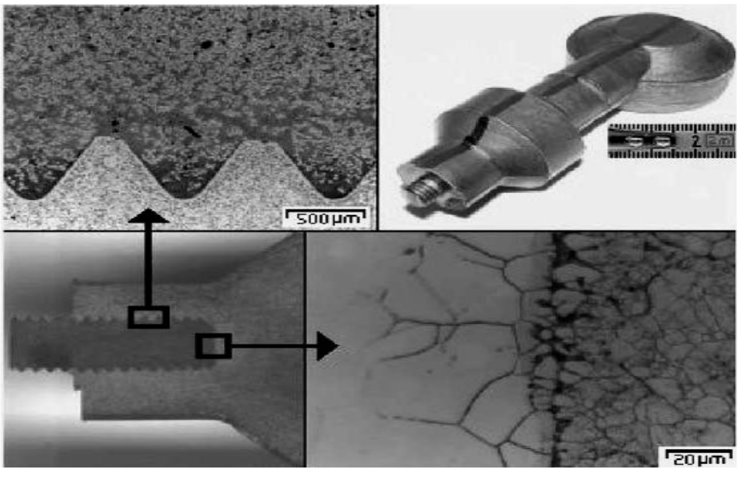
with multi materials, minimize the defects related to conventional welding process. In addition a semi-solid joining can be used for joining low melting point metal with high melting point metal (Kiuchi 1998 and 2000). The metal in thixotropic behavior has many features such as: high softness, good flowability, superb Workability and excellent join ability (Kiuchi 2002). Moreover, various previous research projects conducted in this particular area showed that the process of joining with globular microstructure base metals in deferent methods like: laser welding and friction stir welding but problems like porosities, loss of alloying elements, bad geometry and softening of heat affected zone happened with not homogenous microstructure in heating effected zone cause by remelting temperature (Narimannezhad 2008, Govender 2008 and Zhang 2011). The partial remelting is considered one of the most effective solid state processes especially for high melting pint metals to produce non-dendritic microstructure when the metal is directly heated into the temperatures between solidus and liquidus (Omar 2011, Mohammed 2012). However, as reported by other studies, there are two methods that possible to produce thixo joining process such as: combining forming and bonding are in one step and use a thxotropic metal as filler for joining materials (Baadjou 2006 and Mendez 2002). As shown in Fig. 1, a solid stainless steel screw used as an insert and M2 tool steel as a base metal in semisolid state and the microstructure of joined cross section area showed good interface connection and full covering of the base metal to the front face of the screw without any pores but there was only changing in the grain size at the border area at the heat affected area (Kopp2002). This joining technology is done at relatively recent years. Therefore, it is necessary to carry out fundamental investigations for the purpose of obtaining additional information about the general characteristics of the bonding between the base metal and the insert. The present work aims to provide globular joining structure in semi solid state by employing AISI D2 tool steel as a base metal and 304 stainless steel as insert via partial remelting method. The study realized a new type of non-equilibrium diffusion interfacial structure was constructed at the interface of base and insert.

Figure-1. Demonstration component for combining two different materials with microstructure at interface (Kopp2002).



EXPERIMENTAL PROCEDURE

The material used in this work is AISI D2 cold work tool steel as base metal which was supplied after soft annealing process. While 304 stainless steel as insert (pin). JMatPro (Java-based Material Properties) is a software that was developed to augment the thermodynamic calculation by incorporating diverse theoretical material models and properties database that let a quantitative calculation for the requisite materials property to be made within a larger software structure (Saunders 2003 and OMAR 2011). Here, JMatPro software is used to estimate solidus and liquidus temperatures as well as liquid fraction profile within the semi-solid zone for both metals. The direct partial remelting experiment was performed using vertical, high temperature carbolite furnace with protective atmosphere. The first process was concerned with cutting base materials into samples with size with 20 x 10 x 5 mm and for inserts with a diameter of Ø 6 x 5 mm as shown in Fig.2. Once the furnace has reached the predefined temperature, the sample (base and pin) was lowered into the hottest place inside the furnace by using chromel wire into the targeted temperature (1320°C). This will ensure a rapid heating of the coupon and it will normally arrived to the temperature in about 3 minutes as shown in Fig. 3. The sample held for 30 minutes and then cooled down in air rapidly. Finally, polish the sample to determine the structure of the bonding interface by using Villela reagent as etching solution and using a BX-51 Olympus optical microscope.

Figure-2. Display part for combining two different materials.

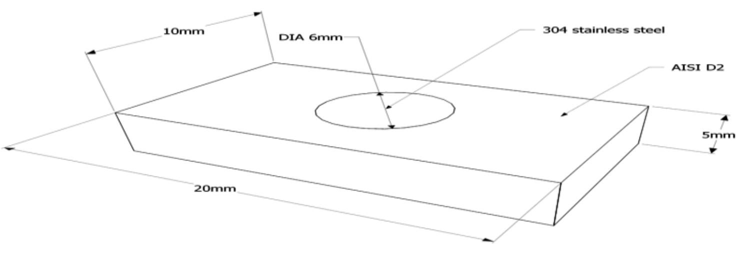
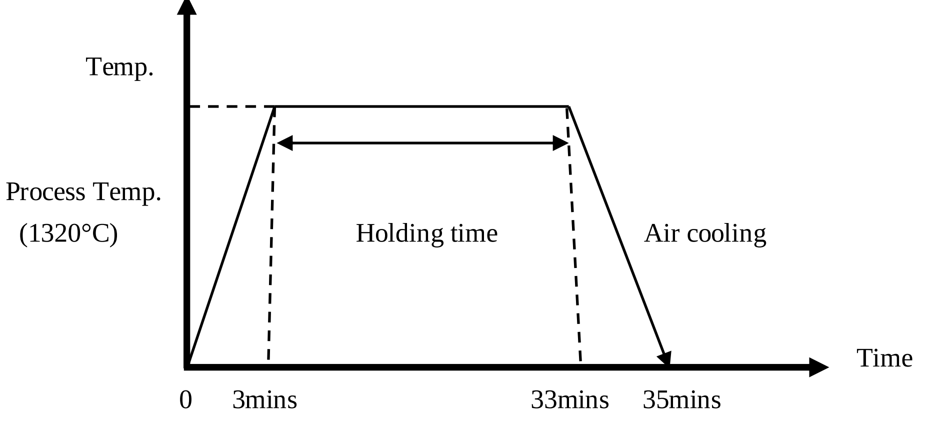


Figure-3. Temperature profile of sample in side the vertical tube furnace.



RESULTS AND DISCUSSION

According to displays of the Fig. 4 and 5, the liquid fraction profile (LFP) curves at 1320 °C for AISI D2 around 35% while for 304 stainless steel is around 2.5%. That is to say there is a huge deferent in liquid fraction percentage at the same temperature between base metal and the insert.

Figure-4. Liquid fraction profile with chemical composition of AISI D2 tool steel obtained from JMatPro simulation

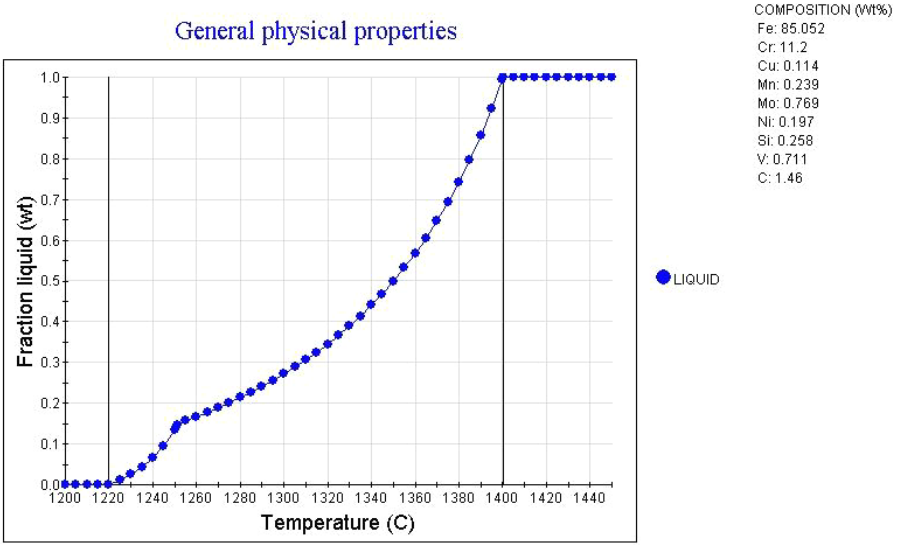


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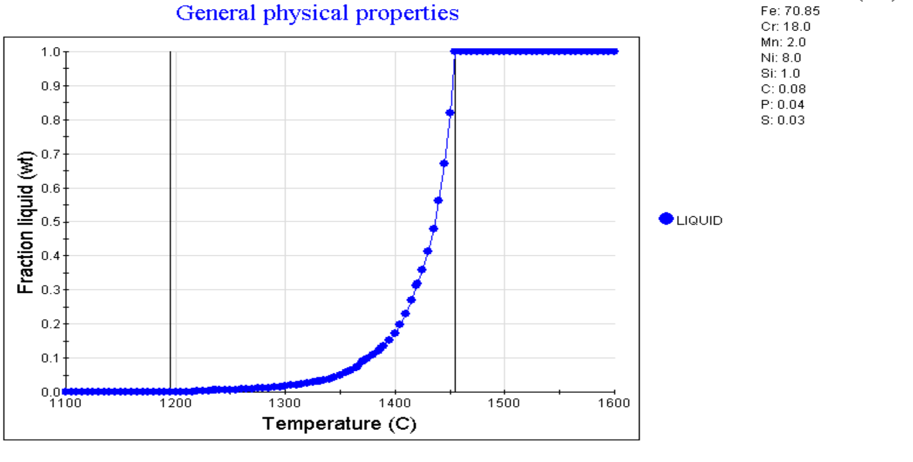
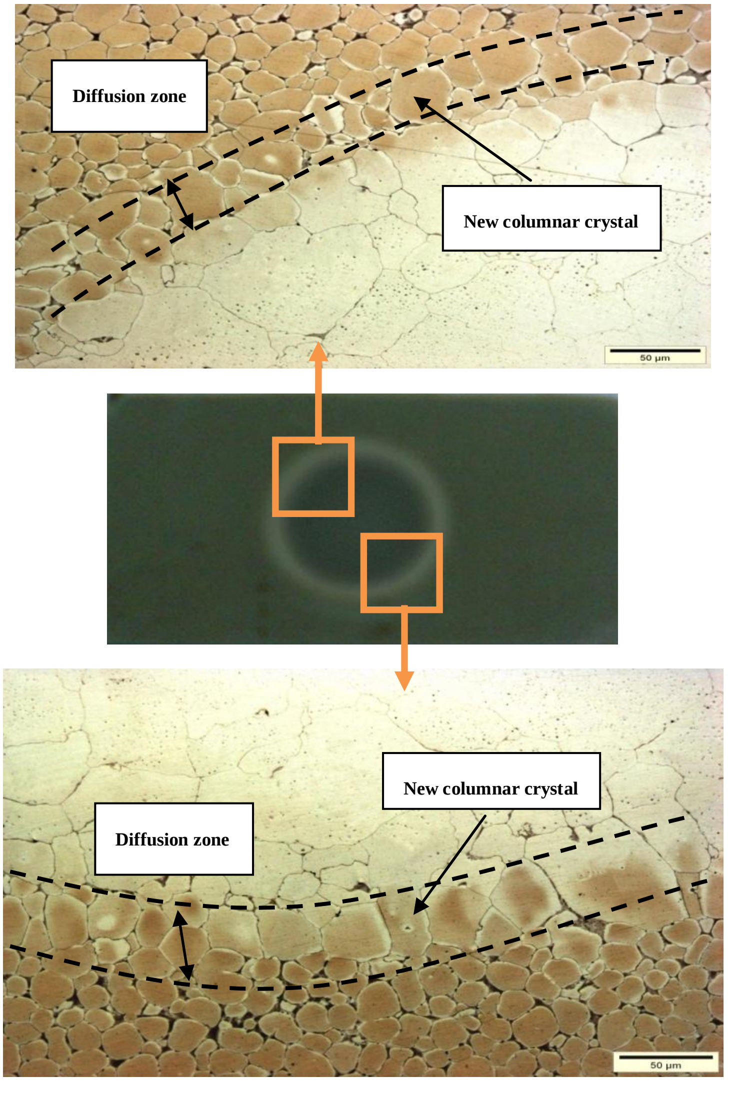
Figure-5. Liquid fraction profile with chemical composition of 304 stainless steel obtained from JMatPro simulation.



Based on the findings, Figure 6 shows the optical microscopic features of the interfaces joined metals between thixotropic AISI D2 tool steel base blank and 304 stainless steel pin. It can be seen clearly that fine boundary between base blank and pin with a smooth transition of the diffusion zone from one to the other. As known from the figures, the transition occurs with no presence of microcracking or porosity is detected, and the shape of the joint looks or appears very smooth and not corrugated. In addition we can see the changing of the base metal grains through the semi-solid processing to form new columnar crystals growth near the convergence zone (diffusion zone). In constructing of interfacial structure, both the solid phase and liquid phase of base metal are connected with a solid phase of the insert along the bonding boundary to give an indicative of a perfect joining at interfaces of products area. From these results it can be concluded that, the thixojoining was performed successfully and fine transition of the joined interface was observed.

Figure-6. Optical microstructure of interfacial diffusion zone.



CONCLUSION

A new type of thixo-joining process of AISI D2 with 304 stainless steel by using of partial remelting method was proposed. This process is not based on conventional method (adhesive, nails, and screws) to produce homogeneous properties with high surface quality. and avoidance of the dendritic microstructure of the join zone. Based on results of the experiments conducted in the present study, the use of thixojoining technique was performed with fine interfacial diffusion along the bonding boundary between base blank and pin. Furthermore a smooth transition from one to the other don through the formation of new columnar crystals growth near the convergence zone. The transition occurs with no presence of microcracking nor porosity is detected.

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