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Analysis of defects in clean fabrication process of friction stir welding

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Abstract: Striving for cleaner production is a sought-after manufacturing philosophy. Friction stir welding (FSW) is a joining technique with par excellence and far less invasive to the environment than even best conventional welding processes. It is energy efficient and free from consumables, affluent and radiations. It is, thus, accepted as a clean welding process that can produce acceptable quality joints. It suffers from some major challenges of defects of its own kind that subject the process open to improvements so as to prove itself a reliable production process. This study presents a holistic characterization of defects commonly found in FSW joints. The finding of the present study reveals that most defects are caused by inadequate heat generation, improper material movement around the pin and inadequate material consolidation behind the pin. The amount of heat generation and material stirring depends on several FSW parameters which may lead to the defect formation, if not selected properly. The results reported in this work are derived from sound literature support and experimentation. Prescriptions are made in the form of characteristics of defects such as likelihood of their location, main responsible parameters along with the recommendations for minimizing them.

Key words: clean welding process; friction stir welding; defect; process parameter

1 Introduction

Welding plays a vital role in producing complex products that are difficult to manufacture as a single component. Various welding processes are used on a large scale for different applications. Generally, fusion welding processes enjoy the status of most preferred joining processes in the industries. Fusion welding processes require several consumables including filler metal and fluxes during welding and also release fumes, harmful gases and radiations which adversely affect the environment. Additionally, the fusion welded zone and material in its neighborhood suffer deterioration of the advantageous effects of the previous processing on the base materials. Evidently, fusion welding processes are invasive to the environment. A fabrication activity such as fusion welding, which is being industrially utilized on a mass scale, yet remains highly invasive to the environment, must be checked with a clean alternative process. An autogenous solid state welding process like friction stir welding (FSW) has recognized as an effective alternative process which minimizes negative environmental impacts, conserves natural resources and energy, and is safe for workers and consumers and economically sounds. FSW, being a solid state welding process, does not require use of consumables (filler material, fluxes and shielding gas, etc.) for joining, produces no harmful emissions, is safe to the human (its features are represented in Fig. 1) and is, therefore, considered to be an energy efficient, environment friendly and clean material joining process.

Owing to such qualities, FSW has been regarded as a clean welding process for joining similar and dissimilar materials as shown in Fig. 2. FSW is distinguished for its ability to join dissimilar alloys which are otherwise unweldable by conventional technique. It has been emerged as a process of choice for joining aerospace grade aluminium alloys (2xxx and 7xxx series) that are difficult to weld by fusion welding. Moreover, fusion welding processes have their own limitations with regard to welding defects such as, hydrogen embrittlement,

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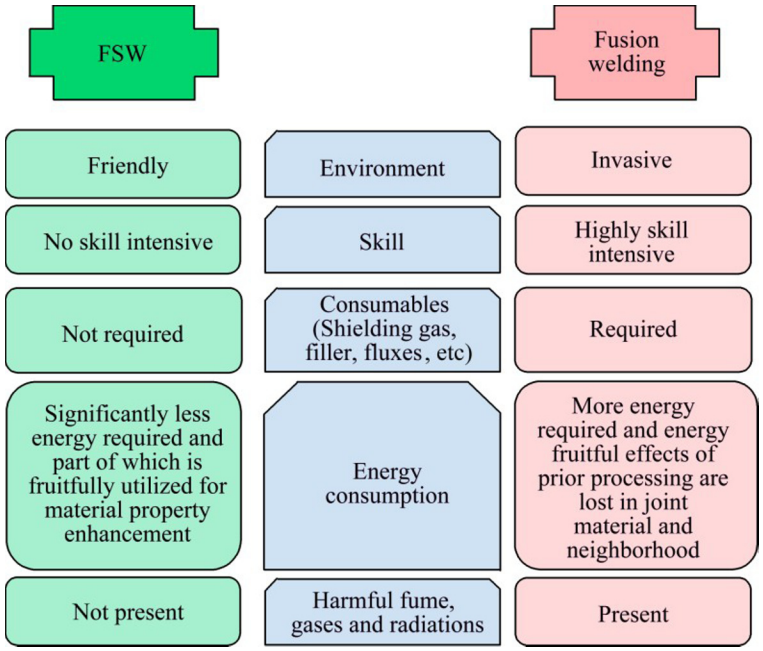

Fig. 1 Advantages of friction stir welding over fusion welding

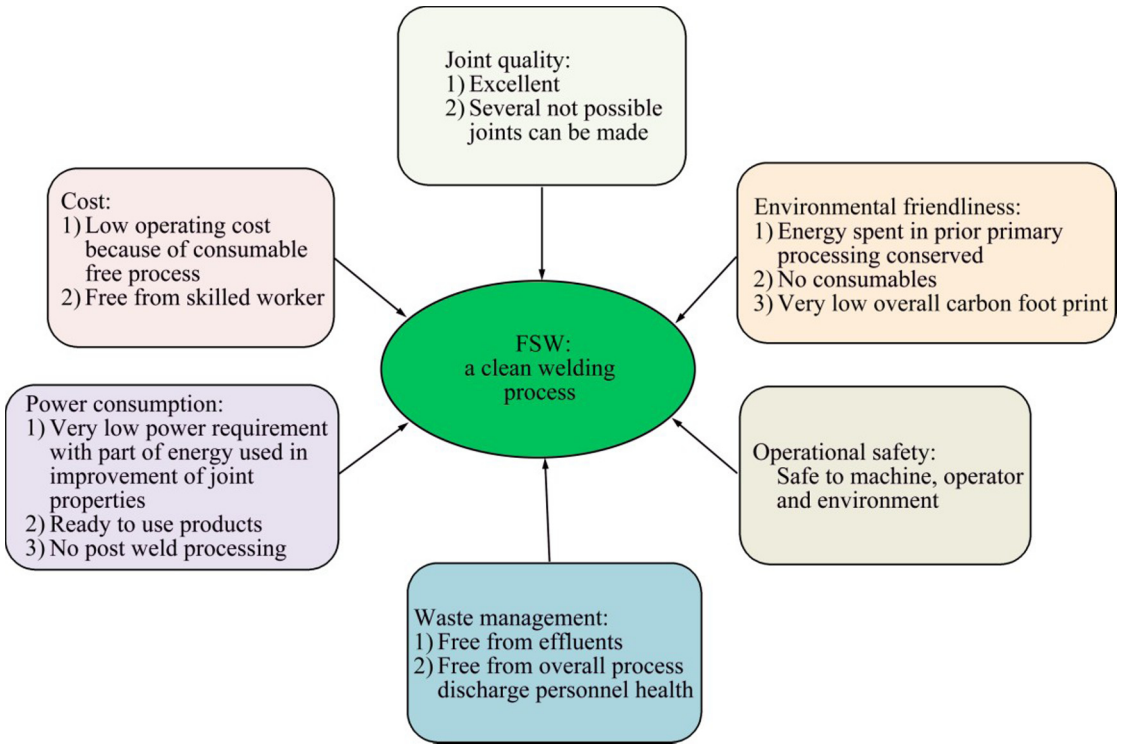

Fig. 2 Friction stir welding as clean welding process

porosity, undesirable metallurgical changes and micro-structural discontinuities. Such defects do not exist in FSW which in turn produces joints free from these fusion related defects. However, FSW also poses concerns of some characteristic defects that are different from fusion welding processes and significantly affect the quality of the welded joint.

Defect formation is more prominent in FSW of dissimilar alloys mainly due to difference in their softening temperature, metallurgy, chemistry, thermal conductivity and flow stress which hinders the material movement and improper heat distribution. Weld defects lead to failures and question the suitability of the FSW as a sound, reliable and dependable alternative. Producing defect-free joint continues to remain one of the major challenges for FSW. Thus, for the FSW as a clean