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APPLICATION OF TRIZ METHODOLOGY IN DIFFUSION WELDING SYSTEM OPTIMIZATION

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Abstract:
Welding is tremendously used in metal joining processes in the manufacturing process. In recent years, diffusion welding method has significantly increased the quality of a weld. Nevertheless, diffusion welding has some extent short research and application progress. Therefore, diffusion welding has a lack of relevant information, concerned with the joining of thick and thin materials with or without interlayers, on welding design such as fixture, parameters selection and integrated design. This article intends to combine innovative methods in the application of diffusion welding design. This will help to decrease trial and error or failure risks in the welding process being guided by the theory of inventive problem solving (TRIZ) design method. This article hopes to provide welding design personnel with innovative design ideas under research and for practical application.

Key words: *bonding pressure, bonding temperature, holding time, bonding strength, diffusion layer thickness, interface hardness*

INTRODUCTION

Diffusion bonding is a solid state welding process employed joining the materials through the formation of bonds at atomic level at elevated temperatures and below the melting point of the metals in controlled or inert atmospheres. Diffusion bonding is relatively simple joining process, which is controlled by three important process parameters. They are bonding temperature, bonding pressure and holding time. In addition, these three parameters are interrelated and thus have an effect on each other.

Zhihong Zhong et al. (2010) conducted an investigation on metallurgical and mechanical properties of diffusion bonded joints between tungsten and F82H steel using a titanium interlayer; And found that the shear strength has increased with the increase of temperature between the faying surfaces [1].

Kundu et al. (2005) carried out an investigation on diffusion bonding of pure titanium to AISI 304 stainless steel with copper as inter layer. It is found that optimum bond strength has obtained at about 900°C, and the strength later reduced with further increase of temperature [2].

J. Gilmore et al. Conducted diffusion bonding studies between magnesium and aluminium metals. It is found that the heat affected zone has increased and deformation was easy, removal of defects with increase of temperature was observed [3].

R.J. Golden Renjith Nimalet al. studied 7075 Al alloy and AZ80 Mg alloy diffusion welds with various welding temperatures and lengths. Microscopic examination and mechanical property evaluation were performed on the samples interface to determine the effect of welding temperatures [4].

Zeyad D. Kadhim et al. conducted the experiments to find the effect of different parameters on the strength of joints bonded by using diffusion bonding process between copper and nickel dissimilar metals at different temperatures, pressures and time values. Various deformations were undertaken with the given parameters for the chosen material joints[5].

Altshuller, G et al. propounded the theory of resolution of invention related tasks (TRIZ) is developed in Soviet Union in an algorithmic approach to the invention of new systems and for improving the existing things [6]. Mann, D.L et.al. Implemented this theory encompassing inventive principles which can be applied to arrive at a specific solution and overcome the contradictions do arise during the process. The 40 inventive principles and 39 contradictory elements are mapped in the form of matrix while implementing TRIZ theory [7].

Milica Petrovińe al. applied TRIZ and Multi- Agent Methodology for scheduling and planning aspects. In this investigation a methodology for development of software application for integration of process planning, scheduling, and the mobile robot navigation in manufacturing environment. Experimental results show that developed software can be used for proposed integration in order to improve performance of intelligent manufacturing systems [8].

Feng Liuet al. applied the TRIZ principles in metal casting process and identified the various contradiction and improving features relevant to it. The integration of the systematic method and the solving tools of TRIZ enhanced the efficiency of casting process optimization [9].

J.L. Chenet al. implemented in the product service systems (PSS); About103 PSS cases are collected and analyzed to identify consumers use habit in the PSS cases using the TRIZ principles [10].

In this investigation application of TRIZ method is undertaken for the diffusion bonding process in joining of various similar and dissimilar materials.

RESEARCH METHODOLOGY

Diffusion Bonding

Diffusion Welding or Diffusion bonding of materials is a solid state joining technique carried out at a suitable temperature and pressure and is defined as a joining process wherein all the faces to be bonded are held together by a pressure to cause minimum detectable plastic flow, at a temperature below the melting point of any of the parts. This diffusion causes coalescence of contacting surfaces and the operation can be carried out either in vacuum or in inert atmosphere (Fig. 1) [11, 12].

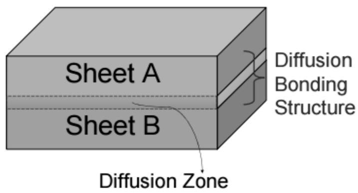

Fig. 1 Diffusion Bonding Process

The process needs attention to achieve a perfect diffusion welding joint governed by the properties of materials to be joined and also the process parameters. The main process parameters contribute significantly in the diffusion welding process are bonding pressure, bonding temperature, dwell time and nature of the interlayer [12].

TRIZ Theory

The TRIZ theory originates as of invention in different technical fields and integrates science and engineering. It is beyond field limitation and can be fully applied in all industries. TRIZ is extensively applied as a technical tool for engineering conflict and inventive R&D. The convenience of TRIZ is that it can transfer system contradictions and conflicts into a helpful factor and be compiled into an effective method to solve the problems [13].

The TRIZ theory based upon 40 inventive principles and 39 contradictory elements mapped in the form of matrix while developing the new technologies or improving the existing ones [14]. A generic method of applying the TRIZ theory initiates from analyzing the problem in the light of engineering features and inventive principles for obtaining and implementation of an optimal solution is presented in the flow chart given in the Figure 2.

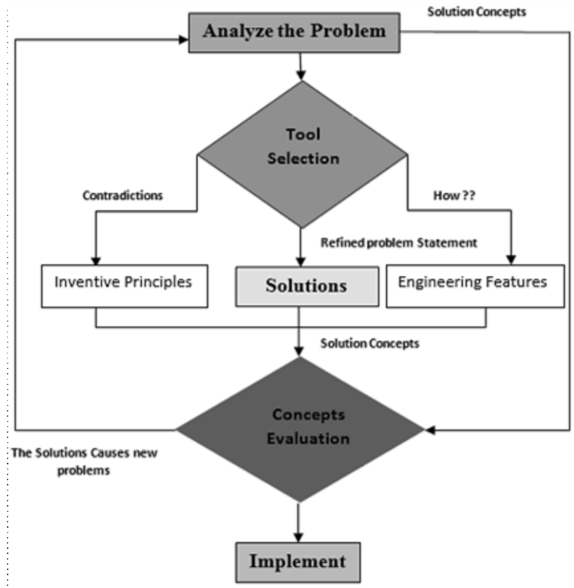

Fig. 2 TRIZ resolving flow chart

TRIZ APPLICATION IN DIFFUSION BONDING

The TRIZ application in the joining of similar and dissimilar thick as well as thin plates can be accomplished by proper selection of welding method, Joining Design parameters, Fixture design etc.

Welding requires heating to reach melting of the faying surfaces and sufficient amount of force causes a sound joint. In the light of mechanical and metallurgical properties of materials, the welding method is to be selected. The improving and worsening features considered in the joining process are evaluated from the 39 engineering features vis-a-vis their effect can be assessed selecting the 40 inventive principles. These are often weighed with their effects being called as contradictive matrix given in Table 1.

Any metal joining requires optimum amount of heat to reach melting point or recrystallization status; Insufficient heat produces incomplete fusion in the metal joint,to the contrary if input heat content is too high, the heat affected zone will be wider and it will affect the weld quality. Hence fusion welding processes are not selected for the purpose of joining the thin materials.

Table 1
TRIZ solutions of feature # 20, # 21 and # 22 relative to feature # 27, # 10 and # 9

Worsening Feature / Improving Feature	# 27 Reliability	# 10 Force	# 9 Speed
# 20 Energy spent by non moving object	10 Preliminary action 23 Feedback 36 Phase transitions	--	--
# 21 Power	--	2 Taking out 26 Copying 35 Parameter changes 36 Phase transitions	2 Taking Out 15 Dynamization 35Parameter Changes
# 22 Waste of energy	--	36 Phase transitions 38Strong oxidants	16 Partial or excessive actions 35 Parameter changes 38 Strong oxidants

The controlled heat input is important in metal joining processes and that can be regarded as "# 20 Energy spent by a non moving object" as per the TRIZ improving engineering features while TRIZ worsening parameter"# 27 Reliability", should not affect negatively and hence can be observed with the corresponding inventive principles namely # 10, # 23 and # 36 as shown in Table 1.

"# 36 Phase transitions" inventive principle focuses on temperature. The fusion welding changes the weld metal composition due to phase transitions while in the solid state welding this kind of phase transition does not occur as the materials do not reach melting point; the energy consumption is excessive especially for thin sheet joining. In such cases diffusion bonding offers a prospective joint for thick as well as thin materials [15].

The engineering features # 11 pressure, # 17 temperature vis-a-vis with the inventive principles # 37 thermal expansion, # 39 Inert atmosphere mapped in the TRIZ contradictive matrix along other inventive principles as shown in Table 2. And hence make the diffusion bonding process a prospective alternative to the fusion welding processes in joining especially thin materials.

Table 2
TRIZ solutions of feature # 17 Temperature relative to feature # 11Pressure

Worsening / Improving	#11 Pressure
# 17 Temperature	# 37 Thermal Expansion # 39 Inert atmosphere # 36 Phase Transition # 33 Homogeneity # 32 Change of color

Every manufacturer wants to minimize numbers of welding spots to reduce the effect of metallurgical defects in the weld area in order to get best quality welding and thereby making resistance spot welding process inferior compared to diffusion bonding process. Similarly in case of Friction welded joint the extra material (flash) need to be machined which increases the manufacturing cost where as the TRIZ methodology selects the correct welding process by contradicting the improving parameters and worsening parameters considered namely # 23 waste of substance and # 32 Manufacturability with the corresponding inventive principles namely # 15 Dynamization, # 33 Homogeneity and # 34 Discarding and Recovering.

The inventive principle # 14 Strength warrants the welding process to be selected from the engineering features # 27 Reliability more popularly called as responses being governed by the inventive principles # 40 Composite materials, # 8 anti-weight and # 30 Flexible shells and thin films. And there by making a prospective parameter selection in the diffusion bonding process employing the TRIZ methodology as given in Table 3.

Table 3
TRIZ solutions of feature # 14 Strength to feature # 27 Reliability

Worsening / Improving	# 27 Reliability
# 14 Strength	# 40 Composite materials # 8 anti-weight # 30 Flexible shells and thin films

In the process evaluation using TRIZ design principles it is established to employ diffusion bonding process for joining of thin and thick sheets for similar and dissimilar metals, with or without interlayers. The parameters governing this process are optimized according to the type of material and thickness employing the TRIZ methodology.

CONCLUSION

This investigative article proposes to combine TRIZ and necessary concept design suggestion of the diffusion bonding process. Through the TRIZ methodology the diffusion bonding process is effectively designed and optimized the process design and subsequently the welding parameter, to achieve the sound joints between similar and dissimilar materials with interlayer and remarkably reduce the material wastage with higher productivity.

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