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Optimization of a Diffusion Welding System Using the TRIZ Methodology

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ABSTRACT

Welding is widely utilized in the industrial industry for connecting metal parts together. Diffusion welding is a relatively new technique that has greatly improved weld quality in recent years. However, diffusion welding's research and practical development have stalled to some degree. Diffusion welding, which involves combining thick and thin materials with or without interlayers, suffers from a lack of useful data on welding design considerations such fixture, parameter selection, and integrated design. This piece is an attempt to bring together novel approaches to implementing diffusion welding design. The theory of creative problem solving (TRIZ) is a design strategy that may assist reduce the likelihood of failure or wasted time during the welding process. This article's stated goal is to provide welding design staff access to cutting-edge design concepts for use in both theoretical and applied settings.

INTRODUCTION

Diffusion bonding is a solid state welding process that involves creating atomic-level connections between the materials at high temperatures and below the melting point of the metals in controlled or inert atmospheres. Diffusion bonding is a simple way of joining that may be controlled by only three factors. Conditions of heat, pressure, and time are required for bonding. These three variables are intertwined and mutually affect one another. Zhihong Zhong et al. (2010) studied the metallurgical and mechanical properties of diffusion bonded junctions between tungsten and F82H steel using a titanium interlayer, and found that when the temperature difference between the faying surfaces was raised, the shear strength of the joint increased [1]. The effects of copper as an interlayer in diffusion bonding pure titanium to AISI 304 stainless steel were studied by Kundu et al. (2005). The strongest bonds are formed at a temperature of around 900 degrees Celsius, while bond strength is found to decline above this point [2].

J. Gilmore et al. investigated the nature of the bonds formed between magnesium and aluminum via the process of diffusion. When temperatures were increased, it was found that the heat affected zone grew in size, deformation became simple, and flaws vanished [3]. The work of R.J. RenjithNimale et al. looked into the effects of different welding Temperatures and weld periods on diffusion welds in 7075 Al alloy and AZ80 Mg alloy. A microscopic examination of the interface and an evaluation of its mechanical properties were performed to discover how welding temperatures impacted the samples. Copper and nickel are two different metals, thus Zeyad D. Kadhim et al. conducted experiments to assess the effect of temperature, pressure, and time on the joint strength obtained by the diffusion bonding method. Several deformations were carried out in accordance with the joint requirements for the chosen materials[5].

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Theory of Invention-Related Tasks (TRIZ) was developed by G. Altshuller et al. [6] in the Soviet Union as an algorithmic approach to creating new systems and improving existing ones. New ideas are presented in this theory by Mann, D.L., and colleagues, and they may be used to reach a desired outcome and triumph over potential roadblocks. When putting TRIZ theory into reality, a matrix is used to map the 40 creative principles and 39 competing components.

RESEARCH METHODOLOGY

Diffusion Bonding

Diffusion Welding, also known as Diffusion Bonding, is a joining process in which 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, and is performed in a solid state. Coalescence of contacting surfaces occurs as a result of diffusion, and the process may be performed in a vacuum or an inert environment (Fig. 1) [11, 12].

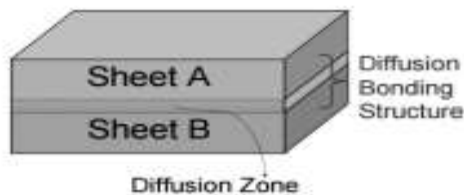


Fig. 1 Diffusion Bonding Process

To have a great diffusion welding connection, you have to pay attention to the technique and the qualities of the materials you're joining together. Bonding pressure, bonding temperature, dwell duration, and interlayer nature are the most influential process factors in diffusion welding [12]. The Theory of Irrational Success The theory of Inventive Problem Solving (TRIZ) draws on the history of innovation across several disciplines in the technological sciences. The technology has no practical limits and may be used in any sector. TRIZ is widely used as a technical tool for solving engineering problems and doing creative research and development. TRIZ is useful because it allows for the conversion of systemic contradictions and conflicts into a positive component, which can then be collected into an efficient approach to issue

solving [13]. When creating new technologies or bettering current ones, the TRIZ theory may be used [14] thanks to its 40 innovative principles and 39 contradicting components represented in the form of a matrix. Figure 2 is a flowchart depicting a general approach to implementing the TRIZ theory, which begins with examining the issue in light of engineering characteristics and innovative ideas in order to acquire and execute an ideal solution.

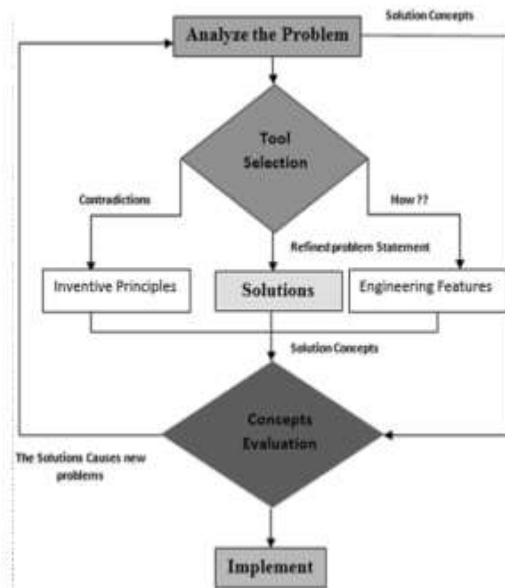


Fig. 2 TRIZ resolving flow chart

TRIZ APPLICATION IN DIFFUSION BONDING

By making the right choices for the welding process, Joining Design parameters, Fixture design, etc., TRIZ may be used to the joining of comparable and unlike thick and thin plates. The welding process results in a strong union by applying heat until the flaking surfaces melt, and then applying a significant amount of force. The welding technique should be chosen with consideration for the materials' mechanical and metallurgical qualities. From among the 40 innovative concepts, you may determine how much of an improvement or decrease you can expect from any given one of the 39 engineering aspects taken into account throughout the joining process. It is common practice to compare and contrast the outcomes using the "contradictory matrix" shown in Table 1. If the input heat content is too high, the heat

affected zone will be larger, and the weld quality will suffer. Inadequate heat causes incomplete fusion in the metal joint, whereas excessive heat has the opposite effect. Because of this, fusion welding techniques are not chosen to combine the thin materials.

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

Improving Feature	Worsening 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 35 Parameter Changes
# 22 Waste of energy	-		36 Phase transitions 38 Strong oxidants	16 Partial or excessive actions 35 Parameter changes 38 Strong oxidants

Metal joining processes rely on regulated heat input, which can be thought of in terms of TRIZ's "# 20 Energy spent by a nonmoving object" principle. However, the "# 27 Reliability" principle, which is on the list of "TRIZ worsening parameters," should not have any negative effects. Temperature is the primary consideration in the "#36 Phase transitions" creative concept. with fusion welding, phase transitions alter the weld metal's composition, but with solid state welding, the components never reach their melting point, therefore less energy is used (although this is particularly true for connecting thin sheets). If this is the case, diffusion bonding might be used to create a junction between thick and thin materials [15]. Table 2 shows how the TRIZ contradictory matrix maps the engineering aspects of pressure and temperature to the creative concepts of thermal expansion and inert atmosphere. Thus, combining particularly thin materials using diffusion bonding is a promising alternative to fusion welding.

Feature 17 Temperature TRIZ Answers in Context of Feature 11 Pressure

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

To achieve the highest possible welding quality, every producer strives to decrease the number of welding spots in the weld region. This disadvantages the resistance spot welding technique in comparison to the diffusion bonding procedure. Similarly, in the case of Friction welded joints, the extra material (flash) needs to be machined, which increases the manufacturing cost; however, the TRIZ methodology chooses the appropriate welding process by contrasting the improving parameters and worsening parameters considered, specifically #23 waste of substance and #32 Manufacturability, with the corresponding inventive principles, specifically #15 Dynamization, #33 Homogeneity, and #34 Discarding and Recovering. According to creative concept #40 Composite materials, #8 anti-weight, and #30 Flexible shells and thin films, the welding technique must be chosen from engineering characteristics #27 Reliability, also known as responses. And using the TRIZ approach shown in Table 3 to make a foresightful choice of diffusion bonding process parameters.

Table 3: TRIZ answers for characteristics 14 (Strength) and 27 (Reliability).

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

For combining thin and thick sheets of comparable and dissimilar metals, with or without interlayers, the diffusion bonding technique is determined to be the best option in a process assessment based on TRIZ design principles. Using the TRIZ approach, the process's controlling parameters are tuned based on the material and thickness of the substrate.

CONCLUSION

This research study makes the case for integrating TRIZ with the concept design suggestion inherent in the diffusion bonding process. To achieve the sound joints between similar and dissimilar materials with interlayer and to remarkably reduce the material wastage with higher productivity, the diffusion bonding process is effectively designed and optimized through the TRIZ methodology.

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