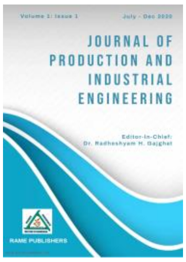

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Parametric Optimization of Friction Welding of Aluminum Alloy 6351 and Steel 304

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Abstract - **The joints form in the friction welding state through the use of friction-generated heat. The purpose of the study is to produce the friction weld component of Aluminum 6351, Steel 304 and to improve the welding quality parameters. This paper examines the strategy of Taguchi design experiment to increase friction welding strength Al (6351) and steel 304 tensile strength. Symmetrical exhibit of L9 was the effect from the rigidity of the rotational speed, force, time, and the optimum welding condition for maximizing tensile strength is determined using ANOVA and signal to noise ratio of critic analysis and further tests by NDT to measure weld progression were carried out with NDT (radiography test).**

Index terms - Friction Welding, Stainless Steel, Aluminum, Tensile Strength, Optimization by Taguchi methodology, ANOVA

I. Introduction

This paper contributes to the final ambition of aluminum materials for friction welding steel research. After a written study has revealed that the friction welding process was chosen to join the steel with the aluminum material. The aim of this application is to help this machine to be joined together and to increase its involvement in welding this particular material mixture, because there is not much testing to be carried out in this respect.

The standards of aluminum welding steel can also be applied to other different material combinations [2]. Energy investment funds and environmental protection are important issues to be identified by us. As one of the efficient measures is the reduction in heaviness of vehicles, the use of the steel and aluminum blend in the manufacture of vehicles has increased. Different preliminaries were therefore directed to the welding of steel into aluminum. In spite of the fact that some parts of the structure can be supplanted with aluminium amalgam components, the present structures made of treated steel cannot be totally supplanted in the light of the quality, welding capacity, and financial considerations [2].

A. Friction Welding

Friction welding is a strong process of fit that can create high-quality welds with comparable or disparate compound arrangements between two parts. The friction welding parts must rub against each other and therefore generate heat at the interface. The material on either side of the scoring interface is softened. In order to start a weld the melted materials start to flux together. When sufficient warmth is created, the scoring activity is completed and the contact pressure is maintained or extended for a while to increase the strong stage relationship. The friction

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weldinging process requires a machine that is intended for the joint interface, which utilizes relative development between the pieces of work, to change over mechanical vitality into heat. [1-5]. The welding procedure involves friction between the finishes of two sections to be used alongside the warmth needed for the welding. One section to be connected is rotated quickly and the other part is pivotally aligned with the following section and squeezed firmly against it. The friction between the two sections increases the finishing temperature. The revolution of the part is unlikely to stop at that point and the weight of the fixed part is increased for joining to be possible. This is also referred to as friction welding.

Friction welding, as is known, is nowadays widely used in several companies. Heat in friction welding is created at the work pieces' interface during tension by transforming mechanical energy into heat energy. A friction welding strategy can be integrated without much extent into a different ferrous and non-ferrous composite, with round or non-circular cross sections with distinguishing warm and mechanical properties. Friction welding is a strong state welding process that produces metallic holding at temperatures below that of the base metal's liquefying purpose. The most striking limits for friction welding [3] are frictional time, friction pressure, forging time, forging pressure and rotating speed. Friction Stir Welding Friction Stir Welding (FSW) was created at Welding Institute (TWI) in Cambridge, UK, and is a late friction welding process. [19]. This strategy uses a non-consumer welding tool. This process uses a non-usable rotating tool for the production of frictional warmth and distortion at the welding position, which disturbs the progression of a joint while the material is strong.

B. Friction Stir Welding

Friction Stir Welding (FSW) was established at The Welding Institute (TWI), Cambridge, UK, as part of a late friction welding process [19]. This strategy uses a non-consumption welding tool. This procedure uses an unsuspendable pivoting tool to produce frictional warmth and contortion in the welding position, thereby disrupting the joint progress while the material is solid. FSW's main advantages, being a solid-state technique, are low change, lack of dissolution associated faults and unbelievable joint strength, even in combinations considered to be non-joinable by regular practices (e.g.,5xxx and 6xxx arrangement aluminum composites). In addition, filler-induced glitches, or imperfections, are considered as non-appearances because the strategy doesn't require any filler. The hydrogen damage during the welding of steel and other iron compounds must also be avoided by reducing the hydrogen substance of the stir welded joints. [6-7].

- *Principal of FSW Process*

Friction welding is completed by the translation or rotation, by extending a compressor force through the joint, of one part near to another. The frictional heat produces the two segments at the limit, which means that when the outskirts material has been changed, the consolidated material is removed from the finish, so that new material is provided from every module. Then the relative speed stops and a propelled force is applied to shut the compressor before cooling on the joint. The key component of friction welding is that the weld is not produced in solid state as a melted force [7].

- *The American Welding Society's definition of friction welding (AWS)*

The standard C 6.1-89: "Friction welding is a solid-state joint process producing material mixtures in compressive strength contact of the rotating or moving work parts to produce heat and plastically root material from the facing surfaces. Filling metal, flux and protective gas are not required under typical conditions [7-11].

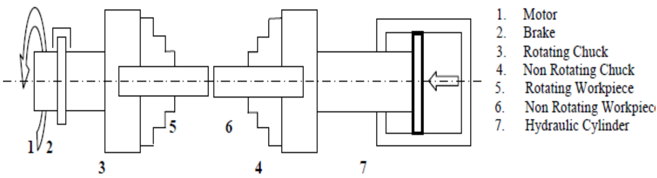

Figure 2: Drive friction welding continuous layout

The principle of this method is to transform kinetic energy in heat energy (through friction, whether rotational or translational). One part is fixed and rotating around its axis while the other part is fascinated and not spun yet can be axially migrated to communicate with the turning segment. The rotation is stopped and the forming pressures spread at the time when the combination temperature is reached. Warmth is caused by erosion and is filled with grain structure and contained on the edge. There is no material melting at that point in the joint.

- *Stages of the process*

In general, three fundamental phases of friction welding. The two components are linked in the first phase, sometimes referred to as the heating stage, and an axial compressive force with a relative motion is applied. The temperature at the friction interface, which reduces the flow stress of the materials, is increased by friction-generating heat. The material cannot ultimately withstand the axial compressive force and streams plastically outwards to frame the bubble, transferring oxides and defilements. The Flash formation takes place during this step, which is meant to be the burn-off stage. The welding process is finished by stopping relative movement and using a high compression strength during the production process [1]. In Figure 3, the initial workpiece is pivoted and the other is kept as shown in Figure A. The centrifuge force applies at the point at which the correct spin-off speed is reached, as shown in Figure B. Scouring the workpiece locally heats the interface and upsets the workpiece, as in Figure C.

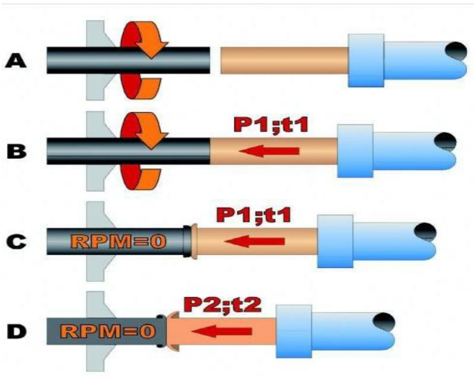

Figure 3: The basic steps in friction welding

C. Objectives

i. Optimum process parameters FSW identification.
ii. Effect of every FSW process parameter.
iii. Find optimal process parameter values through experimental design

The literary review undertaken in connection with the present work will be presented in the field of friction welding optimization.

In fact, the main force for starting sliding a material is better than moving, so that the static friction coefficient is more prominent than the dynamic friction coefficient. It is identified that the selection of norms of frictional force fluctuates by requests of scale reliant on the range of the tenders, naturally visible or minute.

Mathematically,

Friction force = coefficient of friction × normal weight

A.R.D. Industries manufacture and execute subcontract friction soldering of consumer goods for countless organizations including agrarian, automotive, electric, ranger, mining, transporting companies and related businesses. A.R.D. Businesses is perhaps the greatest erosion welding sub-contract producer in Canada.

The motivation behind the work was to evaluate the advancement of strong state joints of unique material AA1050 aluminum and AISI 304 tempered steel, which can be utilized in channels of tanks of fluid fuels and different segments of the Satellite Launch Vehicle. Tests were directed with various welding process boundaries and the outcomes were dissected by methods for ductile tests, Vickers miniaturized scale hardness, metallographic tests and SEM-EDX. The quality of the joints fluctuated with expanding friction time and the utilization of various weight values [13-14].

Dissimilar friction welding of 6061-T6 aluminum and AISI 1018 steel. In particular, the presentation of aluminum compound parts into a steel vehicle body requires the advancement of dependable, productive and monetary joining forms. Since aluminum and steel exhibit diverse physical, mechanical and metallurgical properties, recognizable proof of appropriate welding procedures and practices can be risky. In this work, inactivity contact welding has been utilized to make joints between a 6061-T6 aluminum composite and an AISI 1018 steel utilizing different boundaries. Ideal speed rpm identified with twisting quality (MPa) [12].

Calvin Blignault learns about Friction welding set up experimental equation that decides the connection between welding speed, material thickness, instrument geometry and material sort. The accompanying recipe shows the connection between these parameters [18].

$$V = \frac{\phi \times \beta}{t} \quad (1)$$

Where,

V = feed rate mm/min

ϕ = material factor

β = tool factor

t = material thickness (mm)

J. Adamowski et al. investigated the mechanical properties of friction Stir Welds with various process boundaries and miniaturized scale auxiliaries in the AA 6082-T6. The elastic welds were tested and connections were assessed between the procedural boundaries. Under optical lenses, the microstructure of the weld interface has been seen. Additionally, miniaturized scale hardness of the subsequent joint was estimated. It was seen that test welds show protection from augmentation of welding speed, Hardness decrease was seen in weld chunk and warmth influenced zone (HAZ). The explanation behind this event was the active and warm asymmetry of the FSW procedure. The hardness was substandard compared to that of combination welding. Passage abandons were found in the chunk zone [15].

M. Vural investigated the friction mix welding competency of the EN AW 2024-0 and EN AW 5754-H22 Al amalgams. These two Aluminum composites are widely utilized in the business. The investigation introduced that the hardness estimation of EN AW 2024-0 at the weld region is expanded around 10-40 Hv. This might be the aftereffect of recrystallization and smaller grain structure arrangement. Be that as it may, hardness of EN AW 5754-H22 got diminished due recrystallization and free grain structure arrangement. Welding execution of EN AW 2024-0 is 96.6 and for EN AW 5754-H22 it is 57%. Welding execution of disparate Aluminum compounds EN AW 2024-0 and EN AW 5754-H22 is arrived at an estimation of 66.39%. Investigation of Welding zone utilizing examining electron magnifying instrument demonstrated no adjustment in the microstructure in the welding zone. Hardness dissemination at the weld zones didn't show any noteworthy change in hardness [17].

Yong-Jai Kwon et al. researched the contact mix welding between 5052 aluminum amalgam plates with a thickness of 2 mm. The apparatus revolution speeds were running from 500 to 3000 rpm under a consistent navigate speed of 100 mm/min. Welded joints were gotten at device turn speed 1 000, 2000 and 3000 rpm. At 500, 1000, and 2 000 rpm onion ring structure was plainly seen in the friction mix welded zone (SZ). The impact of hardware revolution speed on the onion rings was watched. Addition size in the SZ is littler than that in the base metal and is diminished with a decline of the apparatus pivot speed. The examination demonstrated that the quality, rigidity of the joint is more than that of the parent metal. The examination additionally showed that the joint is less pliable than the parent alloy [20].

Yeung et. al. is explored microstructure and mechanical properties of alumina-6061 aluminum composite joined by erosion welding alumina-6061 aluminum amalgam joints were welded effectively by friction welding. Some fascinating advancements of microstructure and properties were seen in the welding territory. The HAZ is extremely tight, if not non-existent, on account of 1250 rpm and the twisting quality qualities got were more prominent in joint utilizing rotational speed of 2500 rpm than with 1250 rpm. The utilization of higher rotational speed with consistent friction time and weight builds the twisting quality of friction welded because of warmth input, high plastic disfigurement and shearing of grains at the interface [16].

Wang et. al. examined friction welding to join hardened steel 304 and aluminum 6082 materials by means of constant drive contact welding procedure and learn about austenitic tempered steel (AISI 304) and aluminum materials were welded effectively. The welding procedure was researched by ductile testing, sway testing, Vickers small scale hardness testing, weariness testing, smaller scale basic perception, and EDS estimations with the accompanying outcomes. The weld joint with ideal miracle weight and upset time consumed important measure of vitality speaking to the total holding and great weld quality at the interface, contrasted and the other two, lesser surprise weight and upset time, and higher bombshell weight and upset time weld joint specimens [2,19].

D. Muruganandam considered Friction mix welding of various materials for four distinctive apparatus pivot speeds to be specific 600, 800, 1000 and 1200 rpm. Radiology was done to contemplate the imperfections in the weld joint. The examination demonstrated that imperfection fixation was greatest for the 600-rpm apparatus pivot. It was somewhat diminished for 800 rpm and significantly lesser for the 1000 rpm speed turn. Least imperfections were found at the most noteworthy rpm (1200) [21-22].

Shyam Kumar Karna1 et. al. was done application of Taguchi method in Indian industry and he research Taguchi parameter design is an incredible and proficient technique for improving the procedure, quality and execution yield of assembling forms, in this manner an integral asset for meeting this test. Disconnected quality control is viewed as a successful way to deal with improve item quality at a moderately minimal effort [12].

III. METHODOLOGY

A. Taguchi method

Taguchi began to grow new techniques to upgrade the way toward designing experimentation. He accepted that the most ideal approach to improve quality was to plan and incorporate it with the item. He built up the strategies which are presently known as Taguchi Methods. His fundamental commitment lies not in the scientific detailing of the plan of tests, but instead in the going with reasoning. His ideas delivered a one-of-a-kind and ground-breaking quality improvement method that varies from conventional practices. He produced "powerful" or harsh frameworks for every day as well as occasional different types of conditions, machine wear and other external variables [10]. Taguchi proposes a three-phase process to achieve desirable product quality in design: design of the system, design of parameters and design of tolerance. System design means a product or process that must be employed to be conceptualized and synthesized. The framework configuration stage is the place new thoughts, ideas and information in the territories of science and innovation are used by the structure group to decide the correct mix of materials, parts, procedures and configuration factors that will fulfill utilitarian and practical particulars. To accomplish an expansion in quality at this level requires development, and along these lines' upgrades are not generally made. In boundary structure the framework factors are tentatively dissected to decide how the item or procedure responds to wild "commotion" in the framework; boundary configuration is the central purpose of Taguchi's approach. Boundary configuration is identified with finding the proper plan factor levels to make the framework less delicate to varieties in wild clamor factors, i.e., to make the framework powerful. Thusly the item performs better, decreasing the misfortune to the client. The 8-phase methodology in Taguchi is -

Step1: Identify major function, effects, and mode of failure

Step 2: Identify noise factors, test conditions and characteristics of quality

Step3: Identify the optimized objective function

Step 4: Determine control and level factors

Step 5: Select the experiment with the orthogonal matrix

Step 6: Experiment with the matrix

Step7: Data analysis, optimal level and performance prediction

Step 8: conduct a test and plan a future measurement. [10]

B. Non-Destructive Test

Nondestructive testing (NDT) is the inspection, testing, or evaluation process for discontinuities of materials, components or assembly, or characteristics difference, without destroying the part or system serviceability. In other words, the part can still be used when the inspection or test is finished. Unlike NDT, other tests are destructive in nature and therefore are carried out for a limited amount of samples ("lot sampling") instead of actually putting materials, components or assemblies into operation. These destructive tests are often used in order to determine the physical characteristics of materials such as resistance to impact, ductilities, yield and ultimate tensile strength, tensile strength and fatigue strength, but NDT more effectively finds discontinuities and difference in material characteristics. Modern non-destructive testing in manufacturing, manufacturing and in-service inspections nowadays is used to ensure product integrity and reliability, to check manufacturing processes, reduce production costs and ensure a consistent level of quality. NDT is used in construction to ensure material quality and joint process during the manufacturing and erection phases, NDT inspections are used to ensure the integrity of products in use to ensure their usefulness and public safety.

C. Design of Experiment

Design of Experiment (DOE) is an incredible method utilized for investigating new procedures, increasing expanded information on existing procedure and improving these procedures for accomplishing world class execution. DOE is an exploratory technique where impacts of numerous components are concentrated at the same time by running tests at different degrees of the variables. What levels should we take, how to join them, and what number of tests should we run, are topics of conversations in DOE. The Design of trial is utilized to build up a format of the various conditions to be contemplated. A test configuration must fulfill two destinations: first, the quantity of preliminaries must be resolved; second, the conditions for every preliminary must be determined. Prior to planning an analysis, the information on the item/process under scrutiny is of prime significance for recognizing the components liable to impact the result. Structure of investigations, DOE, is utilized in numerous modern divisions, for example, in the Development and improvement of assembling forms. Run of the mill models are the Production of wafers in the gadgets business, the assembling of motors in the vehicle business, and the amalgamation of mixes in the pharmaceutical business. Another principle kind of DOE-application is the improvement of explanatory instruments. Numerous applications are found in the logical writing portraying the streamlining of spectrophotometers and Chromatographic gear. Generally, be that as it may, an experimenter doesn't hop straightforwardly into an enhancement issue rather starting screening trial plans are utilized so as to find the most productive piece of the test district being referred to. Other fundamental sorts of utilization where DOE is helpful is vigor trying and blend structure. The key element of the last application type is that all elements whole to 100%. Territories where DOE is utilized are in mechanical exploration, improvement and creation, Optimization of assembling forms, Optimization of scientific instruments screening and recognizable proof of significant elements power testing of techniques Robustness testing of items Formulation tests [16].

In this examination of erosion welding, disparate material Aluminum composite 6351 and tempered steel 304 is fixed to an installation for the test and the apparatus thus is held with the assistance of throw of an inside machine and the device is appended to the drill chalk with water driven force pack framework.

D. Material Selection

Genetic disparate metal joining offers the possibility to use the benefits of various materials frequently giving one of a kind answers for designing necessities. The principle purposes behind divergent joining are because of the mix of good mechanical properties of one material and either low explicit weight or great erosion opposition or great electrical properties of second material. Thus, joining forms for disparate materials have gotten impressive consideration in the ongoing years. The need to grow the utilization of lightweight structures in the car business has increment enthusiasm for the utilization of both aluminum and magnesium as basic materials. In any case, the expense of aluminum contrasted with steel confines its application for vehicle parts. [1] Solid-state holding of aluminum combinations to prepares has been explored by numerous creators for over 50 years, presumably in light of the fact that these are auxiliary materials most generally utilized in an assortment of enterprises, and have mechanical and compound properties very not quite the same as one another. As of late, it draws in much more thoughtfulness regarding satisfy the needs for weight decrease and improvement of the vitality productivity of vehicles from a natural perspective.

E. Aluminum Alloy AA6351

Aluminum alloy AA6351 is a combination of medium strength and fantastic resistance to erosion. The 64430 arrangement composites have their most remarkable quality. The AA6351 compound is called an auxiliary amalgam. The compound AA6351 is the most commonly used for machining in plate structures. Much manganese spreads control the grain structure, resulting in a more grounded compound. Compound AA6351 machines good and produce tight swarf curls when using chip breakers. Anyway, for accompanying reasons, joining aluminum to steel is not easy:

1. Much higher dissolving purpose of steel contrasted with aluminum.

2. Difference of the warm extension coefficients among steel and aluminum, the exceptionally persevering shallow oxide film on aluminum compounds, which meddles with the Achievement of a metal-to-metal contact at the interface,

3. The most difficult issue is the development of fragile intermetallic mixes coming about because of the response of Al with Fe. Specifically, combination welding includes the development of a lot of intermetallic mixes in the weld metal since steel and aluminum are blended in the fluid state and hence has been viewed as inadmissible for combination welding [3].

On the other hand, plan of the intermetallic compound in solid state welding can be compelled by picking sensible holding limits, since the creation of the IMC is obliged by scattering of reacting parts in the solid state. For this, various assessments have been represented of solid state holding of aluminum compound to steel. Contact welding is a methodology most comprehensively used for joining of one of a kind metals by virtue of its high benefit and constancy of the joint execution, despite the controllability of the improvement of the IMC layer [3]. However, a couple of makers have point by point cases were pounding welds of aluminum to steel broke at the interface demonstrating lower quality than the base metal, regardless, when the IMC layer was under 1 μm thick. In such way, no sensible explanation has been given for the controlling variable of the joint quality. In particular, aluminum amalgams with a high Mg content have a lower joint viability and a littler Pieter Rombaut 18 Academic Year 2010-2011 limit window to secure a high joint profitability. Magnesium is along these lines a critical segment blended it up of current Al amalgams [3]. Selection of contact welding boundaries and their levels.

Rotational speed, axial forces and welding time are the main factors for direct drive friction welding. These factors determine the measurement of vitality in the welding region and the interface rate of the warmth age. The heat rate is not consistent over the welding interface. It should also be noted that it changes during the different phases of the weldinging cycle.

Constant experimental process parameters

- Material for the workpiece – 6351 aluminum and 304 steel
- Workpiece diameter - 16 mm

Experimental variables parameter

- Rotation speed
- Forging pressure (MPa)
- Friction time

- *Rotation Speed*

Fiction welding is a process where the rotating speed due to heat is generated at the workpiece's interface by direct conversion of mechanical energy into thermal energy.

- *Forging Pressure*

As a solid-state welding process that produces a welding under compressive force (forging pressure) contact between work parts that rotate or move relative to each other, heating and plastically display of material from the fallen surfaces. The American Welding Society (AWS) The joint strength increased and then decreased with an increase in pressure and upset time after reaching maximum value.

- *Friction Time*

A more drawn out miracle time caused the abundance puncturing into a smooth aluminum material shaping an intermetallic layer. Notwithstanding, a portion of the welds demonstrated helpless quality relying upon some collection of alloying components at the interface, which are the aftereffect of a temperature rise and the presence of intermetallic layers, for example, FeAl. The means remembered for the Taguchi boundary configuration are: choosing the best possible symmetrical exhibit (OA) as indicated by the quantities of controllable components (boundaries); running tests dependent on the OA; breaking down information; recognizing the ideal condition; and leading affirmation runs with the ideal degrees of the considerable number of boundaries according to audit paper [12].

TABLE I

FRICTION STIR WELDING PARAMETERS AND THEIR LEVELS

Parameter	Factor	Level		
		1	2	3
Rotational speed (rpm)	A	965	1200	1500
Forging pressure (MPa)	B	200	210	230
Friction time (sec)	C	8	9	10

IV. EXPERIMENTATION FOR OPTIMIZATION OF SMAW

A. *Experimental set-up and procedure*

i. *Machine Specification*

All gear lathe and machine specifications below: EN-8/EN-9 alloy steel for critical components, including shafts, gears, pins, lead vane; head-stock force lubrication system; bed-type rigid and box-segment type; and precise Indian standard IS: 1878 (Part-1) – 1993.

- Centre height – 175 mm
- Admit between centre – 650 mm, 1000 mm
- Swing over bed – 350 mm
- Over cross side – 215 mm
- In gap – 540 mm
- Speed – 965,1200,1500 rpm
- Motor – 1440 RPM, 50 cycles, 3-phase, AC power, 2.25 kW/3 HP

ii. *Geometry of the Specimens*

Materials were machined with specimens in accordance with the dimensions needed [2]. The specimen size is as follows: AISI 304 stainless steel and Aluminum alloy AA 6351 Bars in length 100mm, diameter 16 mm and steel 304 in length 76mm and size 27 pieces in total.

iii. *Material Properties*

The reference to mechanical and chemical properties for the present study is ASTM (American standard material testing):

TABLE II

CHEMICAL PROPERTIES OF MATERIAL USED IN PRESENT STUDY

AA-6351	Si	Zn	Mg	Mn	Fe
	0.907	0.89	0.586	0.65	0.65
	Cu	Ti	Sn	Ni	Al
	0.086	0.015	0.003	0.002	Balance

Steel 304	Si	S	P	Mn	C	Cr	Ni
	0.38	0.024	0.036	1.67	0.65	0.054	18.2

TABLE III

MECHANICAL PROPERTIES OF MATERIAL USED IN PRESENT STUDY

Base material	Tensile Strength (Mpa)	Elongation (%)	Yield strength (MPa)
AA 6351	150	16	85
AISI steel 304	515	48	205

After the symmetrical exhibit has been chosen, the second step in Taguchi boundary configuration is running the investigation. The aluminum combination and steel were utilized in this examination for being one of the most well-known materials in flight related applications. All the welds were aluminum bar Ǿ16 mm and steel 304 likewise Ǿ16 mm. For trial set-up and plan, constant friction welding technique was utilized. This strategy required a machine taking after to a machine furnished with a method for applying and controlling pivotal weight. This all apparatus Lathe of having power 3Hp is made to work as a friction welding machine by fitting the accompanying extra segments.

- Hydraulic framework outfitted with manual weight pointer used to quantify produce burden and manufacturing pressure.
- One-part hold in machine toss and other part to hold in flame broil toss the given work piece
- In explore run on all apparatus machine with various turn speed, distinctive fashioning pressure with time variety.

iv. *Experiment set up*

The arrangement utilized for the current work was planned and built by the directors of persistent drive welding machine. The shaft is driven by electric engine. Axial forces are constrained by a water powered mechanical valve. In this machine as much as 20 Ton limit a heap cell is utilized to gauge the axial force and controlled on a shut circle. A modern PC stores and shows terrifically significant boundaries – Axial Force, Spindle speed, Displacement and Spindle force. A drive engine limit with 3hp and to the 1400 rpm speed with sufficient force limit was utilized for the erosion welding of steel and aluminum bars of 16mm widths considering the friction and the furious weights. Generally, the structure is genuinely unbending to give steadiness to the gear working at high speeds and is driven by high weight manufacturing. Present day gear is programmed and permits all the boundaries be balanced, controlled and observed legitimately on the control board. Figure 4 shows the ceaseless drive friction welding arrangement.

Figure 4: Experiment set up

v. *Selection of Orthogonal Array*

To choose a fitting symmetrical exhibit for tests, the all-out degrees of opportunity should be registered. The degrees of opportunity are characterized as the quantity of examinations between process boundaries that should be made to figure out which level is better and explicitly how much better it is. For instance, a three-level procedure boundary means two degrees of opportunity. The degrees of opportunity related with cooperation between three procedure boundaries are given by the result of the degrees of opportunity for the three procedure boundaries. Essentially, the degrees of opportunity for the symmetrical cluster ought to be more noteworthy than or possibly equivalent to those for the procedure boundaries. In this examination, a L9 symmetrical cluster was utilized. A sum of nine test runs must be directed, utilizing the blend of levels for each control factor as showed in Table 2. In this way, there are six degrees of opportunity attributable to the three welding boundaries.

When the degrees of opportunity required are known, the subsequent stage is to choose a suitable symmetrical exhibit to fit the particular assignment. Fundamentally, the degrees of opportunity for the symmetrical exhibit ought to be more prominent than or possibly equivalent to those for the procedure boundaries. In this examination, a L9 symmetrical cluster was utilized. This exhibit has twenty-six degrees of opportunity and it can deal with three-level procedure boundaries. Every Friction welding boundary is allocated to a segment and twenty-seven welding boundary mixes are accessible. An aggregate of nine test runs must be directed, utilizing the blend of levels for each control factor (A–C) as demonstrated in table 2.

TABLE 4

ORTHOGONAL ARRAY [L9]

Run	Level		
	A	B	C
1	1	1	1
2	1	2	2
3	1	3	3
4	2	1	2
5	2	2	3
6	2	3	1
7	3	1	3
8	3	2	1
9	3	3	2

vi. Tested Workpiece

Figure shows the examples number 9A, 9B, 9C after they were tried and expelled from the tractable test machine. Impacts of upset time and upset weight on the quality of joints were analyzed in welding of equivalent distance across parts. Erosion time was kept consistent. The quality of joints was dictated by tractable tests, and the outcomes were contrasted with those of completely machined examples. The break happened at the interface of the disparate metal weld joint, quality of the weld joint was lesser than tensile strength of AL6351 aluminum compound and steel 304 at 230 MPa there was an unbounded area around the focal point of the crack surface, in spite of the fact that the aluminum composite was halfway attached to the treated steel. The welded examples were machined by ASTM segment IX (200), and exposed to pliable tests on a machine Fie Make all-inclusive testing machine , UTS-40.

Figure 5: Before tested part & after tested part

IV. RESULTS

It is found that the weldinged joints have different strength in different cases, after all the twenty-seven experiments. In the case of aluminum bar 6351 and steel 304 diameter 16mm, no joint is formed as the material has been deformed before any joints are formed. This can be because the surface velocity at the interface of each workpiece may be too high and due to the deformations it cannot produce sufficient frictional heat and thus no welded joint formation. In friction welding the drill chuck has no role. Their role is only to provide the stainless bar with mechanical support and to prevent deformation.

This experiment is promising because welded joints are formed. However, the joint strength is not enough, which is eminent since it gets broken with a little pressure. Due to the high stress on the workpieces during the experiment the poor strength of the joint may result. The only reassuring fact here is that the configuration can produce sufficient surface speed and thus enough friction heat to form a joint between Aluminium and steel, two different materials. In the case of the rotary velocity of the aluminum bar the deformation should be high as shown in the experiment.

The Taguchi method analyzes the results of the experiments to achieve the following aims:

- To achieve the best or best conditions for the product or process,
- Establishing the contribution of different factors
- To estimate the answer on an optimal basis.

A. Conduction of Tensile Test

After welding the traction testing was conducted, in addition to parameter settings, optimization and qualification of welding procedures and processes, tensile strength of the joints was evaluated. The softened specimens were machined to ASTM A370, subjected to tensile testing at room temperature of 25°C and to a test speed of 1mm/minute on a machine with a load cell capacity of 100kN. In welding of equal diameter parts, the effect of friction time and friction pressure on the joint strength has been investigated. Time has been maintained constantly. Tensile tests determined the strength of the joints, comparing the results with the results of fully machined specimens. In the table 4, the tensile strength of the joints was estimated by the division of the ultimate load by specimen area, for all the respective three tests. The interface of the unlike welded metal joint was fractured, its strength was less than tensile strength of AA6351 aluminum alloy 230MPa, the center of the fracture surface was unbounded, although the aluminum alloy was partially attached to stainless steel.

With increasing friction time and friction pressure for the joints, the joint's tensile strength also increases Table 6, while joint strength passes a maximum and with a further increase of friction time and friction pressures for the joints, the joints decrease tensile strength. Friction time and the friction pressure are therefore shown to have a direct impact on joint time and friction pressure on the cue of the metals, but this has been slightly softened. The mechanism of fracture of joints at a shorter time can be different from that of joints with a longer friction period. After welding, tensile tests were performed to assess, apart from settings parameters, optimization of welding methods and processes, the mechanic properties of the joints. In accordance with ASTM IX (200) weldinged specimens were machined and tensile tests on a Fie Make Universal Test Machine, UTS-40 were conducted.

Figure 6: Universal Testing Machine

TABLE 5
S/N RATIO OF EXPERIMENT READING

Run	Level			Tensile Strength (MPa)				Standard Deviation	S/N Ratio
	A	B	C	Trial 1	Trial 2	Trial 3	Mean		
1	950	200	8	65	91	52	69.33	10.65	17.36
2	950	210	9	84	91	96	90.33	4.92	25.27
3	950	230	10	86	93	63	80.66	12.81	15.92
4	1200	200	9	59	50	123	77.33	8.44	18.37
5	1200	210	10	85	59	109	84.33	20.41	12.32
6	1200	230	8	85	87	107	93	9084	19.45
7	1500	200	10	64	96	107	89	18.23	13.37
8	1500	210	8	111	122	108	117.33	12.2	19.66
9	1500	230	9	137	124	99	120	15.74	17.69

B. Experimental Analysis

Subsequent to welding was performed, tensile tests were done to assess the tensile strength of joints, other than boundary settings, improvement and capability of welding methodology and procedures. The welded examples were machined by ASTM A370, and exposed to tractable tests on a machine with a heap cell limit of 100 KN at room temperature of 25°C, and a test speed of 1 mm/minute. The impact of friction time and erosion pressure on the quality of joints was analyzed in welding of equivalent distance across parts. Upset time was kept consistent. The quality of joints was dictated by elastic tests, and the outcomes were contrasted with those of completely machined examples. Acquired rigidity for all the three relating preliminaries is invigorated in the table 4. Tensile of the joints was evaluated isolating a definitive burden by region of the example. The break happened at the interface of the disparate metal weld joint, quality of the weld joint was lesser than rigidity of AA6351 aluminum compound 230Mpa, there was an unbounded area around the focal point of the crack surface, in spite of the fact that the aluminum combination was in part clung to the treated steel.

As friction time and friction pressure for the joints are expanded, tensile strength of the joints likewise builds Table 6, at the same time, quality of the joints goes through a greatest, at that point, when friction time and erosion pressure for the joints are additionally expanded, rigidity of the joints diminishes. Along these lines, it is demonstrated that friction time and erosion pressure directly affect joint y time and contact pressure influence signal of the metals the weld lessens the joint quality, yet it was marginally mollified. The crack instrument of joints with a shorter time might be not the same as that of joints with a more extended erosion time. Subsequent to welding was performed, ductile tests were done to assess the mechanical properties of joints, other than boundary settings, improvement and capability of welding methods and procedures. The welded examples were machined by

ASTM segment IX (200), and exposed to pliable tests on a machine Fie Make general testing machine, UTS-40.

The average SN value is calculated for each factor and level for Parameter 1 (T1), following the calculation of the SN ratio of each experiment in the array: after these SN values have been computed for each factor and for each level, the SN ratio values are tabulated and the R (R = high SN - low SN) range is determined in the table for each of the parameters. The larger the parameter R value, the greater the impact of the variable. The same signal change has a greater effect on the measured output variable. Once the SN-ratio values for each factor and level have been calculated, the SN-ratio values are calculated and input into the table in the form below. The larger the parameter R value, the greater the impact of the variable. The same signal change has a greater effect on the measured output variable.

TABLE 6
OPTIMUM PARAMETER

Sr. No	RPM	PRESSURE	TIME
1	19.51	16.5	18.82
2	16.75	19.08	20.42
3	16.89	17.67	14
Δ (Range)	2.8	2.58	6.42
RANK	2	3	1

The most significant effect on friction time is the deposition rate and the least impact on processor output is a forging pressure. It is noted that optimum froze pressure and friction time parameters lead to strong linkages at the interface of the different metal joints, resulting in greater weldinging strength.

C. Analysis of variance

In design of experiment the results are analyzed due to one or more of the following three objectives.

- To establish the best or the optimum condition for a product or a process.
- To estimate the contribution of individual factors.
- To estimate the response under the optimum condition.

By studying the main effects of each factor, the optimal condition is identified. The main effects show the general trends in the factors' influence. The level of factors which are expected to produce the best results can be predicted by knowing the characteristics, i.e. whether a higher or lower value produces the preferred results. Variance analysis (ANOVA) is the statistical treatment most often used to determine the proportion contribution of each factor for the results of the experiments. For a particular analysis, ANOVA table study helps to establish which of the factors are controlled or not. Once the best conditions have been determined, a confirmatory experiment is usually a good practice. Some full factorial tests are performed in the case of a fractional factory. The analysis of the partial experiment must include a trust analysis that can be carried out in the results. Therefore, variance analysis is used to measure trust. The analysis provides variation of noise and controllable factors. Robust operational conditions can be predicted by understanding the source and magnitude of variance.

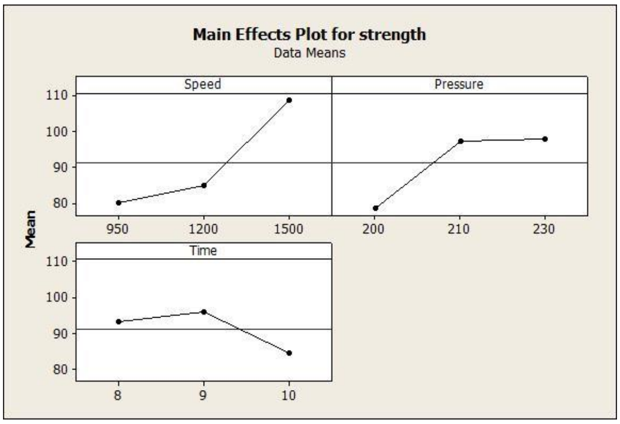

Figure 7: Graphical analysis tensile strength with different parameter.

The above experimental results and studies have shown how much the tensile strength is affected by turning speed, forging pressure and friction.

- Increases the tensile strength of the joint with increased rotational speed.
- The increase in forging pressure remains constant

TABLE 8
CHEMICAL PROPERTIES OF AA 6082 AND AA 6351 WITH STEEL 304

Element AA 6082	Si	Zn	Mg	Mn	Fe	Cu	Cr	Zn	Ni	Al
	0.75	0.08	0.718	0.536	<0.100	0.052	<0.001	0.08	0.004	Balance
Element AA 6351	Si	Zn	Mg	Mn	Fe	Cu	Ti	Zn	Ni	Al
	0.97	0.89	0.586	0.65	0.65	0.086	0.015	0.003	0.002	Balance
AISI 304 STAINLESS STEEL	Si	S	P	Mn	C	Cr	Ni	Zn	Ni	Al
	0.38	0.024	0.036	1.67	0.054	18.2	8	0.004	0.002	Balance

after certain tensile strength.

D. *Radiography Test Results*

After welding the discontinuity of joints and film density measured and confirmed between 1.5 and 4.0 have been measured, not distracting tests have been carried out. In addition to parameter settings, welding processes and processes optimization and qualification. SWSI technique, Sigma Inspection and Testing, tested the weldinged specimens according to the ASME SEC V, ARTICLE 2 and 22 radiography tests. Ltd. - Ltd. (An ISO 9001- 2008 certified company). Industry radiography include the exposure of a test object to penetrative radiation to inspection and a medium for recording the object to the opposite side of the object. Electrically generated radiation (X-rays) is commonly used for thinner or lower dense materials, such as aluminium, while gamma radiation is commonly used for thicker or thinner materials. The results of the radiography test observed during the experiment were table shown below.:

TABLE 7
NDT TEST REPORT

Sr. No	Test Parameter	Result
1	Radiography test	No significant defect Indications is noticed. Hence acceptable.

E. *Validation*

Validation of aluminum 6351 and steel 304 friction welding in comparison to 6082 and 304 friction welding. The friction was examined using taguchi methodology for different materials 6351 and stainless steel 304. This is why other materials 6058 and steel 304 have been approved. Both AA 6351 and 6058 composite and mechanical properties are significantly extraordinary. Tensile strength of various materials AA 6351 and steel 304 to AA6082 and steel 304 have been investigated and approved for this. The strength of various friction welding 6351 to 6082 was estimated by us. We have approved. ASTM E 8M (2004) machined the welded examples and was exposed to mixable testing on machines with a heap cell limit of 100 KN at 25°C and a test speed of 1 mm/minute. ASTM E 8M (2004) The basic advance was to analyze crack surfaces for any significant distinctions between insonate joints with shorter and long rubbing occasions in the break component. Results of tensile strength were obtained from a given table.

TABLE IX
OBTAINED TENSILE STRENGTH RESULTS AA 6082 AND STEEL 304

Trials	Rotating Speed (RPM)	Friction Time (s)	Upset Pressure (Mpa)	Tensile Strength (Mpa)
1	1400	3	210	136.43

2	1400	5	210	188.4
3	1400	7	210	149.6

TABLE X
OBTAINED TENSILE STRENGTH RESULTS AA 6351 AND STEEL 304

Trials	Rotating Speed (RPM)	Friction Time (s)	Upset Pressure (Mpa)	Tensile Strength (Mpa)
1	1400	8	210	107
2	1400	9	230	108
3	1400	10	200	99

V. REMARK

Finally, we validated the strength of friction welding of dissimilar AA 6082 and AA6351 materials using steel 304. We compare friction welding parameters such as rotational speed, friction time, forging and tensile strength in Table 1 and Table 2 of the displayed material.

- We conclude that there are some variations in the joining material's strength in this some direct effect to the joining strength.
- Different composition of the AA6082 aluminum alloy chemical and mechanical properties and AA 6351 alloys.
- The results of this study, which have been established in some experimental mistake, are fundamental to understanding and understanding of the major characteristics of the weldinging process.
- Error between experimental readings.

VI. CONCLUSIONS

The current study successfully welded materials in stainless steel (AISI 304) and aluminum 6351. A tensile testing and a non-distractive test (radiography) with the following results were carried out for the welding process:

- In the friction welding of dissimilar material parts, optimum welding parameters should be properly selected;
- Tensile strengths for 304 stainless steel and 6351 aluminum components resulted in a positive outcome compared to basic metals. The joint strength increased and then fell with increasing friction time after reaching a maximum value. There could not be sufficient heat to produce a strong joint with a shorter friction time. The excess formation of an inter-metallic layer caused a longer friction time. However, some weldings demonstrate poor strength depending on the accumulation of alloys at the interface that are caused by an increase in temperature and by intermetallic layers, such as FeAl.
- Results from mechanical tension tests show that mechanical properties cannot be achieved by fusion welding processes are presented.
- The application of the Taguchi method parameter design to optimize the friction welding parameters was presented. Based on the test results of this study, the following findings can be drawn: the robust orthogonal array design method used by Taguchi can be used to analyze this problem.
- It has been found to be a simple, systematic, effective method for optimizing the friction weldinging parameters by the Taguchi method's parameter design.
- Finally, we have also performed NDT test in radiography and measure no signification discontinuity of friction welding with dissimilar material.

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