MECHANICAL PROPERTY ANALYSIS OF RESISTANCE SPOT WELDED LAP JOINT SPECIMEN

A Project Report

Submitted by

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to

APJ Abdul Kalam Technological University

in partial fulfillment of the requirements for the award of the Degree of

Bachelor of Technology (B. Tech)

in

MECHANICAL ENGINEERING

Under the guidance of

Mr. VINAYAN E G

CREATING TECHNOLOGY
LEADERS OF TOMORROW
ESTD 2002

DEPARTMENT OF MECHANICAL ENGINEERIN

Jyothi Engineering College

NAAC Accredited College with NBA Accredited Programmes*

Approved by AICTE & affiliated to APJ Abdul Kalam Technological University

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March 2021

DECLARATION

We the undersigned hereby declare that the project report “Mechanical Property Analysis of Resistance Spot Welded Lap Joint Specimen”, submitted forpartial fulfillment of the requirements for the award of degree of Bachelor of Technologyof the APJ Abdul Kalam Technological University, Kerala is a bonafide work done by us under supervision of Mr. Vinayan E G and Mr. Christy V Vazhappilly. This submission represents our ideas in our own words and where ideas or words of others have been included, we have adequately and accurately cited and referenced the original sources. We also declare that we have adhered to ethics of academic honesty and integrity and have not misrepresented or fabricated any data or idea or fact or source in this submission. We understand that any violation of the above will be a cause for disciplinary action by the institute and/or the University and can also evoke penal action from the sources which have thus not been properly cited or from whom proper permission has not been obtained. This report has not been previously used by anybody as a basis for the award of any degree, diploma or similar title of any other University.

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This is to certify that this project work entitled ***''Mechanical Property Analysis of Resistance Spot Welded Lap joint Specimen''*** is an authentic report of the project work done at ***Central Planning and Material Cutting Facility (CPMF) of Internal*** Fabrication ***Facility(IFF) Group, Materials and Mechanical Entity(MME), Vikram Sarabhai Space Centre(VSSC), Thiruvananthapuram*** by the following students of ***Jyothi Engineering College, Cheruthuruthy, Thrissur*** in partial fulfilment of the requirements for the award of Bachelor of Technology in Mechanical Engineering.

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This is to certify that the report entitled **"MECHANICAL PROPERT ANALYSIS OF RESISTANCE SPOT WELDED LAP JOINT SPECIMEN"** submitted by **JOSHWIN EMMANUAL JOHNSON (JEC17ME070), JOYAL VARGHESE JACOB (JEC17ME071), MUHAMMAD SHIYAS K (JEC17ME084), NIHAL PAUL (JEC17ME086)** to the APJ Abdul Kalam Technological University in partial fulfillment of the requirements for the award of the Degree in Bachelor of Technology in **Mechanical Engineering** is a bonafide record of the project work carried out by them under my/our guidance and supervision. This report in any form has not been submitted to any other University or Institute for any purpose.

Mr. Vinayan E G	Mr. Christy V Vazhappilly	Dr. Biju P.L
Assistant Professor	Assistant Professor	Professor
External Supervisor	Internal Supervisor	Head of the Department

External Examiner

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VISION OF THE INSTITUTE

Creating eminent and ethical leaders through quality professional education with emphasis on holistic excellence.

MISSION OF THE INSTITUTE

- To emerge as an institution par excellence of global standards by imparting quality Engineering and other professional programmes with state-of-the-art facilities.
- To equip the students with appropriate skills for a meaningful career in the global scenario.
- To inculcate ethical values among students and ignite their passion for holistic excellence through social initiatives.
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- To provide an education that builds a solid foundation in Mechanical Engineering.
- To prepare graduates for employment, higher education and enable a lifelong growth in their profession.
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PEO 3: Graduate Engineers shall have excellent teamwork, communication and interpersonal skills, having high morals and ethical values.

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PSO 1: Graduates would be able to apply their knowledge in the domains of manufacturing, fluid and thermal sciences to solve engineering problems.

PSO 2: Graduates would be able to apply the principles of design and analysis on product design with the help of modern CAD/CAM tools.

PSO 3: Graduates would be able to apply the basic principles of engineering and management practices in various practical fields to engage themselves in research/ Industry/Society.

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3. **Design/development of solutions:** Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations.
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7. **Environment and sustainability:** Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.
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COs	Description
C417.1	Students will have the ability to effectively gather and interpret information from literature survey and use this knowledge to identify, formulate, analyze and solve complex problems and to evaluate and interpret various solutions.
C417.2	Students will gain the ability to communicate effectively with written, oral, and visual means in a technical setting.
C417.3	Students will have the ability to use modern design and analysis tools to analyse and evaluate complex problems.
C417.4	Students will be able to carry out calculations involved in design, consider and evaluate alternate assumptions, approaches, and procedures. Ability to fabricate system components related to engineering problems giving consideration to environment and society.
C417.5	Students will have the ability to serve as effective team member to plan and complete the project/task within a specified budget and time.

CO MAPPING TO POs

	POs											
COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
C417.1	3	3	3	3	1	-	-	-	-	-	-	3
C417.2	2	-	-	-	-	-	-	2	2	3	-	-
C417.3	-	2	2	2	3	-	-	-	-	2	-	1
C417.4	-	2	3	3	-	3	3	-	-	-	-	-
C417.5	-	-	-	-	-	-	-	-	3	-	3	-
Average	**2.5**	**2.33**	**2.67**	**2.67**	**2**	**3**	**3**	**2**	**2.5**	**2.5**	**3**	**2**

CO MAPPING TO PSOs

	PSOs		
COs	PSO1	PSO2	PSO3
C417.1	3	3	3
C417.2	2	2	2
C417.3	2	3	2
C417.4	3	3	3
C417.5	2	2	2
Average	**2.4**	**2.6**	**2.4**

ABSTRACT

Resistance Spot Welding (RSW) has grown in popularity as one of the most efficient methods for sheet metal joining. It offers several advantages, ranging from high speed and adaptability of automation and thereby facilitating large-scale production. Among the numerous fields in which RSW finds its application, the automobile industry, aerospace industry and the marine industry are some of them where the method is extensively used. These are the domains where mass optimization becomes vital. This will be accomplished in general through the proper selection of materials, design optimization, fabrication process optimization and so on. Efficient designing of RSW joints would help in considerable reduction on structure mass without sacrificing the strength and rigidity requirements and thereby aid in mass optimization. This project work mainly focused on mechanical property analysis of resistance spot welded lap joint through experimental method and compares the test results with mathematic model generated through the software MSC Apex SP1. Here, Finite Element Analysis of the designed software model is done with the help of the software Simufact.weld.6.0. and joint strength simulation is performed. On future aspects, it aims for design of resistance spot weld joints for improved hardware assembly strength and optimize its stiffness

Key words: Resistance Spot Welding, Sheet Metal Joining, Mechanical properties,
Design Optimization, Finite Element Analysis.

CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVATIONS

RSW	Resistance Spot Welding
FSW	Friction Stir Welding
FSSW	Friction Stir Spot Welding
FSpW	Friction Spot Welding
RWMA	Resistance Welder Manufacturers Association
NEMA	National Electrical Manufacturers Association
TWIP	Twinning-Induced Plasticity
FEA	Finite Element Analysis
UTM	Universal Testing Machine

LIST OF SYMBOLS

σ =Tensile Stress

P = Applied Tensile Load

P_f= Applied Tensile load at Fracture

t = Thickness of the sheet

d = Diameter of the nugget

F = Force

A = Cross-sectional area of the sheet

ε = Strain

δl = Displacement

CHAPTER 1

INTRODUCTION

Welding, the fabrication process of joining materials, existed in its rudimentary form 4000 years back. In ancient times, the Egyptians were the first to perfect the process of combining two or more parts by the application temperature or pressure. Until the nineteenth century, these procedures persisted in their most elementary forms. Since the second part of the nineteenth century, the process has evolved into the present form through several stages owing to technological improvement and ongoing increasing refinement. Resistance welding, arc welding, friction welding, electron beam welding, and laser welding are the most common welding processes. These are further divided into many categories, with each technique having its own set of applications. Choosing the optimum manufacturing technique for a certain product, as well as optimising the design for manufacture and assembly, are all acts that have a direct influence on cost and quality. Finding a perfect fit between the type of material used and a fabrication technique that meets the specifications must be chosen early on in the design process. Sheet metal joining is one of the most essential welding applications. Sheet metal is incredibly significant and lucrative in today's building, manufacturing, and construction industries. Sheet metal is utilised in many sectors, including automobile production, aviation components, tools, agriculture, mining, catering, shipping, medical, electronic equipment, and construction. With the Government introducing stringent rules and regulations for assured safety and quality, the automobile industry has started using high strength sheets for the purpose of manufacture, with it being a constituent comprising of over 40% of the entire vehicle body. For sheet metal assemblies, two welding subgroups stand out: resistance spot welding (RSW) and friction stir welding (FSW). This project focuses on Resistance Spot Welding technique. In RSW, the heat created by the resistance to the flow of electric current joins the metal sheets that are held together under pressure in an overlapping manner by electrodes in one or more areas. The resistance to current flow determines the heating required to generate the welding tip in resistance spot welding (RSW). RSW technique is applicable to various materials including carbon steel, stainless steel, aluminium as well its alloys. High strength low alloy steels, stainless steel, nickel, titanium and copper alloys are also spot weld commercially. In terms of sheet metal joining, RSW offers greater versatility for hard-to-reach joining. RSW's fast speed and adaptability for automation and big volume manufacturing are two more advantages that make it an excellent choice. Despite of all these advantages, inconsistency in the weld still remains as an issue in RSW. This might have an impact on automation and jeopardise weld quality. Due to the same reason, ensuring weld quality becomes an inevitable factor. The quality of an RSW weld can be assessed by three ways which include physical weld attributes, mechanical properties and the failure modes. Among these the analysis of the mechanical properties was chosen to access the quality of the weld specimen. This was done by destructive testing as well as the software-based analysis of the specimen. On future aspects, the findings of this project may be able to provide a leverage in terms of designing spot weld joints that help to achieve improved assembly as well as aid optimization during fabrication.

1.1 Objective

The main objective of this project is to determine the mechanical characteristics of a resistance spot weld specimen, namely the tensile stress and strain, by subjecting it to destructive tensile testing. It also aims to create an identical model to that of the experimental setup by using the software MSC Apex SP1. To create a Finite Element Analysis of the designed software model with the help of the software Simufact.weld.6.0.

1.2 Specific Objective

To validate the destructive test result by comparing it with the software generated results. To use these results to design spot weld joints to enhance the quality of assembly.

1.3 Expected outcome

To obtain similar stress- strain curves outputs as the end result of both the test methods.

CHAPTER 2

LITERATURE SURVEY

The following papers were considered at the time of Literature Survey. These papers helped in finalizing many details regarding this project.

1. Sheet metal joining process selector
2. Resistance Spot Welding
3. Specimen Dimensions and Procedure for Shear Testing Resistance Spot and Embossed Projection
4. Weld Properties of Resistance Spot-Welded TWIP Steels
5. The finite element modelling of the resistance welding process

2.1 Sheet Metal Joining Process Selector

Mechanical (forming), metallurgical (welding), and chemical (adhesive) operations are the three types of sheet metal joining techniques. These approaches, however, are not confined to sheet metal joining. Among them, welding is the method by which metals are joined by the application of heat, with or without pressure, and without the need of a filler substance. Welding can be classified into different types. Welding is grouped into three types: pressure welding, fusion welding, modern or miscellaneous welding. Each of them is further subdivided into many more categories, each with its own set of applications. Instead of this, they may be also classified as Solid-State Welding and Liquid State or Fusion welding. For sheet metal assemblies, two welding subgroups stand out: resistance spot welding (RSW) and Friction Welding (FSW). FSW is a solid-state joining technology that involves inserting a non-consumable rotating tool with a specifically designed pin and shoulder into the contacting edges of the sheets or plates to be joined and traversing along the joint line. On heating, the region around the pin melts and the rotational and translation movement of the tool displaces the material towards the rear portion of the pin. Friction Stir Spot Welding (FSSW) is another type that originated from FSW and consists mostly of three stages: plunging, stirring, and retracting. Friction Spot Welding is another approach that typically produces excellent quality welds by assuring appropriate filling and so limiting the margin for deterioration as well as stress concentration. In RSW, the heat created by the resistance to the flow of electric current joins the metal sheets that are held together under pressure by electrodes in one or more areas. In RSW, the heat produced is determined by the resistance to the current flow. Some of the elements that might affect the resistance to current flow include the nature of the surface, the presence of contaminants, and the dimension of the material.

2.2 Resistance Spot Welding

Resistance Spot Welding (RSW) is a welding procedure in which two or more opposing surfaces are connected in one or more spots by heat created by resistance to the flow of electric current through workpieces held together by electrodes. A short-time pulse of low-voltage and high-amperage current is utilised to heat the contacting surfaces in the current concentration zone, resulting in the formation of a fused nugget of weld. When the electricity is turned off, the molten metal cools and hardens quickly, forming the weld. The RSW is a quick technique that involves retracting the electrode as soon as the weld is done. Thus, the manufacturing process is accelerated. Spot welding has several merits, including fast working speeds, adaptability for automation and robotization, and incorporation in high-production assembly lines alongside other fabrication procedures. Spot welding is the most common joining technique for sheet metal components such as automobile body-in-white assemblies, home appliances, furniture, construction items, enclosures, and, to a lesser extent, aviation components. Among these applications, this process is widely used in the automobile industry, and it is estimated that a single vehicle body can contain up to hundreds of spot welds. If the sheet metal stampings do not need to be air tight, RSW is frequently considered a cost-effective option. In such cases, RSW would be a better alternative than other mechanical approaches. RSW equipment is primarily composed of three components. An electrical circuit, a control circuit, and machining equipment are among them. The electric circuit consists of a welding transformer, tap switch as well as a secondary circuit. The control circuit is responsible for deciding the time period for which the current has to be passed. The mechanical fixtures consist of clamps and fixtures that holds the workpiece in the required position for the weld to be performed. RSW machines are classified into three kinds. They are pedestal type machines, portable welding guns, multiple spot-welding machines incorporating lightweight gun welding units. Generally, resistance spot or projection welding procedures are performed on pedestal-type welding equipment. Typical machines are either rocker arm or static, direct-acting machines, as characterised by the rocker action of the moving upper electrode arm. When large scale jobs that cannot be easily transported has to be used, portable welding guns are used in RSW. The water-cooled electrode holders, an air or hydraulic actuation cylinder, hand grips, and an initiating switch comprise the portable welding gun. An air cylinder provides the welding force, and the gun is normally suspended from an adjustable balancing device. They are generally classified into S-type and J-type guns. The pace of force building and the amount to which the gun's arms deflect under load are two critical aspects that determine the performance of these sorts of welding guns. The Resistance Welder Manufacturers Association (RWMA) has standardised criteria for resistance welding equipment, whereas the National Electrical Manufacturers Association has established criteria for controls (NEMA).

2.3 Specimen Dimensions and Procedure for Shear Testing Resistance Spot and Embossed Projection Weld

Accessing the quality of the weld is critical to ensure quality. Because of the ease of specimen fabrication and testing, tension-shear or tensile-shear testing is the most often utilised static test for assessing weld strength. This test consists of pulling a test specimen created by lapping two strips of metal and connecting them with a single weld under tension to destruction on a standard testing equipment. On certain occasions, a specimen will have two or more welds for tensile-shear testing. The final strength of the test specimen, as well as the kind of fracture, whether by shear of the weld material or tear of the source material, and whether a ductile or brittle fracture is achieved, should be documented. It is preferable to determine the diameter of a weld in a tension-shear specimen. Accurate measurement may be difficult to acquire since the specimen is twisted during the test and a substantial portion of base metal is frequently left around the weld when it is taken out. There will be margins for error. Typical failure modes are shown, together with the accompanying characteristic load vs. displacement graphs developed in the experiment.

2.4 Properties of Resistance Spot-Welded TWIP Steels

Havva Kazdal Zeytin, in his paper, deals with characterization and understanding the effect of welding current and time on the mechanical properties and microstructure of the resistance spot welded TWIP steel. Excessive thermal cycles, such as welding and heat treatment, damage the microstructure and characteristics of TWIP steels. The paper’s main objective is to explain the impact of excessive thermal cycles on TWIP steel. The diameter of weld nuggets, as well as the hardness, tensile shear strength, and failure mode of samples, were measured for this purpose. The tensile shear strength of the samples was observed to rise with increasing welding current and welding time without expulsion, reducing the weldment's strength. For low-heat input welds, tensile shear samples failed due to a partial interfacial fracture mechanism. With enough heat input but no outflow, pull-out fractures were observed.

2.5 The Finite Element Modelling of the Resistance Welding Process

In this circumstance, numerical simulation (such as finite element analysis) is a great tool. Numerical simulations may provide detailed heat profiles, stress and strain distributions, and deformation at various phases. A detailed modelling of the interacting mechanical-thermal-electrical process of RSW is required for accurate prediction of weld structure and characteristics. The scarcity of material characteristics, particularly their temperature dependency, accessible for numerical modelling has stymied development in this area. For example, due to a lack of data and process unpredictability, the substantial variance in contact resistance during welding cannot be fully accounted for. However, developments in numerical simulation methodologies, computing software, and computer hardware can enhance simulation precision. With advancements in material research and testing, more trustworthy material data may become accessible.

CHAPTER 3

RESEARCH METHODOLOGY

These are the phases in the overall project approach:

1. Planning
2. Qualitative Study using Literature Survey
3. Resistance Spot Welding
4. Tensile Testing of Specimen
5. Finite Element Analysis

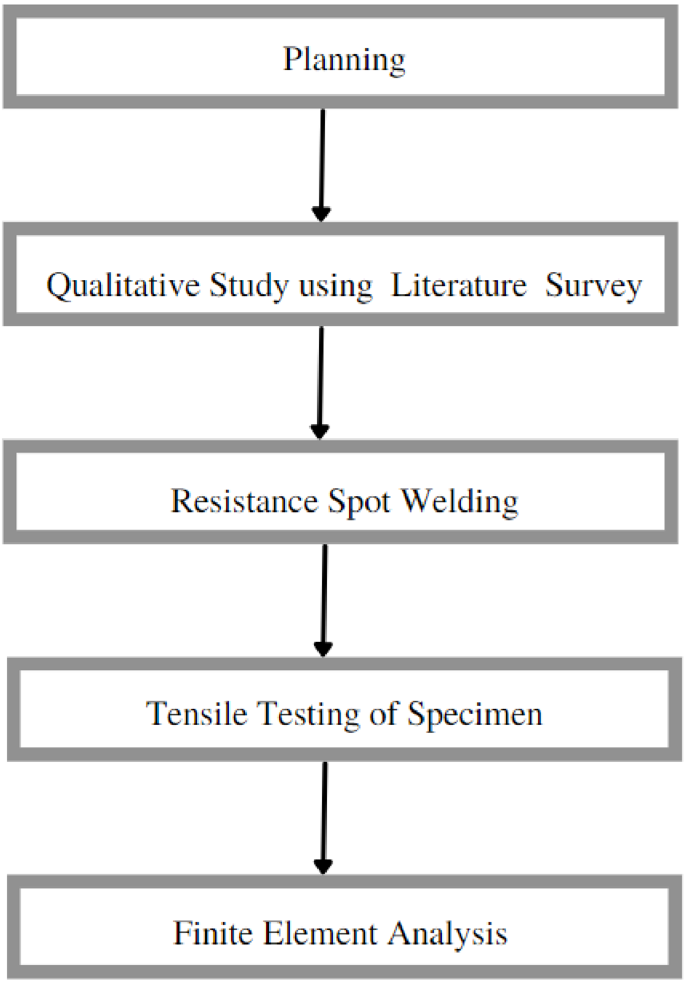


Fig 3.1 Methodology Flowchart

3.1 Planning

A project management technique, in a nutshell, is a systematic way to developing, executing, and delivering a project. The project management methodology is a well-defined set of connected processes, techniques, and procedures that decide how to effectively manage workload. It is a method for planning and completing task objectives. Planning entails breaking all processes into their exact ordinal order and distributing the burden among team members. Planning also allows you to outline the entire project as a continuous process, establish a completion date, and contribute to the effective use of resources and time.

3.2 Qualitative study using Literature Survey

A literature review aids in the development of a rapport with the project issue. The goal of any literature review is to summarise and synthesis current knowledge's arguments and ideas in a certain topic without making any new contributions. Collecting data through a survey will assist everyone understand the topic's researchability and will aid in the development of the theoretical framework. So that one can be guided into developing the methodology.

3.3 Resistance Spot Welding

Spot welding is the connecting of two or more pieces of sheet metal in confined places where heating produced by resistance to the passage of an electric current causes melting and coalescence of a tiny volume of material. This method is commonly used to create a lap junction in sheet metal pieces.

Commercial 15CDV6 chromium vanadium alloy was employed in this project. The alloy sheet was cut into 100 mm X 12.5 mm pieces with a thickness of 0.8 mm. The dimensions and specimens were linked as lap joints for the 5 specimens.

The quantity of heat (energy) provided to the spot before initiating the welding process is influenced by the resistance between the electrodes as well as the amplitude and duration of the current. The quantity of energy is determined to meet the material qualities, thickness, and kind of electrodes of the sheet. Too much energy will melt too much metal, eject molten material, and create a hole rather than a weld, whereas too little energy will not melt the metal or will produce a poor weld. Also ensure that the setting on the spotwelding machine includes two crucial dials: one for the welding current and the other for the welding time. Another critical step before beginning the welding process is to run on the electrodes water supply; this is to keep the electrodes cool during welding procedure because of the excessive heating of the sheet metal.

The Resistance Spot welding consists of three phases, the first of which includes bringing the electrodes to the metal's surface and applying mild pressure. The current from the electrodes is then quickly applied before being withdrawn, but the electrodes stay in place to allow the material to cool.

The Resistance Spot welding workpieces 15CDV6 are fastened to the table. The tool holders of the electrode-holding equipment are brought together, and a light pressure is applied by the electrodes on the 15CDV6 sheet that is secured to the table. After successfully providing moderate pressure to the sheet metal, the needed current is turned on and the process is held for the time necessary to achieve the desired spot weld. The hold period and applied current are hypothetically computed. While the current is turned on, the workpieces conduct electricity, which melts the material to produce the spot weld. After the hold period, the device automatically turns off the current and releases the pressure imposed by the electrodes. The workpieces are now permitted from the heat produced throughout the operation.

The necessary weld is accomplished on the 15CDV6 chromium vanadium alloy with final dimensions of 175 mm X 12.5 mm in this manner with a nugget radius of 5 mm and spot weld area of 78.5 mm ^{2}.

Fig 3.2 Test Specimen after RSW

Fig 3.3 Test Specimen after RSW

Fig 3.4 Test Specimen after RSW

3.4 Tensile Testing of the Specimen

Each specimen is measured and labelled from 1 to 5, with a measurement of 175 mm X 12.5 mm.

The PC linked to the Instron UTM is turned on, and the Bluehill 3 software is launched. Special clamp heads for holding the test specimen are installed according the size and shape of the test specimen. After successfully registering the new test, Load cell button is used to calibrate the UTM. After calibration, the screen blinks and all settings are restored. The extensometer is a gadget that measures strain in your specimen more precisely than crosshead displacement. The extensometer is a transducer that has two knife edges that make contact with the specimen. Clicking on the extensometer soft key starts the extensometer. This will set the extensometer knife edges to 25mm. Hold them together and hit the calibrate button. During calibrating, keep pressing the buttons together. When the screen blinks and choices reappear, the extensometer has been calibrated. After the calibration of extensometer, the specimen is loaded on the UTM.

Insert the top specimen grip into the load cell and lock it in place with the steel pin. Screw the specimen into the grip, but leave one thread outside the grip so that the specimen may still be retrieved if it breaks near the grips. Place the specimen in the bottom grip (the lower grip should not yet be inserted into the load frame). Rotate the big nut until the specimen has one thread outside the grip and then lift the lower specimen grip up.

By maintaining the extensometer buttons pressed in, draw the two spring clips back with two fingers and move the extensometer across the gauge length of the test specimen, then release the two button-sized push pins. Load soft key is used to balance the load on the test specimen, and the extension is set to zero. The green “play” button is tapped to begin the Tensile test. The crosshead will travel at the pace given until the test’s end requirements are satisfied or the test is explicitly halted. If the end-of-test conditions are satisfied, the screen returns to the start-of-test screen. The stress-strain graph is plotted by the Bluehill 3 software during the test. After the tensile test, the extensometer is removed, as are the test specimens, and the next specimen is loaded.

Fig 3.5 Tensile Test of Specimen

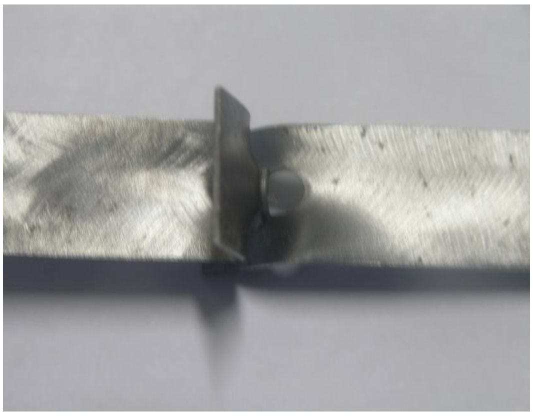


Fig 3.6 Specimen after Tensile Test **Fig 3.7** Specimen after Tensile Test

3.5 Finite Element Analysis

To distinguish between the stress and strain curves of both experimental and theoretical approaches, experimentally acquired values are compared to those derived using Finite element analysis.

The Tensile test performed on the Resistance spot weld is quantitatively evaluated using Finite Element analysis. The fundamental approach is to divide the body into a finite number of elements and assign nodes to each of these parts. The assumptions regarding the variance of the unknown dependent variables across each element are then formed using the interpolation methodology. The discretization procedure generates an algebraic system of equations for unknown nodal values, which approximates the solution. Because the element size, shape, and approximation methodology can be tailored to the circumstances, the methodology can accurately recreate complicated geometry and provide a solution to the given problem.

The exact prototype geometry was reproduced into a three-dimensional (3D) model using MSC Apex Harris Hawk SP1 for Discretization, commonly known as formulating the FE mesh (process of reducing the structure into smaller feasible units). The model was developed to simulate two types of experimental tests: spot weld simulation (thermomechanical simulation) and tensile lap shear simulation. After that,the model is broken down into 6386 nodes and 3250 elements.

JMatPro was used to incorporate material features such as mechanical properties and chemical composition, as well as additional data such as mechanical flow characteristics, mechanical properties such as thermal expansion coefficient, density table, and Young's modules. Define the boundaries and start conditions first, followed by the degrees of freedom limitations, nodal forces, and load. Symmetrical constraints were established to accommodate for geometrical symmetry; all outside surfaces were clamped by additional geometry to withstand distortion during spot weld simulation. A displacement clamp was applied to the node of the top surface of the end along the symmetry axis during tensile shear testing, moving from position zero to input value in set time increments. During tensile test simulations, the axial truss element was positioned at the other end to fix the other end, and all other clamp forces were inhibited.

The numerical model was created in the Simufact. welding 6.0**.**

Model creation and meshing are completed after pre-processing. A thermomechanical simulation is run to produce a mesh with a nugget in its center The tensile test results were obtained in the form of force vs. time and displacement vs. time graphs.

CHAPTER 4

DESIGN AND CONSTRUCTION

4.1 Finite Element Analysis

Finite Element Analysis (FEA) is a numerical approach for solving complicated problems that involve the interpolation of a structure into a number of elements and nodes in order to analyze each component of the complex structure effectively. Finite Element Analysis is primarily concerned with structural analysis, heat transfer, fluid movement, mass transport, and other related issues. The basic principle is partitioning the body into a finite number of pieces called elements and assigning nodes. Then, using the interpolation technique, assumptions are made about the variation of the unknown dependent variables across each element. The discretization process creates an algebraic system of equations for unknown nodal values that approximate the solution. Because the element size, shape, and approximation scheme can be adjusted to suit the situation, the approach may properly replicate complex geometry and find the solution for the given problem.

4.2 Finite Element Modeling:

Many factors, such as residual stress, welding parameter, thickness, nugget radius, and 15CDV6 steel material properties are to be considered for modelling failure of a spot weld spot weld. Which consists of the following

4.2.1 Discretization of structure:

Discretization, also known as establishing FE mesh, is the process of reducing a structure into a feasible number of smaller components. MSC Apex Harris Hawk SP1 was used to create a three-dimensional (3D) model for this. It was possible to reproduce the exact prototype geometry because to the symmetry on the plane parallel to the tensile force action and the axisymmetric geometry. The model was created to replicate two different types of experimental tests: spot weld simulation (thermomechanical simulation) and tensile lap shear simulation. The model is sub divided into 6386 nodes and 3250 elements as shown in the Fig. 5.1

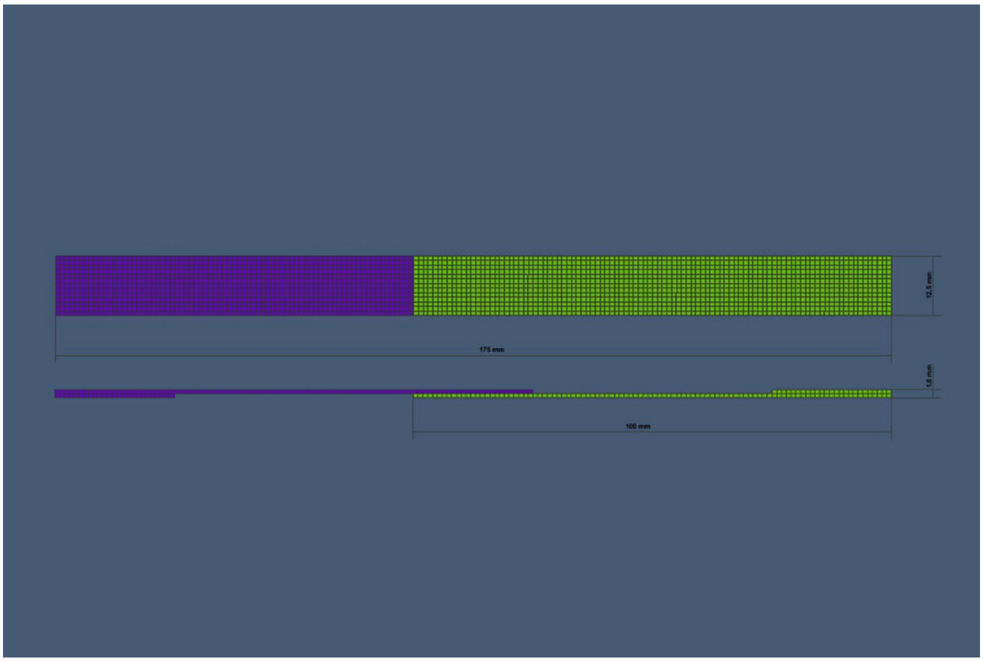
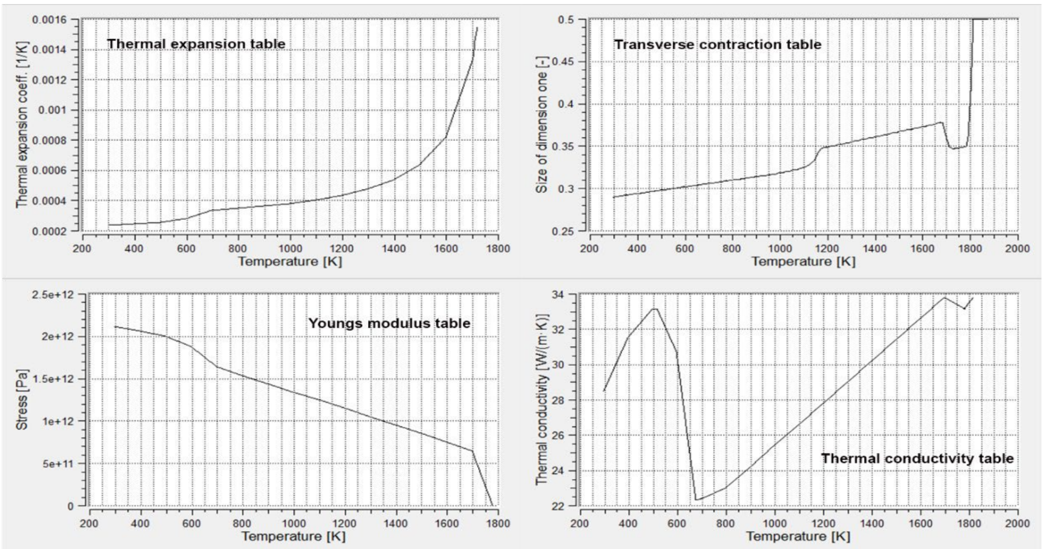


Fig. 4.1 Meshed 3D model of experimental prototype.

4.2.2 Material Property Definition

During the experimental testing of the specimen, a preliminary examination was carried out to determine the material properties. Mechanical properties (table 3.2) and chemical composition (table 3.1) were discovered. Additional information such as mechanical flow characteristics, mechanical properties such as thermal expansion coefficient, density table, Young's modules, and so on. Thermal properties like thermal conductivity, specific heat capacity etc. where implemented in JMatPro.



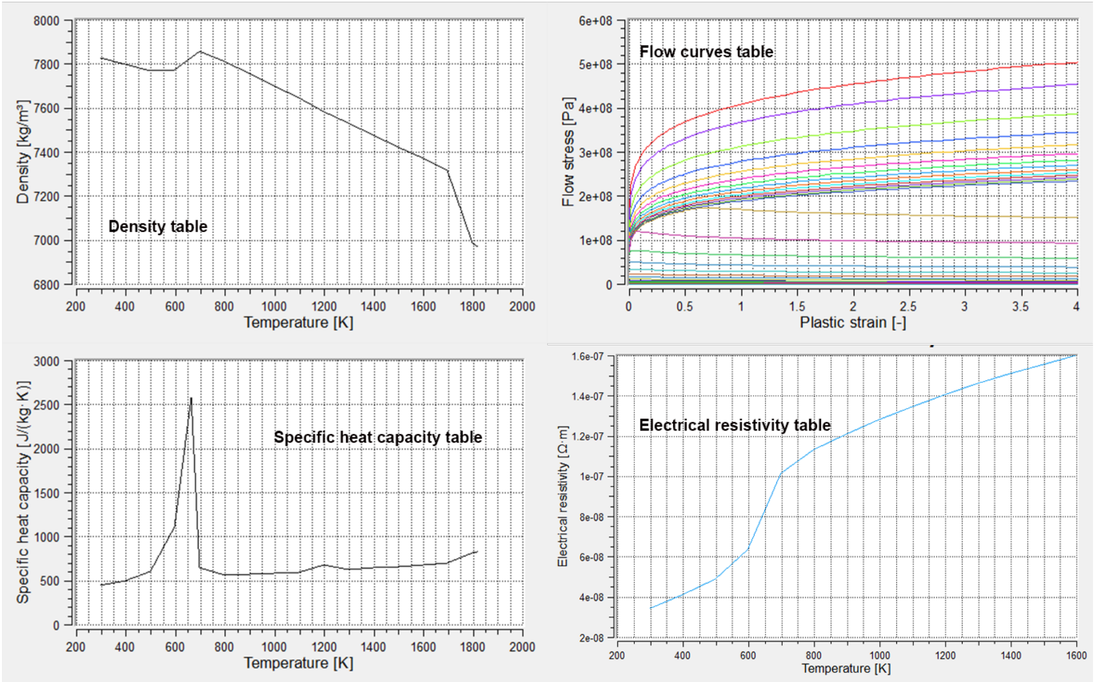


Fig. 4.2 Mechanical, Thermal and Electrical property graphs

4.2.3 Applying boundary/initial conditions

After the type of analysis is defined. Define the boundary and initial conditions, then the degrees of freedom constraints, nodal forces, and load. To account for geometrical symmetry, symmetrical constraints were introduced; all exterior surfaces were clamped by extra geometry to withstand deformation during spot weld simulation. In tensile shear testing, a displacement clamp was applied to the node of the top surface of the end, along the symmetry axis, moving from position zero to input value in defined time steps. The model's scheme with restrictions and loads is shown in Figure 4.3. For tensile test simulations, the axial truss element was positioned at the other end to fix the other end, and all other clamp forces were disabled during this simulation. The numerical model was developed in the environment of the simufact. welding 6.0

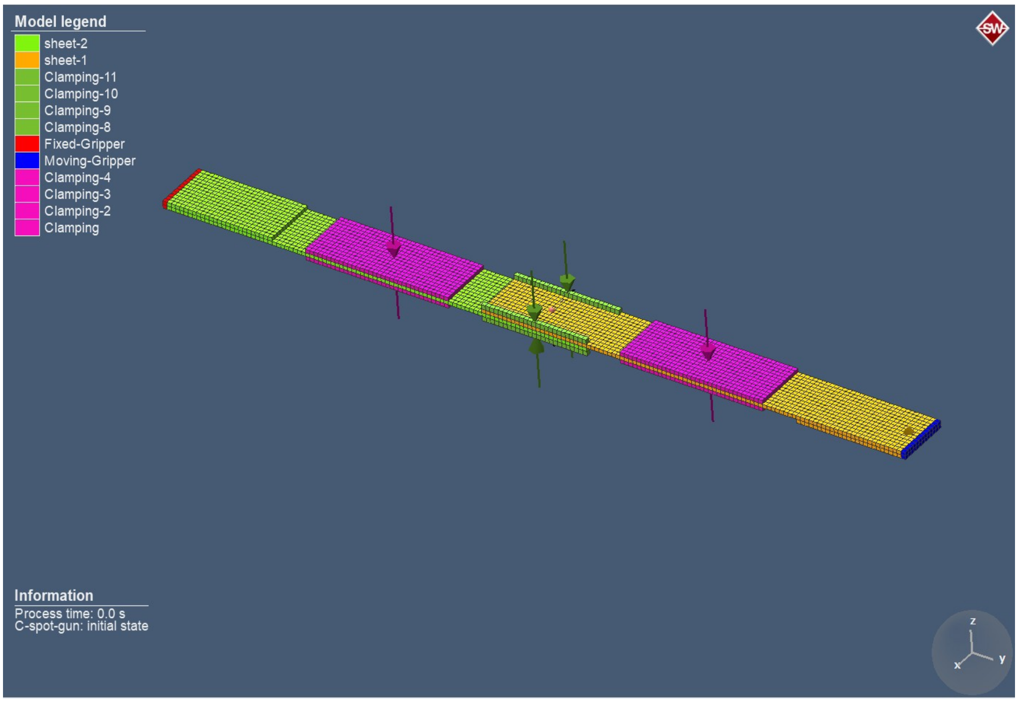


Fig. 4.3 Numerical model with applied constrains and loads

4.2.4 Stress Distribution Assumption

Finding that the failure mode for lap-shear samples is mainly uni-axial tensile load and the weld nugget is circular, a harmonic tensile stress distribution around the weld nugget is considered, as illustrated in Fig. 4.4. The stress distribution may be expressed as.

$$\sigma(\theta) = \sigma_{max} \cos\ \theta$$

Here θ = -90º to 90º

σ_{max} is max tensile stress at θ =0º

As the weld nugget is assumed as symmetry a similar stress distribution occurs

θ = 90º to 270º

σ_{max} is max tensile stress at θ = 180º

At equilibrium condition

$$P = \int_{-\pi/2}^{\pi/2} \sigma(\theta) \cdot \frac{d}{2} t \cdot \cos\ \theta \cdot d\theta = \frac{\pi}{4} td\sigma_{max} = 0.785 td\sigma_{max}$$

Here p is the applied tensile load, at initiation of fracture P becomes P_f *ie.*

$$P_f = 0.785 td\sigma_f$$

Here t is the thickness of the sheet.

d is the diameter of the nugget.

σ_f is the fracturing stress of the material in tension

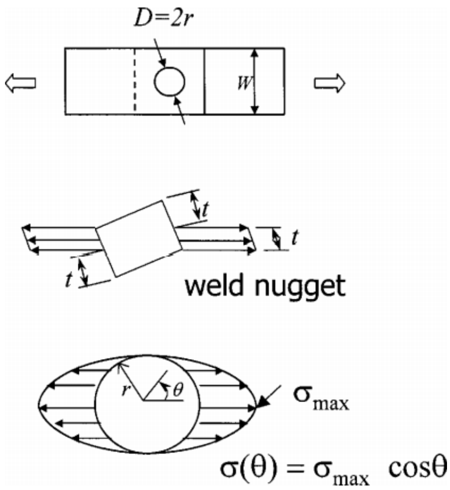


Fig. 4.4 Stress distribution around the weld nugget in a lap-shear sample

4.2.5 Solution

After preprocessing, the model generation, including meshing, is complete. A thermomechanical simulation is carried out to get a resulting mesh with a nugget at its center as shown in the fig. 4.5.

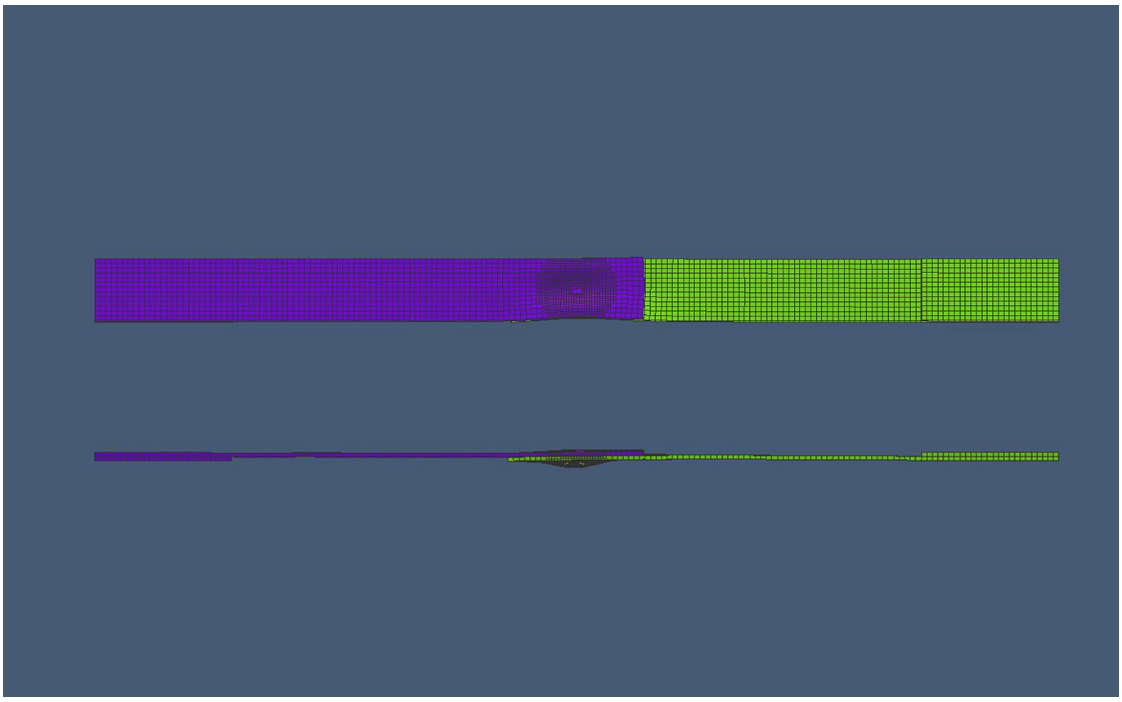


Fig. 4.5 3D mesh after RSW simulation.

Results from the tensile test was collected as in the form of force vs time and displacement vs time graphs as shown in the fig 4.6

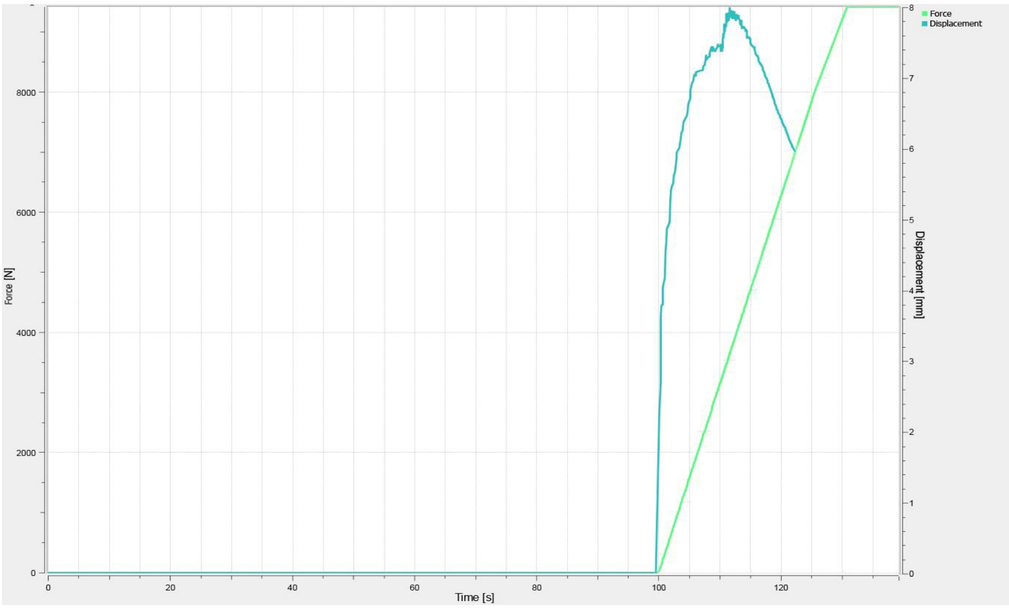


Fig. 4.6 Force vs Time and Displacement vs Time graph generated.

The data of the results were used to find corresponding stress strain values stress expressed as

$$\sigma = F / A$$

Here F is force applied on the sheet by the moving clamp

A is the cross-sectional area of sheet = (.8+.8)x12.5 = 20mm^2

ie.

$$\sigma_i = {}^{F_i}/_{20}$$

Whereas value of strain is expressed by

$$\varepsilon = \frac{\delta l}{l}$$

Here ε is strain

And δl is displacement

l is the length of the prototype geometry = 175mm

ie.

$$\varepsilon_i = \frac{\delta l_i}{175}$$

The new graph (fig. 4.7) stress vs stain that resulted can be used to directly compared with the experimental data.

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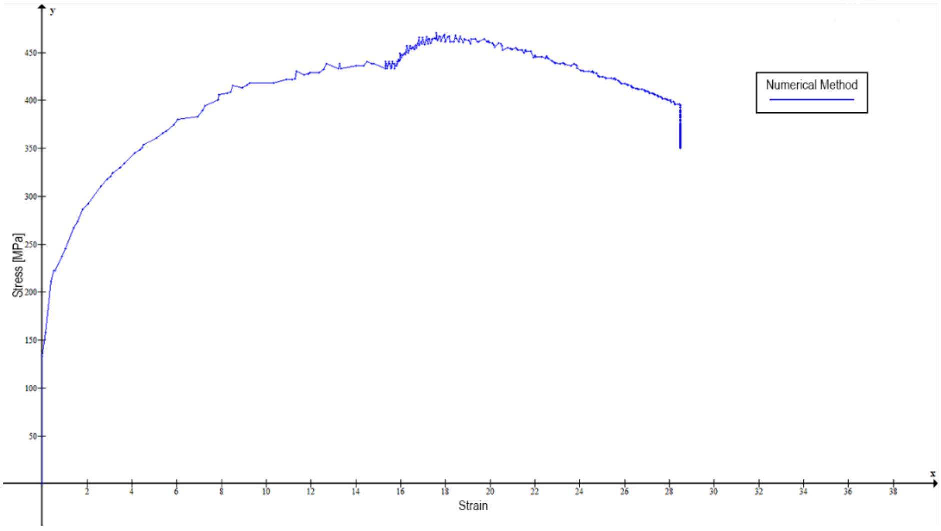

Fig. 4.7 Force vs Time and Displacement vs Time graph generated

4.3 Simufact.welding 6.0 analysis

4.3.1 Equivalent Stress (von-mises stress)

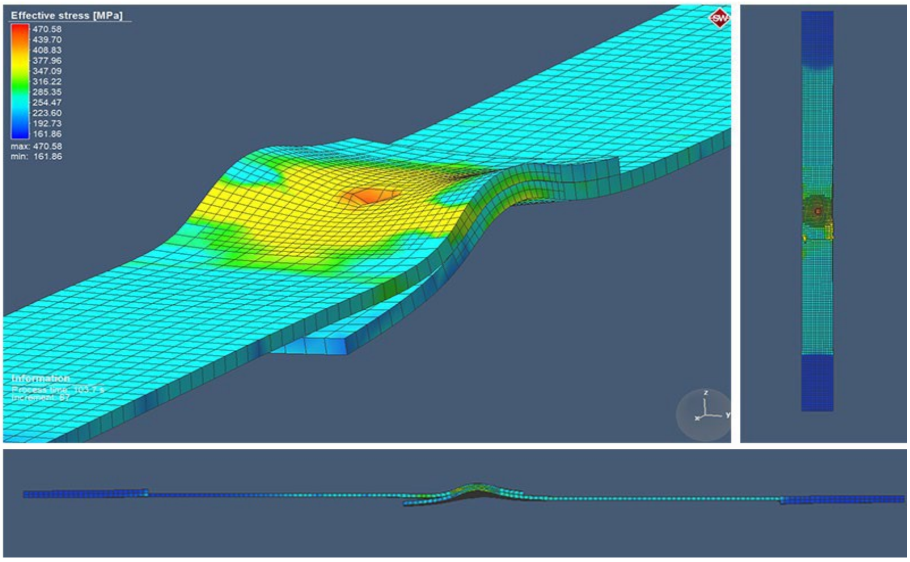

Fig. 4.8 Von-mises stress analysis.

Effective stress (XY) = 470.58 MPa (Maximum)

Effective stress (XY) = 161.86 MPa (Minimum)

4.3.2 Maximum Principle Stress

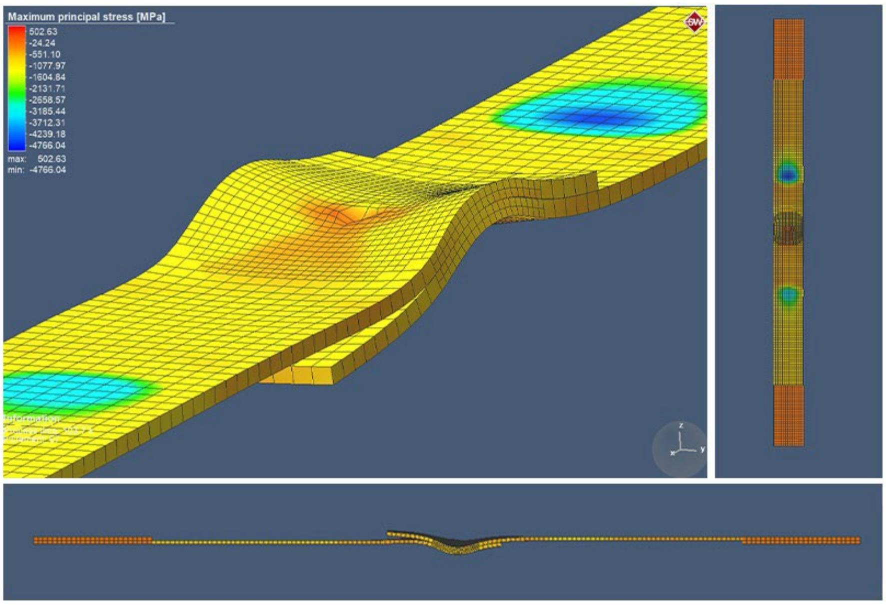

Fig. 4.9 Max principle stress analysis.

Max principle stress (XY) = 502.63 MPa (Maximum)

Max principle stress (XY) = -4764.04 MPa (Minimum)

4.3.3 Equivalent elastic strain

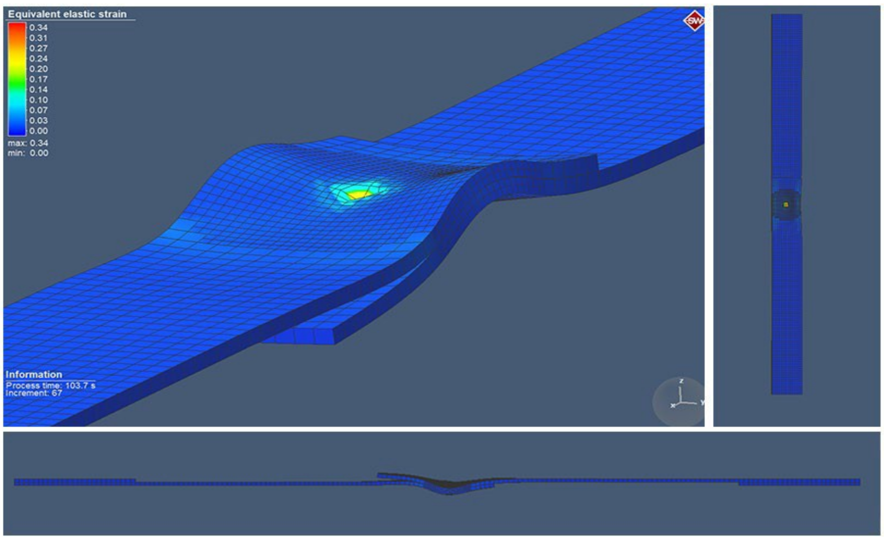

Fig. 4.10 Max principle stress analysis.

Equivalent strain (XY) = 0.34 (Maximum)

Equivalent strain (XY) = 0 (Minimum)

CHAPTER 5

COMPONENTS AND SPECIFICATIONS

Our project's key components are as follows:

1. Test Specimen
2. Resistance spot welding equipment
3. INSTRON 5589 (60 Ton capacity)

5.1 Test Specimen

15CDV6 is a chromium-molybdenum-vanadium heat treatable steel with excellent strength, after the heat treatment (1080-1280 N/mm2). It's simple to weld and doesn't require any post-weld heat treatment. Welding can be done without additional heat treatment and with minimal property loss. The yield strength and toughness of 15CDV6 are excellent.

5.1.1 Chemical Composition (wt %)

	C	Si	Mn	S	P	Cr	Mo	V
Min	0.12	-	0.8	-	-	1.25	0.8	0.2
Max	0.18	0.2	1.1	0.015	0.020	1.5	1.00	0.30

Table. 5.1 Chemical composition (wt %) of 15CDV6 steel

5.1.2 Mechanical Properties

	0.2% proof stress	Tensile Strength	Elongation	Hardness
Condition	MPA (min)	MPA (min)	%	HB
1.7734.2 (Annealed)	320	-	30	197
1.7734.4	550	700	13	207
1.7734.5	790	980-1180	11	293-352
1.7745.6	**930**	**1080-1250**	**10**	**231-363**

Table. 5.2 Mechanical properties of 15CDV6 steel

5.1.3 Dimension of the Test Specimen

Test Specimen	Length	Width	Thickness
15CDV6	100 mm	12.5 mm	0.8 mm

Table 5.3 Dimensions of the Test Specimen 15CDV6 Steel

5.2 Resistance Spot Welding Equipment

The tools required for resistance spot welding can be simple and affordable or complex and expensive, depending on the degree of automation. Spot welding equipment are usually made up of three main components:

- Electrical Circuit: It is composed of a welding transformer, tap switch and a secondary circuit.
- Control Circuit: It controls the duration of current flow and regulates the welding current.
- Mechanical System: This system consists of the frame, fixtures and devices that hold and clamp workpiece and apply welding pressure.

Multiple spot welders and robotic cells are used to perform welding operations in highly automated manufacturing lines. Furthermore, hand welding procedures can be utilised to create subassemblies that are fed into the main production/assembly lines, or final products in many cases. These many end applications necessitate machines with a variety of designs and attributes. RSW machines are classified into three categories:

- Pedestal-type welding machines
- Portable welding guns
- Multiple welding machines incorporating lightweight gun welding units.

The Resistance Welder Manufacturers Association (RWMA) has standardized criteria for resistance welding equipment, whereas the National Electrical Manufacturers Association has established criteria for controls (NEMA).

5.3 Specimen Testing Machine

Universal Testing Systems include electromechanical series and Industrial series to perform static testing, including tensile and compression applications. UTM (Universal Testing Machine of INSTRON technologies is shown in figure 5.1

Fig. 5.1 INSTRON 5589 (60 Tons capacity)

- Crosshead: The horizontal part of the load frame that moves during a tensile test, or down during a compression test.
- Load Cell: Measurement transducer for the load applied. The Instron 5589 has both a 60 KN load cell and a 1 KN load cell.
- Specimen Grips: The specimen grips hold the specimen during the test. These come in many shapes and sizes, but this lab has threaded grips and clamps.
- Upper and Lower Crosshead Limits: Trip switches for the maximum height the crosshead is allowed to travel during a test.
- Manual Up/Down Toggle: Moves the crosshead up and down manually at the user's command. The toggle only works however when the software is loaded on the computer. Using this button without the software being loaded may result in the machine locking.

Emergency Stop: Safety switch, pressing will immediately shut down all machine operations.

CHAPTER 6

EXPERIMENTATION

The Resistance Spot Welding (RSW) technology is widely utilised in the automotive and aerospace industries for sheet metal joining. Typically, mass optimization of the vehicle is one of the primary design objectives in the aerospace industry, particularly in the spacecraft area. This study is an effort to understand the physical and mechanical characteristics of resistive spot welding by destructive tensile testing of the test specimen. The sheet metal to be welded was 15CDV6 steel. The specimen was sliced into strips of 100 mm length and 12.5 mm breadth from a 0.8 mm thick sheet. RSW was performed on 15CDV6 steel and a nugget radius of 5 mm and a weld area of 78.5 mm^2 was obtained from the weld procedure. The specimen's ultimate dimensions following the RSW weld were 175 mm length and 12.5 mm breadth. Destructive tensile testing of the welded specimen was done using the INSTRON 5589 (60 Tons capacity) UTM. INSTRON 5589 is used to test all five specimens. A tensile test is performed, and the findings are recorded. The UTM generates a stress strain graph.

A all the experimental data has been acquired, the experiment is now carried out numerically using Finite Element Analysis. Finite Element Analysis is a computational method for calculating approximate solutions to partial differential equations. It arose as a result of the requirement to solve difficult elasticity and structural analysis issues in Civil, Mechanical, and Aerospace engineering. FEM aids in the visualisation of stiffness and strength in structural simulations. It also aids in reducing the material weight and expense of the buildings. FEM enables detailed visualisation and displays the distribution of stresses and strains throughout a structure's body. The exact prototype geometry was reproduced into a three-dimensional (3D) model using MSC Apex Harris Hawk SP1 for Discretization, commonly known as formulating the FE mesh (process of reducing the structure into smaller feasible units). JMatPro was used to incorporate material features such as mechanical properties and chemical composition, as well as additional data such as mechanical flow characteristics, mechanical properties such as thermal expansion coefficient, density table, and Young's modules. During tensile test simulations, the axial truss element was positioned at the other end to fix the other end, and all other clamp forces were inhibited.The numerical model was created in the Simufact. welding 6.0.

Model creation and meshing are completed after pre-processing. A thermomechanical simulation is run to produce a mesh with a nugget in its center. The tensile test results were obtained in the form of force vs. time and displacement vs. time graphs.

CHAPTER 7

RESULT AND DISCUSSION

The results of a single spot welded lap joint of 15CDV6 steel sheets are achieved both numerically and experimentally. The experiment is carried out on INSTRON 5589 (60 tonnes capacity). The same values of the basic parameters of the tensile test experimental setup were implemented into the FE model in simufact.welding 6.0. The test results generated through the experiment on a single spot welded 15CDV6 annealed specimen was found to be 310 MPa, By taking the average of 0.2% proof stress value. The highest equivalent stress obtained in fig.4.8. using von-mises stress analysis is 470.58Mpa, which is substantially greater than the yield strength reported in the experimental setup, causing a failure at the nugget point (fig7.1.).

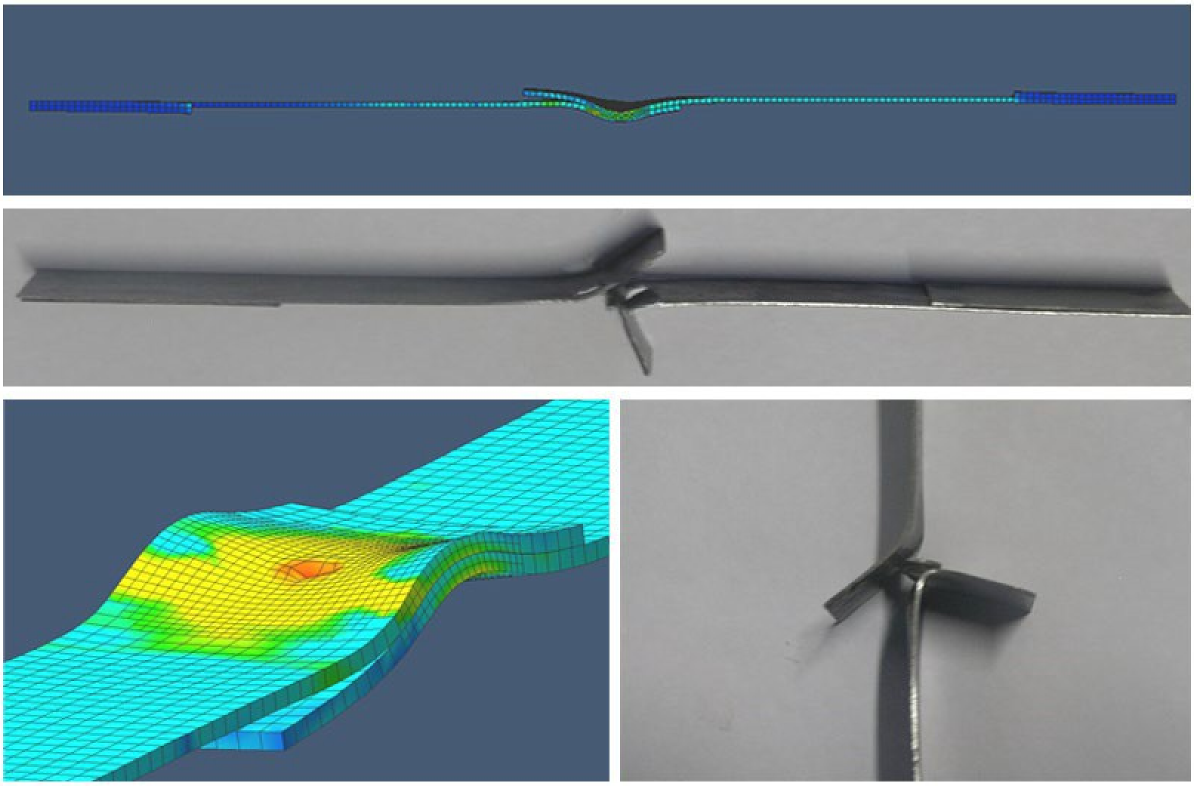

Fig. 7.1 End result comparison between experimental and numerical prototype.

Which perfectly fits the experimental prototype's nugget pullout failure. The results obtained from the experimental and numerical method produced an error percentage of 15.2% (avg) by interpolating values from both the setups as shown in the table.7.1.

Elongation	Tensile Strength (Numerical Model)	Tensile Strength (Experimental Model)	Error
%	MPa	MPa	%
5	352.11	445.28	20
10	409.95	481.65	14
15	427.87	488.54	12
20	403.52	486.57	17
25	416.25	480.76	13
Avg error percentage			15.2

Table. 7.1 Comparison between experimental and numerical prototype table.

It was discovered that the plastic region of the curve had a lower error rate. Figure 7.2. shows the results of the analytical comparison of both curves. By neglecting the error percentage a good agreement between experimental and numerical setups was found.

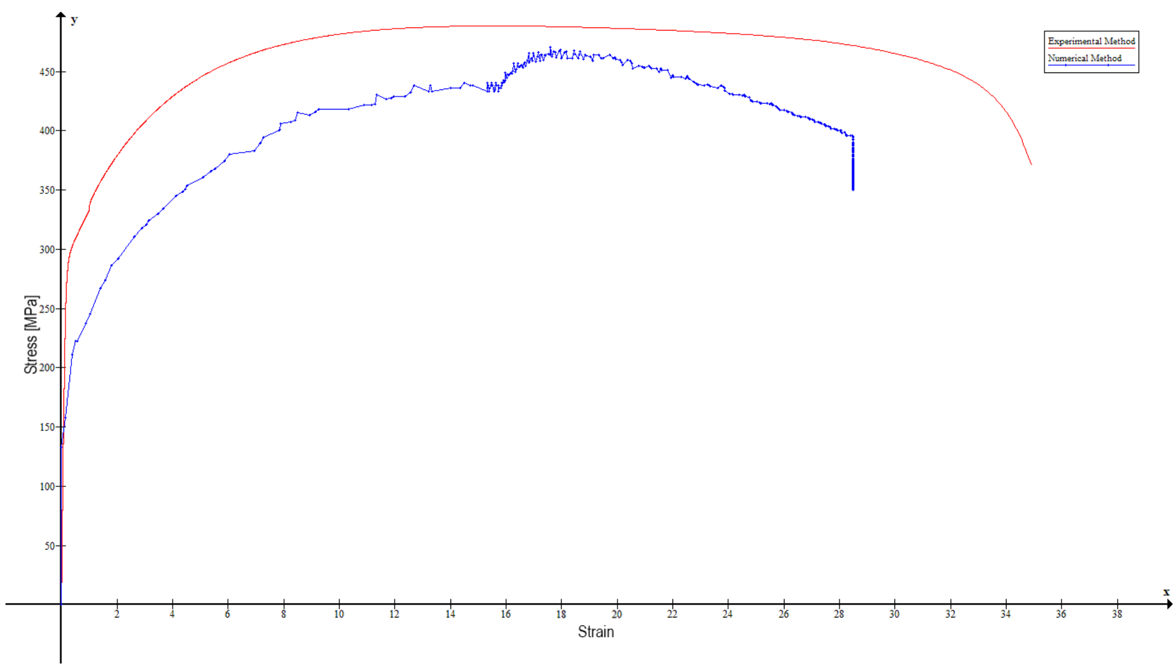

Fig. 7.2 Comparison between experimental and numerical prototype graph.

CHAPTER 8
CONCLUSION

A destructive tensile test was done on a single Resistance Spot welded lap joint sheet of 15CDV6 using an INSTRON 5589 (60 tones capacity) Standard Testing Machine. The testing requirements were satisfied, and the results were obtained. These data are used to generate Stress-Strain graphs and calculate the yield strength of the material..

On one end, a spot welded specimen was restricted to 6 degrees of freedom. Load was applied at the other end as a pressure load, and structural analysis simulation was performed in Simufact.welding 6.0. The experimental and theoretical findings were compared. The results were meant to be the same, however the variety of the obtained results was unanticipated due to global deflections of the Standard testing equipment.

Nonetheless, the work's findings and comparative study can be used by others in the future.

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