KAUNAS UNIVERSITY OF TECHNOLOGY

FACULTY OF MECHANICAL ENGINEERING AND DESIGN

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ANALYSIS OF MECHANICAL PROPERTIES OF DISSIMILAR METALS WELDMENTS

Master's Degree Final Project

Supervisor

Assoc. prof. dr. **Jolanta Baskutiene**

KAUNAS, 2017

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INDUSTRIAL ENGINEERING AND MANAGEMENT (code 621H77003)

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Assoc. prof. dr. Jolanta Baskutiene

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KAUNAS,2017

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(Title and code of study programme)

" ANALYSIS OF MECHANICAL PROPERTIES OF DISSIMILAR METALS WELDMENTS"

DECLARATION OF ACADEMIC INTEGRITY

____ May 2017
Kaunas

I confirm that the final project of mine, **Vijayramachandhar Chinnappashanmugam**, on the subject "Analysis of mechanical properties of dissimilar metals weldments" is written completely by myself; all the provided data and research results are correct and have been obtained honestly. None of the parts of this thesis have been plagiarized from any printed, Internet-based or otherwise recorded sources. All direct and indirect quotations from external resources are indicated in the list of references. No monetary funds (unless required by law) have been paid to anyone for any contribution to this thesis.

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FACULTY OF MECHANICAL ENGINEERING AND DESIGN

Approved:

Head of
Production engineering
Department

____
(Signature, date)

Kazimieras Juzėnas
(Name, Surname)

MASTER STUDIES FINAL PROJECT TASK ASSIGNMENT
Study programme INDUSTRIAL ENGINEERING AND MANAGEMENT- 621H77003

The final project of Master studies to gain the master qualification degree, is research or applied type project, for completion and defence of which 30 credits are assigned. The final project of the student must demonstrate the deepened and enlarged knowledge acquired in the main studies, also gained skills to formulate and solve an actual problem having limited and (or) contradictory information, independently conduct scientific or applied analysis and properly interpret data. By completing and defending the final project Master studies student must demonstrate the creativity, ability to apply fundamental knowledge, understanding of social and commercial environment, Legal Acts and financial possibilities, show the information search skills, ability to carry out the qualified analysis, use numerical methods, applied software, common information technologies and correct language, ability to formulate proper conclusions.

1. Title of the Project

ANALYSIS OF MECHANICAL PROPERTIES OF DISSIMILAR METALS WELDMENTS

Approved by the Dean Order No.V25-11-8, 21 April 2017

2. Aim of the project

To analyse and select the material suitable for exhaust system in two-wheeler motorcycles

3.Structure of the project

1. Introduction	5. Tensile testing
2. Literature Review	6. Hardness testing
3. Modelling and preparation of specimen	7. Microstructure analysis
4. Finite element analysis	8. Conclusion

4. Requirements and conditions

Stainless steel 304, Mild steel 1018; Required dimensions of the specimen - length 150mm, outer diameter - 21Ø, inner diameter -19Ø, Thickness -2.2mm.

5. This task assignment is an integral part of the final project

6. Project submission deadline: 20__ ________ __st.

Student

	______________________________	______________________
	(*Name, Surname of the Student)*	(*Signature, date*)
Supervisor	______________________________	______________________
	(*Position, Name, Surname*)	(*Signature, date*)

Chinnappa Shanmugam Vijayramachandhar, SKIRTINGŲ METALŲ VIRINTINIŲ JUNGČIŲ MECHANINIŲ SAVYBIŲ TYRIMAS. *Magistro* baigiamasis projektas / vadovas doc. dr. Jolanta Baskutienė; Kauno technologijos universitetas, .Mechanikos inžinerijos ir dizaino fakultetas.
Mokslo kryptis ir sritis: Technologijos mokslai, gamybos inžinerija.
Reikšminiai žodžiai: išmetimo vamzdis, suvirinimas, modeliavimas, CATIA, ANSYS, eksperimentinis tyrimas, mikrostruktūra, kietumas

Kaunas, 2017. 40p.

SANTRAUKA

Dabartiniu metu dviračių motociklų išmetimo sistemoms gaminti dažniausiai naudojamas mažaanglis plienas. Pagrindinė išmetimo sistemos gedimų priežastis yra korozija, nuovargis ar abi minėtos priežastys. Apie 70% gedimų įvyksta dėl korozijos, o likusieji – dėl nuovargio. Šiame baigiamajame projekte nagrinėjami išmetimo sistemos detalių gasmybos procesai. Pagrindinbis darbo tikslas yra atlikti analizę ir parinkti medžiagą tinkančią dviračių motociklų išmetimo sistemos detalių gamybai. Nagrinėjamas suvirinimas nelydžiu volframo elektrodu. Panaudojant CATIA programinę įrangą, sudaryti bandinių modeliai ir atlikta analizė naudojant ANSYS programinę įrangą. Pagaminti nerūdyjančio plieno, mažaanglio plieno ir kombinuoti nerūdyjančio ir mažaanglio plieno bandiniai. Atliktas bandinių suvirinimas ir suvirintų bandinių tempimo bandymai. Siekiant įsitikinti kokia yra suvirinimo ir medžiagos kokybė atlikta bandinių mikrostruktūros analizė ir kietumo bandymai. Gauti rezultatai gali būti naudingi parenkant išmetimo sistemos komponentų medžiagą ir gamybos technologiją. Pateiktos atliktų tyrimų išvados,

Chinnappa Shanmugam Vijayramachandhar, ANALYSIS OF MECHANICAL PROPERTIES OF DISSIMILAR METALS WELDMENTS: Master ‘s Final project/ supervisor assoc. prof. Dr. Jolanta Baskutienė. The Faculty of Mechanical engineering and design, Kaunas University of Technology.

Research area and field: Technological Science, Production Engineering

Keywords: exhaust pipe, welding, simulation, CATIA, ANSYS, experimental analysis, microstructure, hardness.

Kaunas, 2017. 40p.

SUMMARY

Nowadays the most common material which is used in Two-wheeler bikes for the exhaust system is mild steel. The main cause for the exhaust system failure is due to corrosion, fatigue or both combined. About 70% of the failure is due to corrosion and remaining is due to fatigue. This final project deals with the exhaust system parts manufacturing processes. The main aim is to analyse and select the material suitable for exhaust system in two-wheeler motorcycles. TIG welding are considered. CATIA models of the specimens are made and analysis is accomplished using ANSYS software. The welded specimens of stainless steel, mild steel and combined stainless-mild steel specimens were made and tensile tests were carried out. The specimen are taken for microstructure analyses followed by hardness test to ensure the quality of the weld and material. Obtained results may be useful while selecting the material and manufacturing technology for the exhaust system parts. Conclusions of the research are given.

ACKNOWLEDGEMENT

First, I would like to thank my project supervisor Assoc. prof. dr. Jolanta Baskutiene of Mechanical Engineering and design department at Kaunas University of technology who helped me consistently when I had a question about my research and writing. She also helped and allowed this paper to be my own work, but steered me in the right the direction whenever he thought I needed it.

I would also like thanks Assoc. Prof. Dr. Evaldas Narvydas of Mechanical Engineering and Design department, for his kind guidelines and support which also allowed me for complete the final master‘s degree project.

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Introduction

The exhaust system of a motorcycle plays a major role in reducing the engine noise, removing waste gases from the engine and aiming to offer good serviceability, design, style and cost per the customer needs. Nowadays the additive manufacturing processes are widely used to make small quantities of structural and functional components such as engine exhausts, drive shafts and gear box components. The exhaust system of motorcycles of high end models is 3D printed and have a lot of advantages like design flexibility, corrosion resistance etc. The exhaust system of motorcycles of low end models is fabricated by welding of different metals, including mild steel, stainless steel, ferritic steel, etc. Majority of modern motorcycles are fabricated using mild steel with zinc coating, ceramics or other kind of coating aiming to increase the corrosion resistance, however, these coatings offer corrosion resistance only for a certain period. Presented research paper deals with the exhaust system parts manufacturing processes. TIG welding are considered. Catia models of the specimens are made and analysis is accomplished using Ansys software. The welded specimens of stainless steel, mild steel and combined stainless-mild steel specimens were made and tensile tests were carried out. Obtained results may be useful while selecting the material and manufacturing technology for the exhaust system parts.

Aim

To analyse and select the material suitable for exhaust system in two-wheeler motorcycles.

Tasks

1. To Analyse the welding process in different materials and defects in exhaust pipes through patents, scientific articles, journals.

2. To select the material and create 3d model using catia.

3. To analyse finite element of the 3d model using ansys simulation software.

4. To analyse the tensile stress strength and hardness of material.

5. To analyse the microstructure and defects of the material under magnification.

1. Current trends in manufacturing exhaust system

The materials which are regularly used for the exhaust components of a motorcycle are of aluminized mild steel, stainless steel. Corrosion is one of the major problems in mild steel which eventually reduces the product life time. Due to aggressive environmental condition, even some stainless steels do not possess strong corrosion resistance [1]. The life time of the main fold is comparatively less when compared to the other parts of the exhaust system in the motorcycle. Steel grades AISI 409 and 439 have less thermal coefficient and can be used in the production of exhaust pipes, but the main disadvantage is that they are difficult to weld [2]. Aluminised mild steel is an-other option for producing exhaust pipes but main problem is that these types of steel are prone to high temperature corrosion and heat resistant. The corrosion resistance of a mild steel, which is subjected to oxidation, may be improved by coating. The exhaust systems, which suffer from poor corrosion resistance, have relatively short life time. The corrosion resistance of mild steel may be eventually improved by zinc- nickel coating shown in the figure1[3]. Therefore, considering a material for production of exhaust pipes and main fold in motorcycles the stainless steel of grade 304 should be considered, because this material is suitable for harsh and aggressive environmental conditions. Table 1 presents mechanical properties of stainless steel of grade 304 and mild steel [4,5].

Figure 1 Zinc – Nickel coated exhaust pipe of mild steel

Table 1 Mechanical properties of stainless steel 304 and mild steel [15]

No	Properties	Stainless steel 304	Mild steel 1018
1.	Ultimate strength, MPa	515	440
2.	Tensile strength, MPa	205	370
3.	Elongation (50%-70%)	40	15
4.	Hardness - Brinell	70	71

2. Selection of material grade

Stainless steel 304 contains more the 8% of chromium. It produces thin film layer on the surface that prevents Stainless steel 304 contains silicon, manganese, nickel, carbon, and molybdenum which provides useful properties like formability, weldability and resistance against corrosion. The film consists of metal oxides and hydroxide which was produced by the elements present in the stainless steel which reacted to oxygen with air and water. The film products are produced due to chromium which is 10% of its composition in the stain less steel. The presence of this film restricts the corrosion layer. Because stainless steel reacts to corrosion it does not easily rust and forms a supportive film on the layer [6]. And in addition, being non-attractive, austenitic stainless steels are not warm treatable. Be that as it may, they can be icy attempted to enhance hardness, quality and stress resistance. Heating it to more than up to 900 degree and cooling it rapidly creates a unique formation. The most widely recognized of these is review 304, which regularly contains more than eighteen percent chromium and eight percent nickel. Molybdenum can be included to a level of around more than 1.5 % for corrosion resistance.

2.1 Composition stainless steel

Considering ferritic and precipitation solidifying steels for instance, it is in this way prudent to be and to allude to the gathering to which the steel has a place with keep away from disarray. Likewise, with alternate sorts of stainless steels, the austenitic stainless steels are consumption and oxidation safe because of the nearness of chromium that structures a self-recuperating defensive film on the surface of the steel. They additionally have great sturdiness at to a great degree low temperatures so are utilized broadly in cryogenic applications. They can be solidified and their quality expanded by cool working yet not by heat treatment. They are the most effortlessly weld capable of the stainless-steel family and can be welded by all welding forms, the primary issues being evasion of hot splitting and the conservation of consumption resistance. An advantageous and regularly utilized shorthand recognizing the individual compound inside the austenitic stainless steel gathering is the ASTM framework. This uses a three-digit number '3XX', the "3" recognizing the steel as an austenitic stainless, and with extra letters to distinguish the structure and certain qualities [7]. Austenitic stainless steels are metallurgically basic combinations. This is not the ferrite to be found in carbon steel however in a high temperature which can be called as delta δ. They cannot extinguish solidified to shape martensite and their mechanical properties are unaffected by welding in exhaust pipes. Alloying components in an austenitic stainless steel can be isolated into two gatherings; those that advance the development of austenite and those that support the arrangement of ferrite. The principle composition are nickel, carbon, manganese and nitrogen; the imperative composition is chromium, silicon, molybdenum. By fluctuating the measures of these components, the steel can be made to be completely austenitic or can be intended to contain a little measure of ferrite; the significance of this will be examined later. In the outline Schaeffler appointed an element to the different components, the element mirroring the quality of the impact on the arrangement of ferrite or austenite; these variables can be found in the chart. The components are then consolidated into two gatherings to give chromium and nickel in reciprocals as an austenitic stainless steel, empowers the extents of the stages to be resolved. Additionally, superimposed on this graph shown in the figure 2 are shaded territories distinguishing a portion of the creation issues that might be experienced with austenitic stainless steels. [8]. All the austenitic stainless steels are touchy to hot breaking the completely austenitic steels falling inside the vertically blue zone in Figure 2 for example, sort 310 are especially delicate. The principle offenders are sulphur and phosphorus. The components have been logically diminished to such an extent that steels with under 0.010% sulphur and phosphorus under 0.020% are currently promptly accessible. In a perfect world, a sort 310 or sort 317 composite oughts to have sulphur and phosphorus levels beneath somewhere in the range of 0.003%. Cleanliness is additionally most critical must be done instantly preceding welding. The steels grades for example, 304, sort 316, sort 347 that fall inside, or near, the little uncoloured triangular area in the focal point of the outline contain a little measure of delta-ferrite and, while not being safe to hot breaking, have enhanced imperviousness to the development of sulphur-containing fluid movies. The purposes behind this area is that sulphur and phosphorus arrangement along the grain limits. The 100% austenitic steels don't have this preferred standpoint. One issue that has emerged with low sulphur steels is a marvel known as 'thrown to cast variety' or variable infiltration. The weld pool in a low sulphur steel (<0.005%) tends to be wide with shallow infiltration; a steel with sulphur over approximately 0.010% has a smaller, more profoundly entering the weld globule [7,8].

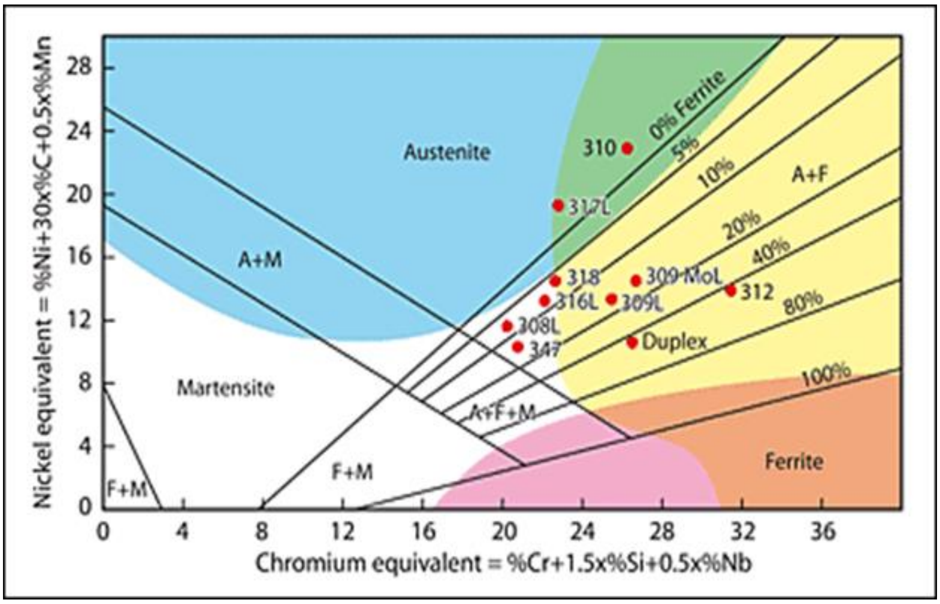


Figure 2 Iron carbide diagram stainless steel [7]

This is just an issue with the utilization of the completely computerized TIG welding process, a manual welder being fit for adapting to the varieties in entrance because of the distinctions in sulphur content in various throws of steel. In any case, robotized TIG welding techniques created on a high sulphur steel, when used to weld a low sulphur steel may bring about absence of infiltration [9]. Changes to the technique that have relieved, however never disposed of, this issue have included moderate travel speed, beat current, utilization of Ar/H2 shield gas blends. Different techniques incorporate indicating a base sulphur of, say, 0.011% or isolating the steels into bunches with known infiltration qualities and creating welding methods to suit. The TIG initiated flux prepare has likewise been observed to be of advantage. The issues of welding the completely ferritic steels that fall into the pink territory, where grain development and embrittlement is an issue. The austenitic stainless steels falling into the yellow range will likewise embrittle yet this is a result of the arrangement of hard weak stages called sigma (σ) and chi (χ). This embrittlement happens in the temperature scope of roughly 500 to 910°C. It is a languid procedure and is not an issue amid welding of the austenitic stainless steels, yet can happen in hoisted temperature benefit or if the welded part is under fatigue condition. [7,8]. Arrangement of these steel grades is advanced by high chromium and molybdenum so that steels, for example, 310 and sort 316 are especially touchy and may demonstrate a considerable loss of malleability. Delta ferrite additionally changes more quickly that austenite so those compounds containing a lot of this stage will debase quicker than an austenitic steel with just a little rate of ferrite; thus, the issues with and super duplex stainless steels. When it is important to push calm a manufacture then the loss of malleability must be represented [8].

3. Causes of failure in exhaust system

The material which is used now days in Two-wheeler bikes for the exhaust system is mild steel which is aluminised. The main cause for the exhaust system failure is due to corrosion, fatigue or both combined. About 70% of the failure is due to corrosion and remaining is due to fatigue. Some Mechanism of corrosion are listed below.

(i) Acid condensation due to which internal corrosion is caused.

(ii) Adverse climatic conditions due to which external corrosion is caused.

(iii)Temperature of the material which is between 300° 400^0C increases the sensitivity

(iv)low cycle fatigue i.e. heating and cooling effect.

(v) high cycle fatigue i.e. vibration from the engine.

The exhaust system can be divided into two types i.e. the hot end and the cold end. Oxidation and formation of sulphur oxide film is main reason for corrosion in the front end or hot end and pitting corrosion at the back end or at the cold end. [10] Temperatures of the different components of exhaust system are shown in table 2.

Table 2 Temperature of the different components of exhaust system [10]

Categories	Components	Operating temperatures(^{0}C)
Front end Components (hot end components)	Exhaust Manifold	300 – 450
Front end Components (hot end components)	Front Pipe	300 – 400
Back end components (cold end components)	Centre pipe and tail pipe	100 - 300

4. Defects in welding

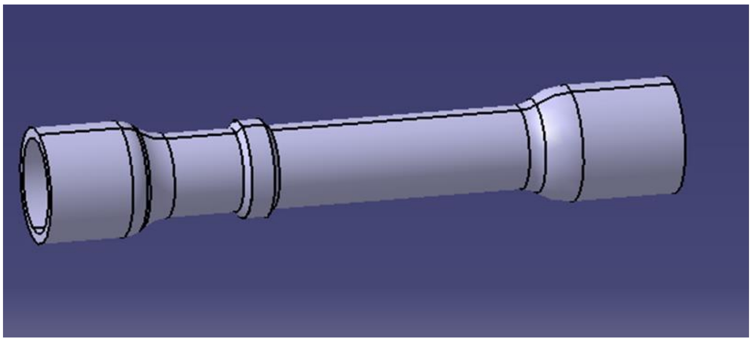
There are different type of defects that can occur in a welded joint due to various reasons and can cause unexpected failures. During the welding, when the filler material is not properly fused with the parent material, the lack of fusion occurs. This defect on the weld can causes incomplete fuse spots. The defect can occur on the side of the weld, in between the weld and on the bottom of the weld. This defect cannot be easily detected by visual inspection. But some-times using the non-destructive testing methods these defects can be detected. It takes n-time magnification to detect lack of fusion in between the weld through microscope [11]. The exhaust pipe on the side of the weld there is lack of fusion. Here the parent material used was mild steel and the filler material was E 70S-2. In this part of the exhaust pipe zinc-nickel coating was applied aiming to prevent the corrosion. But after 6 months the corrosion started on the edge of the parent material [12].

Figure 3 Crack due to lack of fusion and visible result of corrosion

The lack-of-fusion defects are due to unmelted oxide inclusions and non-metallic inclusions. Another important defect is lack of penetration, in welding exhaust pipes using MIG welding mainly to know the thickness of the material arc length and sufficient beads to be penetrated should be known to reduce the defect. Too much of current supplied to the welding machine gives rise to more amount of penetration. When the welder is too much away from the point to be welded which also causes more adequate of penetration. It essential to know best suitable bevel angle for overcoming this defect [11].

5.Modelling and preparation of specimens

CATIA software have been used for modelling of the specimen with additional features and required dimensions. Figure 4 shows the models of the specimens created using CATIA.

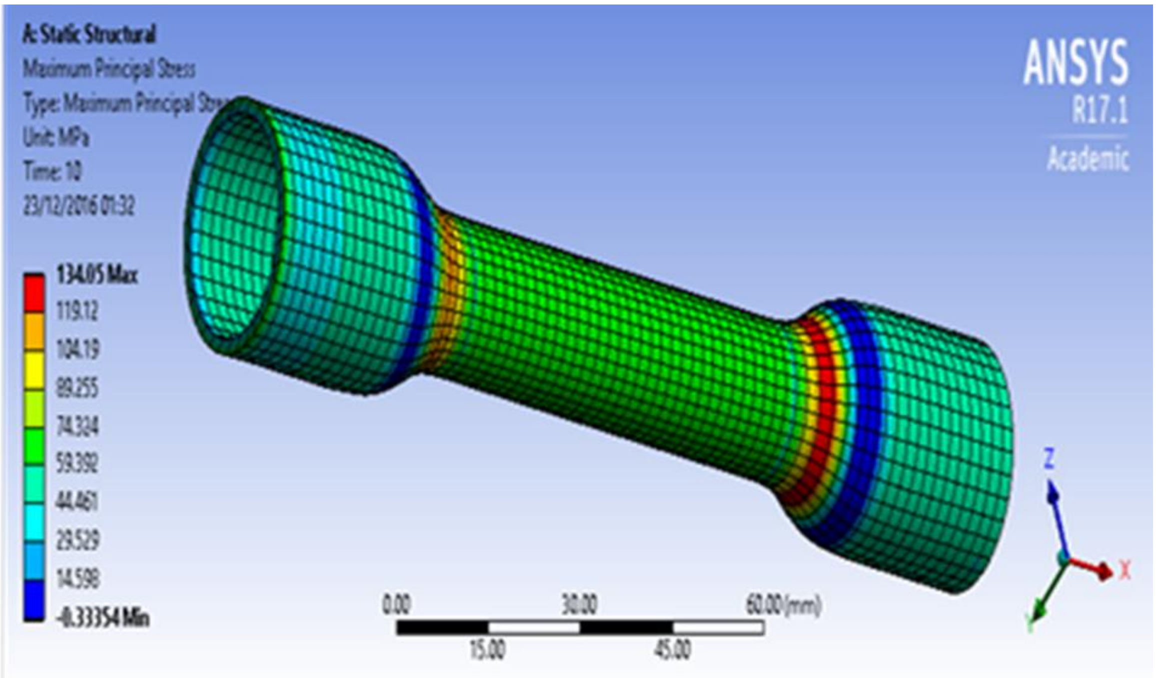


a)

Figure 4 Model of the specimen: a) 3d view of the model

6. FEM analysis

Ansys software is a tool for structural analysis, linear and nonlinear. This simulation provides model behaviour, and supports material models. Using this software, the 3d model created are simulated. The created specimen model has been imported to ANSYS software to carry out the stress strain analysis. To find out the maximum stress σ max and strain ε max for specimen model with different mechanical properties. After obtaining the maximum stress σ and strain ε the values are plotted in graph to show the stress strain curve for each specimen. Using FEM analysis, the specimen model without welding shown in the figure 5 was analysed applying the load along the axis to the fixed part. The force applied in this analyses was 3000 N. The properties of the specimen model were selected from the engineering data of a stainless steel. The corresponding stress and strain were evaluated and plotted in Fig 8. Similarly, for the specimen model stainless steel shown in the figure 6. The filler material selected was 308l. The load applied was 7000 N and the corresponding stress and stain values were evaluated and plotted in Fig 10. The specimen model is shown in the Figure 7 stainless steel and mild steel combined. The selected filler material was 316. The load was applied along the axis and the strain and stress were evaluated and plotted shown in the figure. The model shown in the Figure 8 is for the mild steel specimen. The selected filler material was E 70s-2. The corresponding values were obtained after applying the load along the axis to the fixed specimen. The ultimate purpose of any analysis is to allow the comparison of the developed stresses and deflections with those that are allowed by the design criteria.



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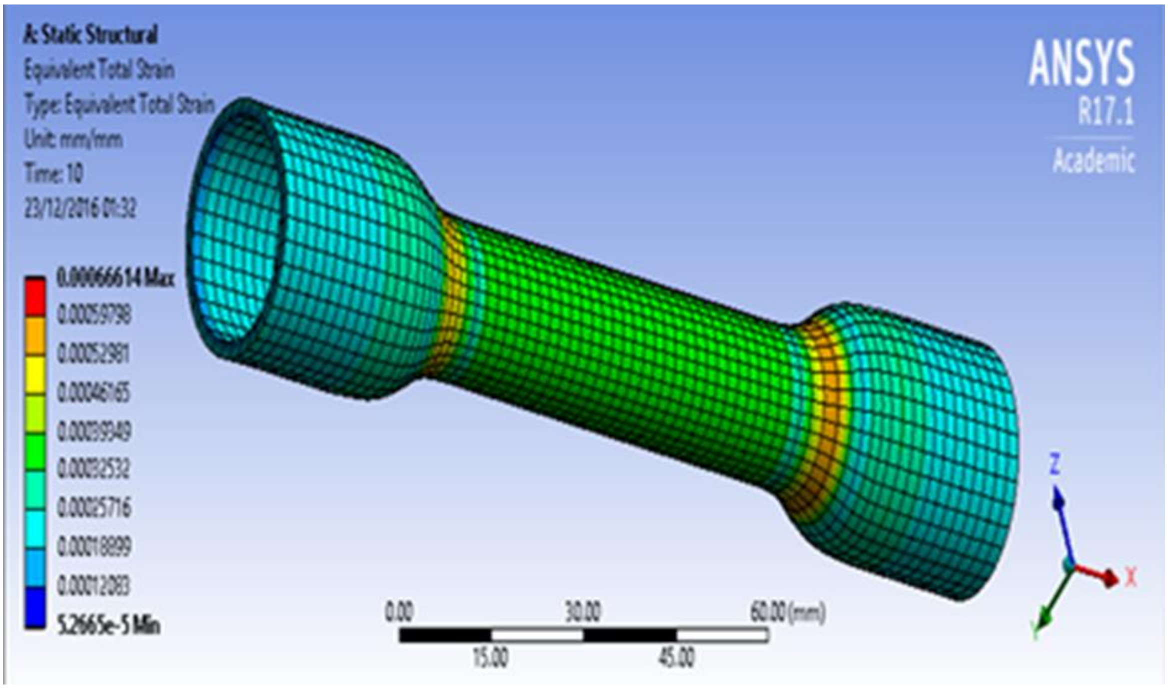
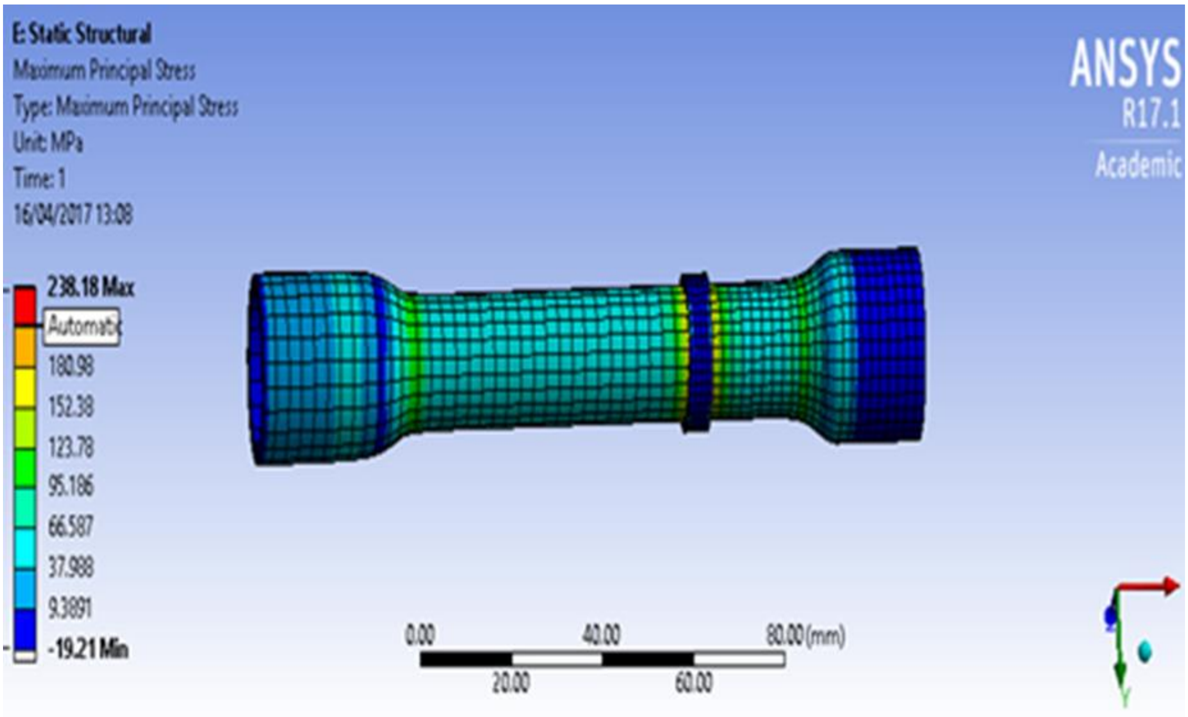


b)

Figure 5 Distribution of: a) stress $\sigma_{\max} = 134$; b) strain $\varepsilon = 6.66e^{-04}$ in the model of the specimen without welding



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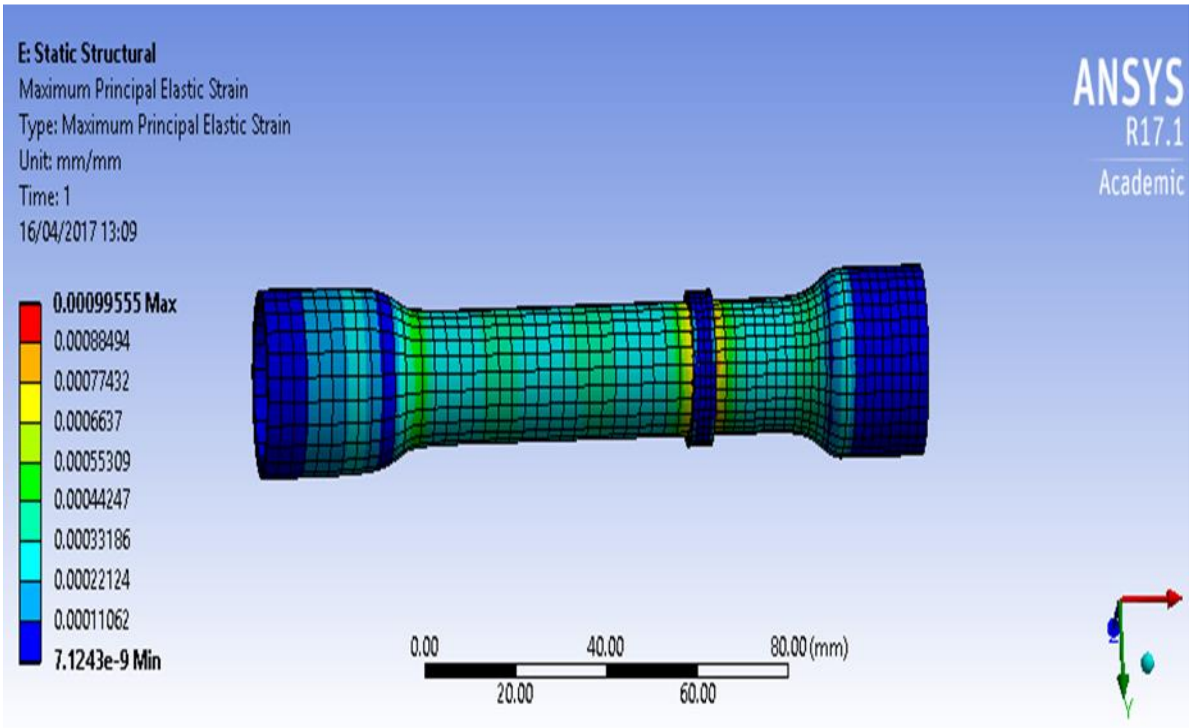
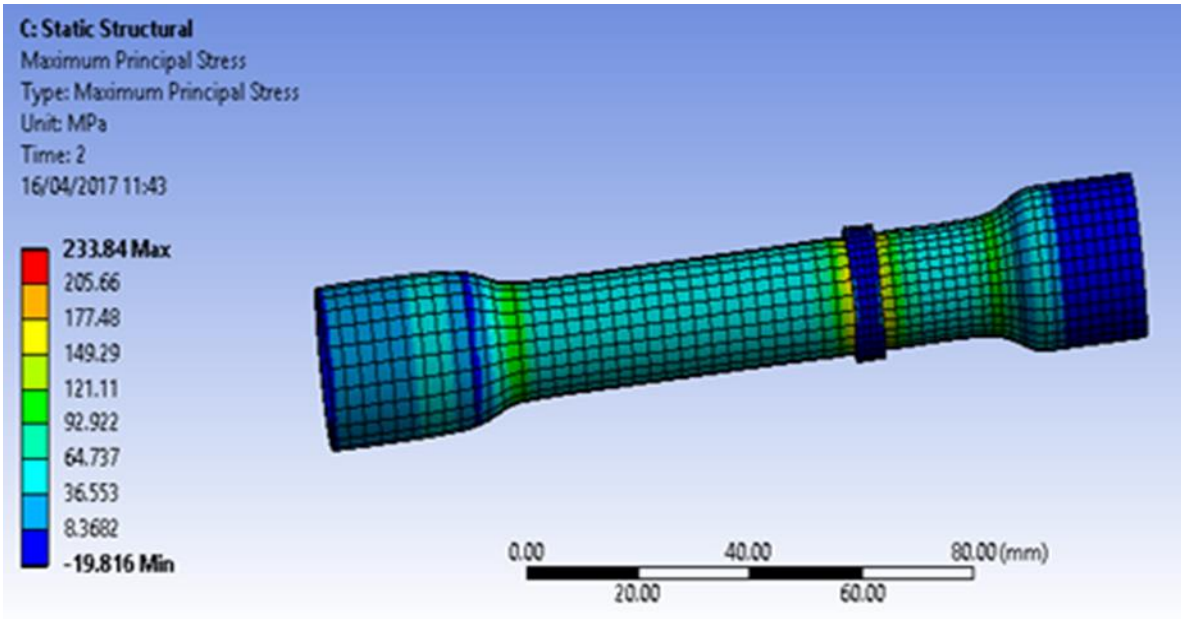
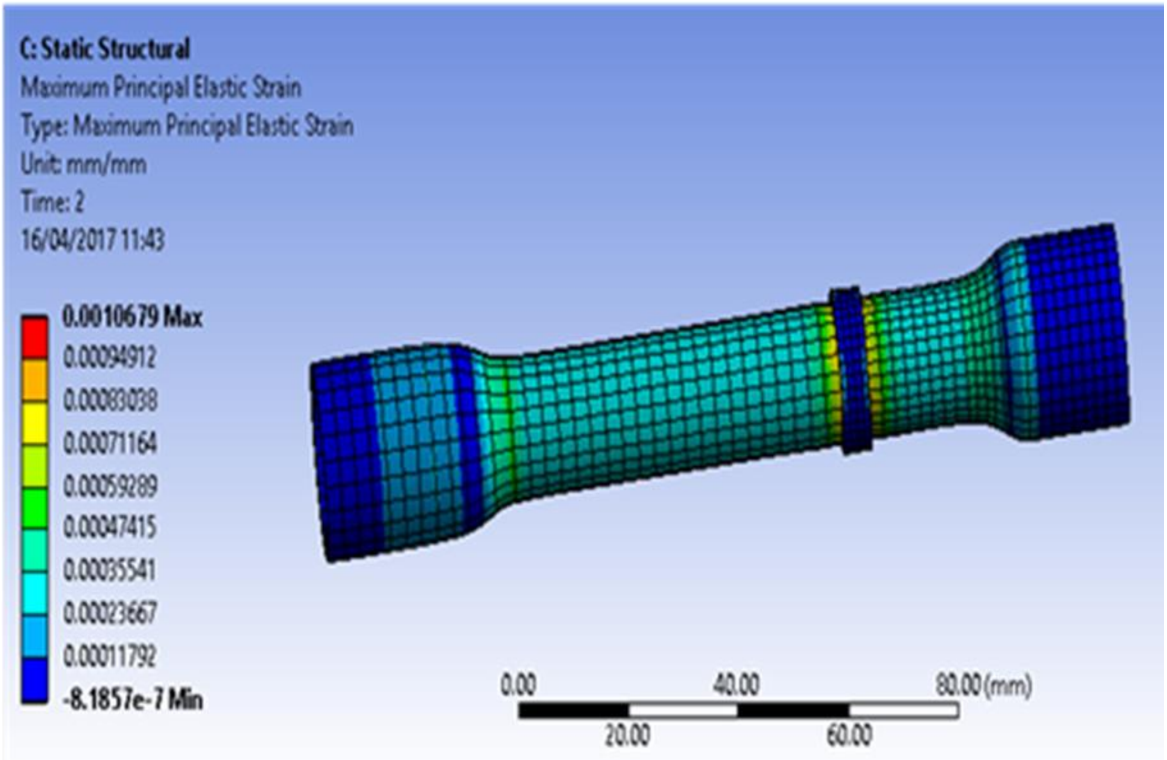


b)

Figure 6 Distribution of: a) stress $\sigma_{max} = 238.18$; b) strain $\varepsilon = 9.96e^{-04}$ in the stainless-steel specimen model



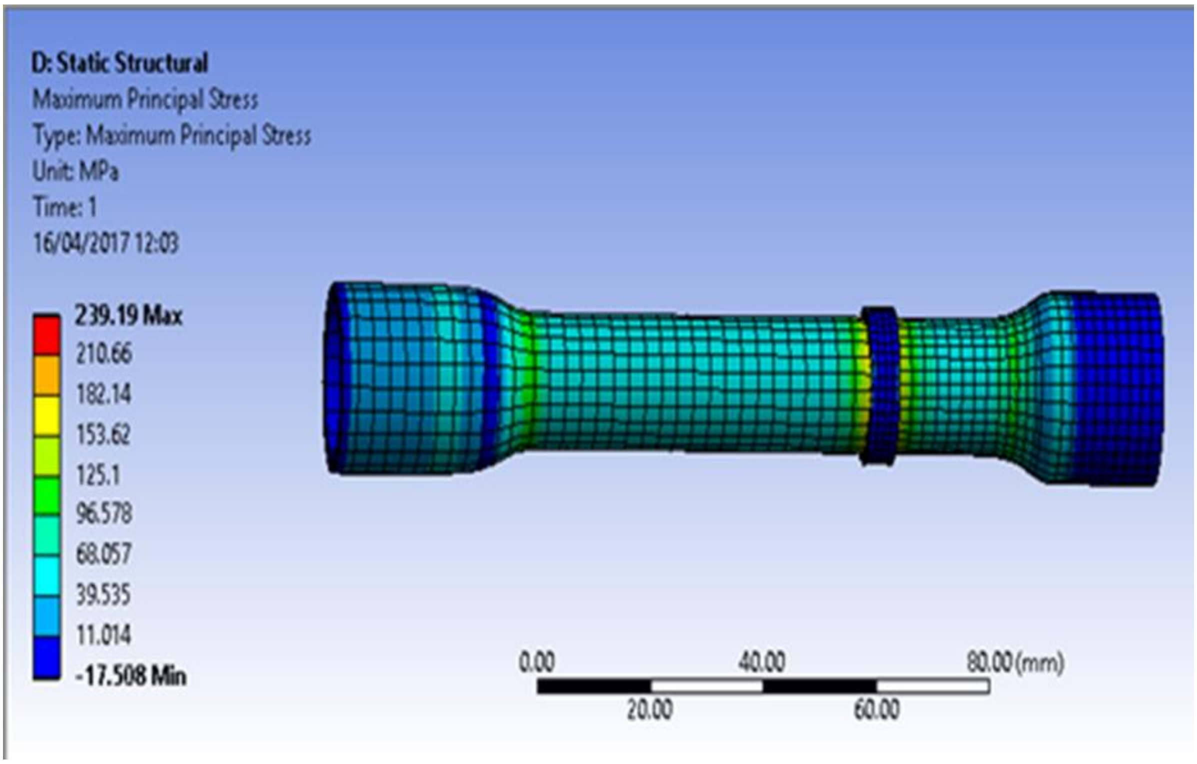
a)



b)

Figure 7 Distribution of: a) stress $\sigma_{max} = 233.84;$ and

b) strain $\varepsilon = 9.59e^{-04}$ in the model of the stainless and mild steel combined specimen



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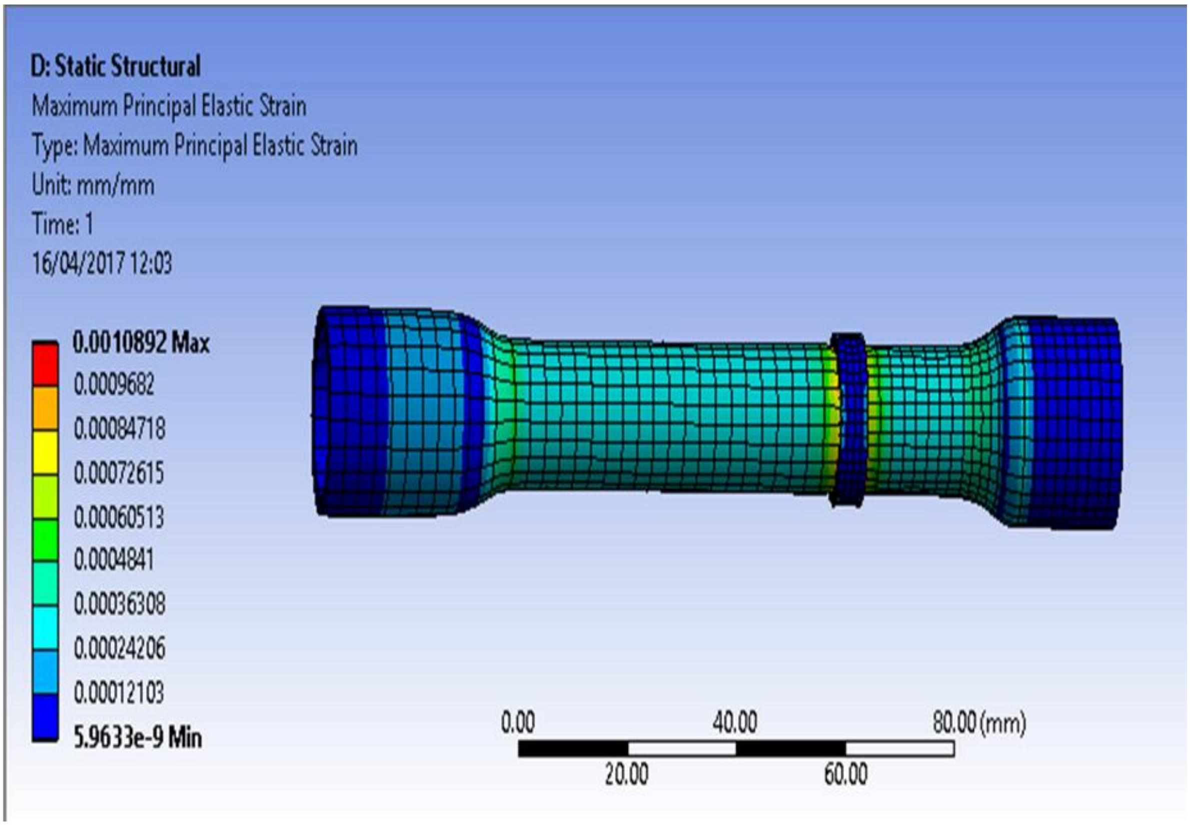


b)

Figure 8 Distribution of: a) stress $\sigma_{max} = 239.19$; b) strain $\varepsilon = 1.07e^{-03}$ in the mild steel specimen model

7.Stress- strain comparison

Stress–strain examination or stress investigation to decide the stress and strains in materials and structures subjected to strengths. In the first step for stress investigation are a geometrical portrayal of the structure, the properties of the materials utilized for its parts, how the parts are joined, and the most extreme or regular powers that are relied upon to be connected to the structure. The yield information is regularly a quantitative depiction of how the connected strengths spread all through the structure, bringing about stress, strains and the diversions of the whole structure and every part of that structure.

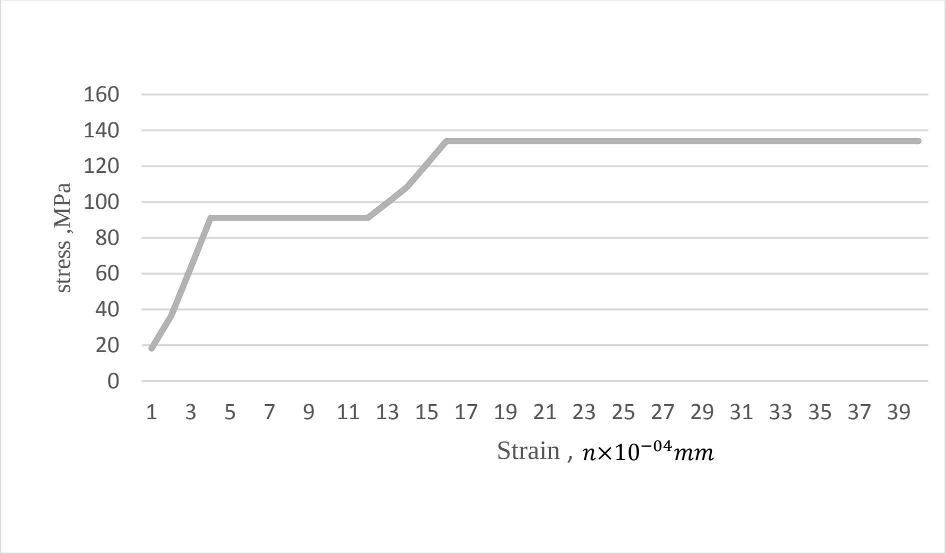


Figure 9 Stress -strain curve for specimen model without welding

Table 3 stress-strain curve points table for specimen model without welding

Stress (MPa)	Strain (mm E-05)
18.225	9.06E-05
36.451	1.81E-04
108.3	5.38E-04
121.17	6.02E-04
134.05	6.66E-04
134.05	6.66E-04
134.05	6.66E-04
134.05	6.66E-04
134.05	6.66E-04

The graphical presentations is known as that material's stress–strain. It is exceptional for every material and is found by recording the measure of twisting at unmistakable interims of malleable or compressive stacking of the material.

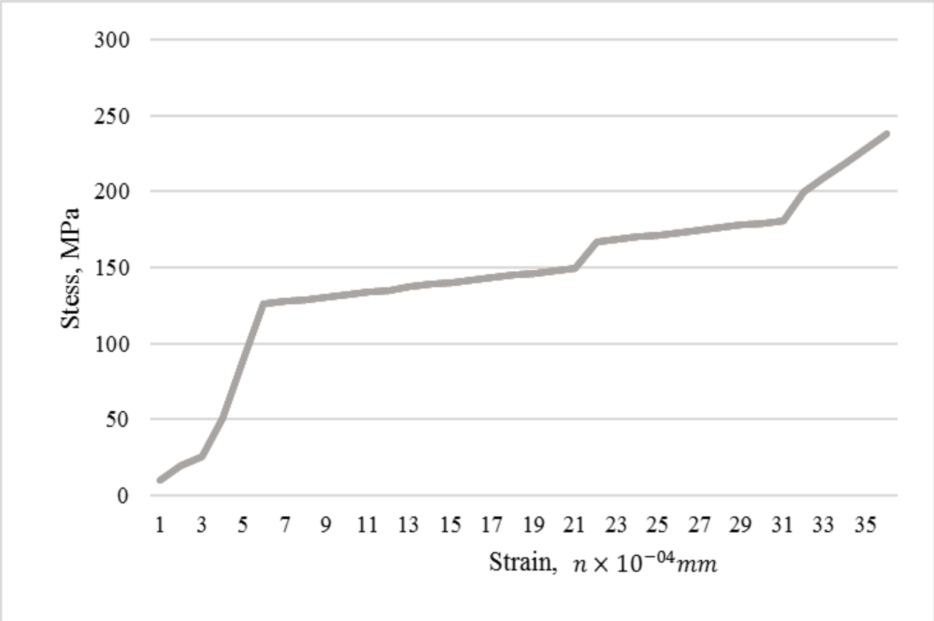


Figure 10 Stress-strain curve for welded part (stainless steel)

Table 4 stress-strain curve points table for welded part (stainless steel)

Stress (MPa)	Strain (mm E-05)
50.473	2.37E-04
88.328	4.15E-04
126.18	5.92E-04
127.44	5.98E-04
171.58	8.05E-04
209.6	8.76E-04
219.13	9.16E-04
228.65	9.56E-04
238.18	9.96E-04

These bends uncover a large portion of the properties of a material (counting information to build up the Modulus of Elasticity, E. Stress–strain bends of different materials fluctuate generally, and distinctive tractable tests led on a similar material yield diverse outcomes, contingent on the temperature as an example.

The yield information is regularly a quantitative depiction of how the connected strengths spread all through the structure, bringing about stress, strains and the diversions of the whole structure and every part of that structure.

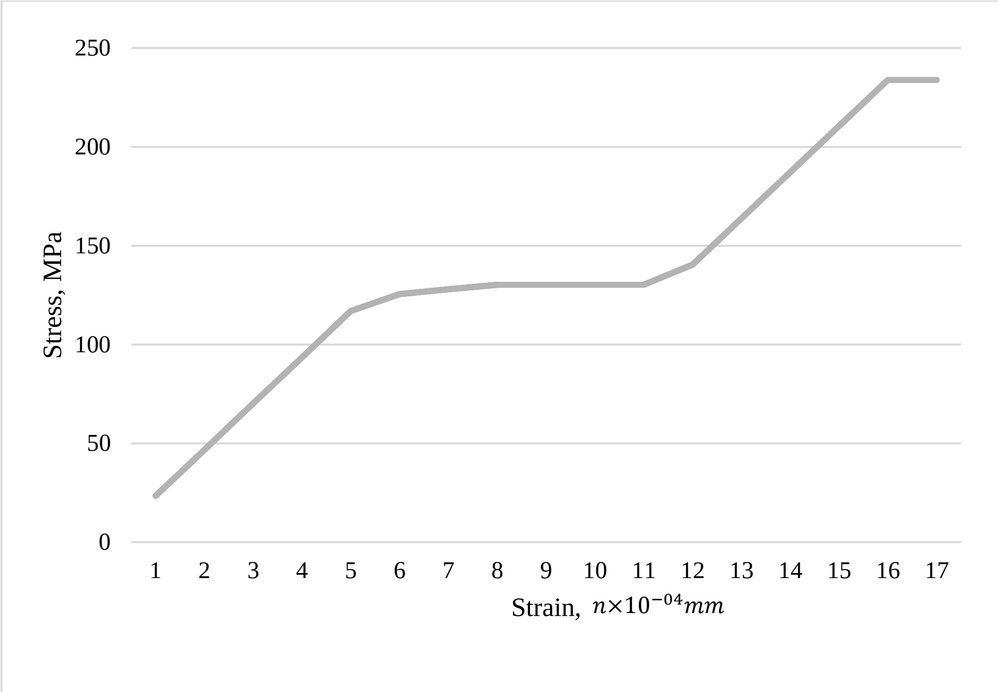


Figure 11 Stress-strain curve for welded part (stainless steel and mild steel combined)

Table 5 stress-strain curve points table for welded part (stainless steel and mild steel combined)

Stress (MPa)	Strain (mm E-04)
23.385	1.07E-04
46.769	2.14E-04
70.154	3.20E-04
93.538	4.27E-04
116.92	5.34E-04
125.56	5.34E-04
127.89	5.34E-04
187.08	8.54E-04
210.46	9.61E-04
233.84	1.07E-03
233.84	1.07E-03

The corresponding values were obtained after applying the load along the axis to the fixed specimen. The ultimate purpose of any analysis is to allow the comparison of the developed stresses and deflections with those that are allowed by the design criteria.

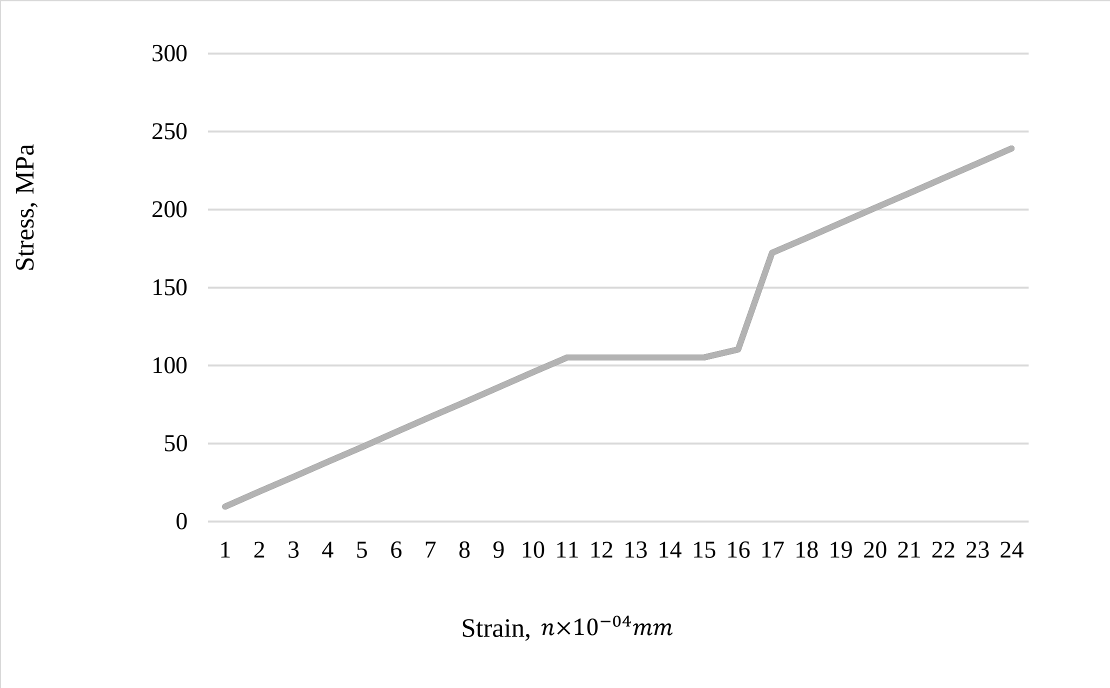


Figure 12 Stress-strain curve for welded part (mild steel)

Table 6 stress-strain curve points table for welded part (mild steel)

Stress (MPa)	Strain (mm E-04)
105.24	4.79E-04
105.24	4.79E-04
105.24	4.79E-04
105.24	4.79E-04
110.224	5.69E-04
172.21	7.84E-04
181.78	8.28E-04
191.35	8.71E-04
200.92	9.15E-04
210.48	9.59E-04
220.05	9.59E-04
229.62	9.59E-04
239.19	9.59E-04

8. Preparation of the specimens

The specimens for the analysis have been made of mild steel and stainless steel. A long round bars of mild steel and stainless steel have been cut into pieces of length and using the lathe machine it is reduced to smaller dimensions using turn operation. After fabricating it to proper dimension, the specimen was drilled to required diameter using a drill bit. The wall thickness of the specimen is 2.2 mm and diameter of the specimen is 21 mm shown in the figure 4. The specimen comprises two parts which are made of stainless steel and mild steel and the tube diameter ism15.6 mm. The total length of the specimen is 150 mm. Finally, the specimens have been welded using different filler materials: 316, 308 and E70-s2.

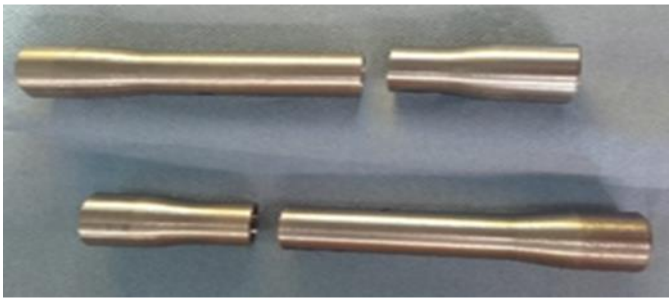


Figure 13 Specimens: – prior to welding

The two parts of the specimen shown in the figure 13 have been joined by welding by Tungsten arc welding using the filler material and welding machine MAGNUM TIG THF 336 PULSE AC/DC. The welding cur-rent was 101 A and voltage during welding was 16.5V - 17V and was kept constant during the welding of the other specimens. The torch was maintained at an angle between 90 degrees and was guided towards the welding direction. The filler wire was fed at an angle of 20 degree to the base material. The filler material was kept close to the gas flow near the nozzle [12].

Figure 14 Specimens after the welding

Similarly, the mild steel specimens have been welded using E 70s2 filler material, whereas stainless steel specimens have been welded using 308 filler material. The components made of mild steel and stainless steel have been joined by welding using 316l filler material. The specimens welded of stainless steel are shown in the figure 14. The properties of used filler materials are given in Table 7 and welding parameters like current, voltage and diameter of the welding wire are presented in Table 8.

Figure 15 TIG welding machine used for welding

Table 7 Mechanical properties of filler material [16]

Filler material	Tensile strength, MPa	Yield strength, MPa	Elongation, %
E70 S-2	516	441	24
308l	600	393	34
316l	540	400	38

Table 8 Welding parameters [16]

Filler material	Wire diameter, mm	Amp DCSP, A	Voltage, V
E70 – S2	3.0-4.5	101	16.5 -17
308l	1/16	101	16.5-17
316l	1/16	101	16.5-17

9. Experimental setup

The most widely recognized sort of test used to quantify the mechanical properties of a material is the Tension Test. Strain test is generally used to give an essential plan data on the quality of materials and is an acknowledgment test for the of materials. The significant parameters that portray the anxiety strain bend acquired amid the pressure test are the rigidity (UTS), yield quality or yield point (σy), versatile modulus (E), percent extension (ΔL%) and the lessening in zone (RA%). Strength, Resilience, Poisson's proportion (ν) can likewise be discovered utilizing this testing procedure [14].

9.1 Procedure followed during the test

Before conducting the test

1. Mark the specimen length

2.The gage length and diameter should be measured using any measuring device.

3.The tensile strength of the specimen should be known before conducting the test.

Step to be followed during the test.

1. During the fracture of the specimen record the load applied

2. Perform the test until the specimen is broken.

Steps to be followed conducting the test

1.Using the measuring device measure the length and diameter of the specimen.

9.2 Tensile testing

The tensile test has been used to measure the mechanical properties of the stainless steel and mild steel specimens. Figure 16 shows the tension-compression machine along with the specimen fixed inside the gripper. The central part of the specimen is important. This part is called the gauge section and has the reduced cross-section area if compared to the ends of the specimen which are used to grip the specimen in the figure 16.

Figure 16 The specimen fixed in the tension-compression machine

The gauge length of the specimen was denoted to be able to define the elongation length after the test. The initial length and diameter were measured. The tensile strength of the stainless steel and mild steel is known. The test was conducted until the breaking point. After the test the neck of the specimen is measured as well as the length of the specimen. In Figure 17 the specimen after the tensile test is shown.

Figure 17 Specimen after the tensile test

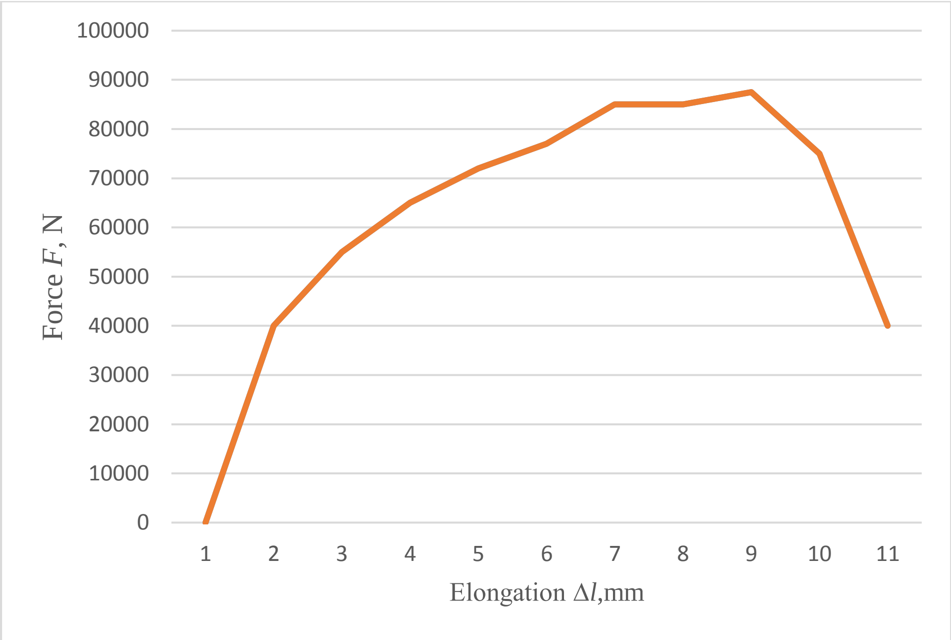


Figure 18 Engineering curve of welded stainless steel specimen

The procedure is repeated for the second time to test the second welded specimen where stainless steel and mild steel welded together using the filler material 316l. The reading is taken and the graph is plotted. The strength and the mechanical properties of two different specimens is noted.

Table 9 The results of the tensile testing stainless steel

Force, N	Elongation Δl, mm
0	0.0
40000	1.0
55000	2.0
65000	3.0
72000	4.0
77000	5.0
85000	5.5
85000	6.0
87500	6.8
75000	7.1
40000	8.0

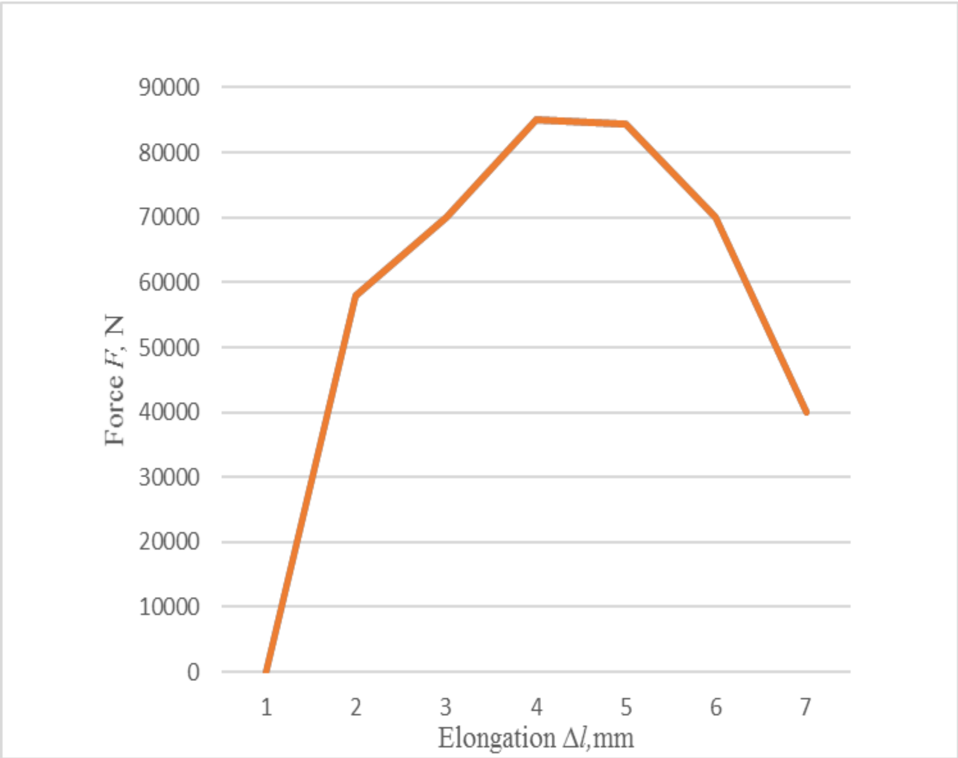


Figure 19 Engineering curve of welded specimen (stainless steel and mild steel combined)

During the test the maximum load was measured and the test was conducted until the fracture. The readings were taken at regular intervals and used in the engineering curve shown in the figure 18.

The change in length of the specimen was also measured and shown in the Table 9. Similarly, for the welded specimen stainless steel and mild steel combined readings were taken shown in the Table 10. The force and length of the specimen data were used for the engineering curve shown in the figure 19.

Table 10 Tensile test results -stainless steel and mild steel combined

Force *F*, N	Elongation *Δl*, mm
0	0.0
58000	1.0
70000	2.0
85000	3.0
84500	3.2
70000	4.0
40000	4.4

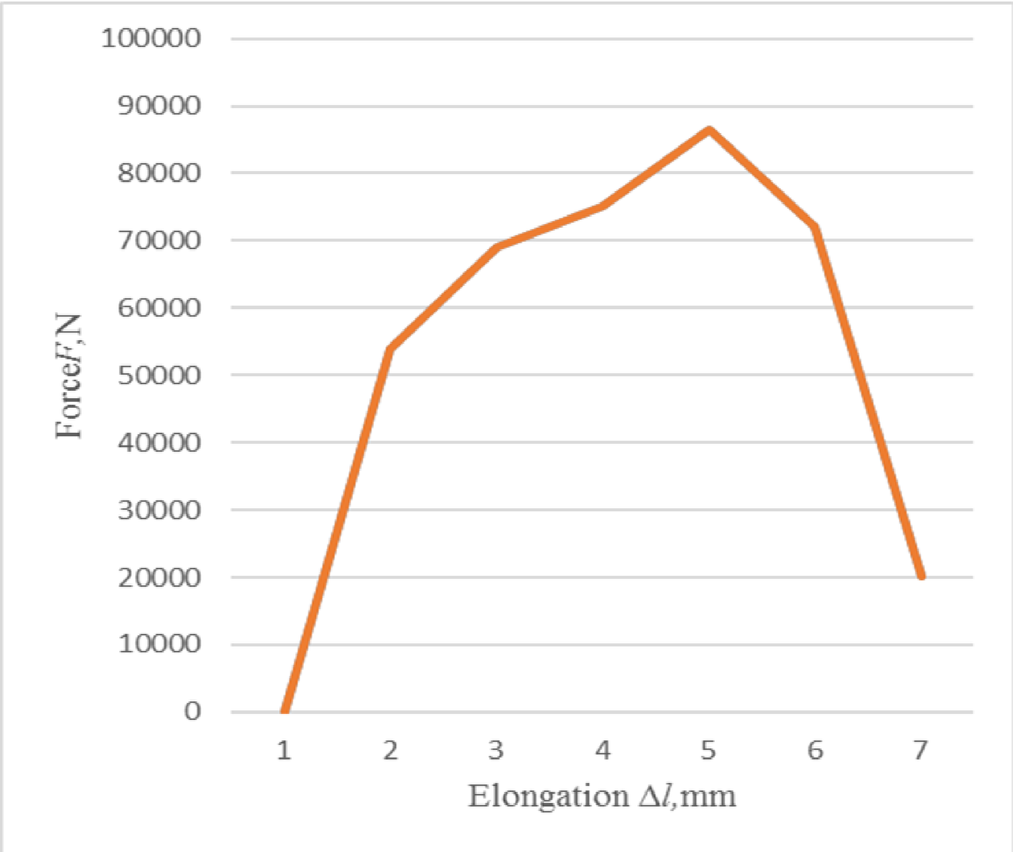


Figure 20 Engineering curve of welded specimen (stainless steel and mild steel combined)

The procedure is repeated for the Third time to test the next welded specimen where stainless steel and mild steel welded together using the filler material 316l. The reading is taken and the graph is plotted shown in the figure 20. The strength and the mechanical properties of two different specimens is noted.

Table 11 Tensile test results stainless steel and mild steel

Force *F*, N	Elongation *Δl*, mm
0	0.0
54000	1.0
69000	2.1
75000	3.0
86500	3.7
72000	4.0
20000	4.4

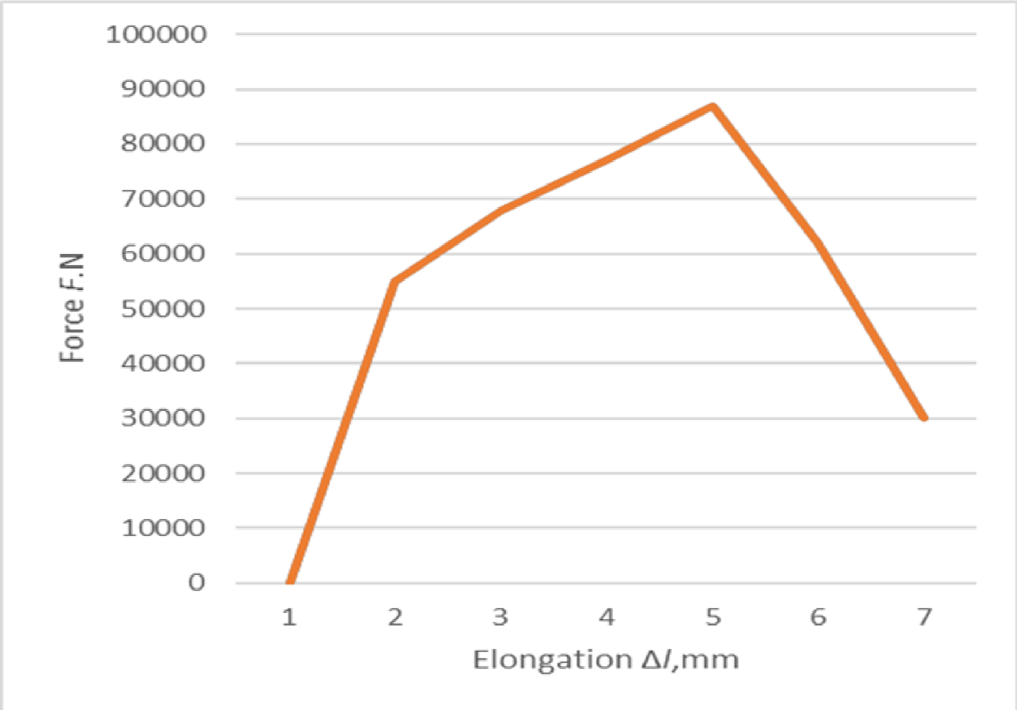


Figure 21 Engineering curve of welded specimen (mild steel)

The change in length of the specimen was also measured and shown in the Table 11. Similarly, for the welded specimen (stainless steel and mild steel combined) readings were taken shown in the Table11. The force and length of the specimen data were used for the engineering curve shown in the figure 20.

The procedure is repeated for the fourth time to test the next welded specimen (mild steel). The filler material used here is E70s2. The reading is taken and the graph is plotted. The strength and the mechanical properties is noted and shown in the figure 21.

Table 12 Tensile test results mild steel

Force *F*, N	Elongation *Δl*, mm
0	0.0
55000	1.1
68000	2.2
77000	3.0
87000	4.7
62000	5.5
30000	6.4

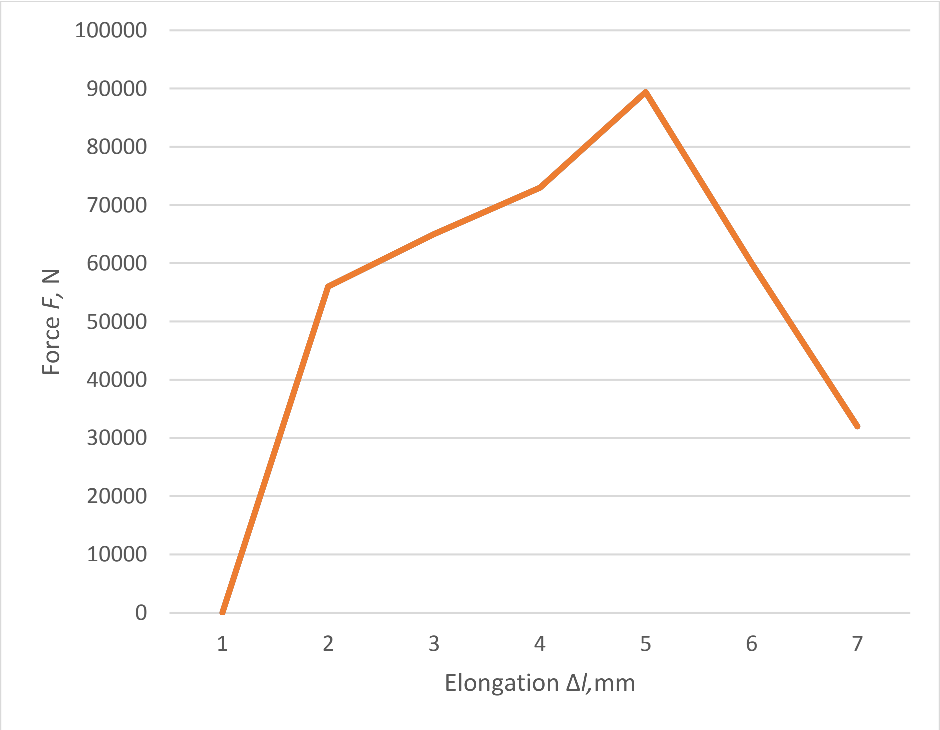


Figure 22 Engineering curve of welded specimen (stainless steel)

The change in length of the specimen was also measured and shown in the Table 12. Similarly, for the welded specimen (mild steel) readings were taken shown in the Table 12. The force and length of the specimen data were used for the engineering curve shown in the figure 21.

The procedure is repeated for the fifth time to test the next welded specimen (stainless steel). The filler material used here is 308. The reading is taken and the graph is plotted. The strength and the mechanical properties is noted.

Table 13 Tensile test results stainless steel

Force *F*, N	Elongation *Δl*, mm
0	0.0
56000	1.0
65000	2.4
73000	3.3
89400	4.2
60000	5.0
32000	5.8

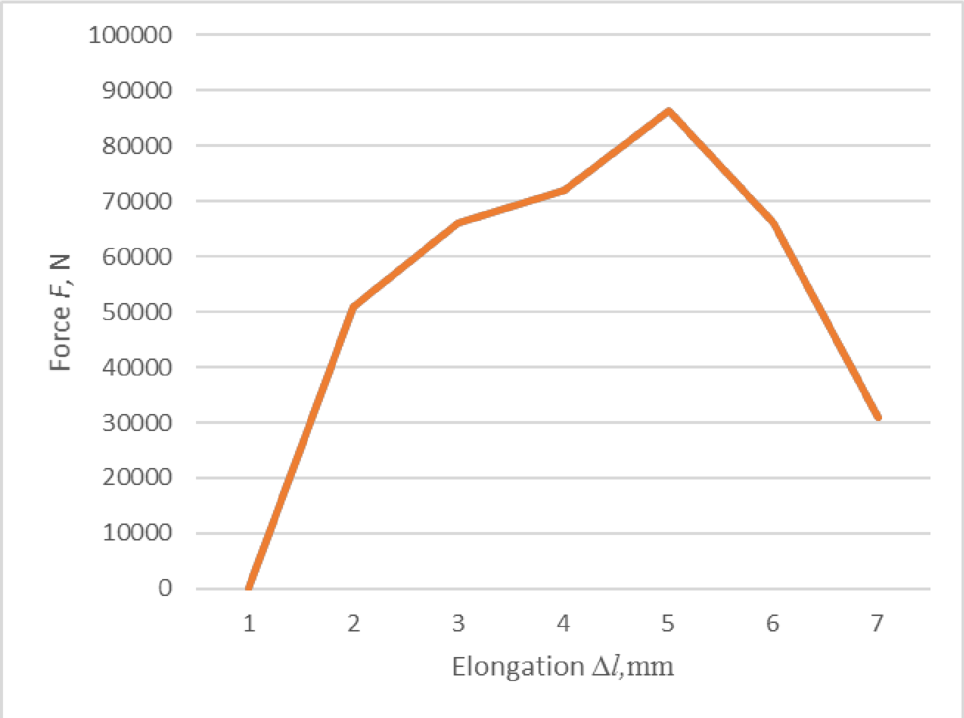


Figure 23 Engineering curve of welded specimen mild steel

The change in length of the specimen was also measured and shown in the Table 13. Similarly, for the welded specimen (stainless steel) readings were taken shown in the Table 13. The force and length of the specimen data were used for the engineering curve shown in the figure 22.

The procedure is repeated for the sixth time to test the next welded specimen (mild steel). The filler material used here is E70s2. The reading is taken and the graph is plotted. The strength and the mechanical properties is noted.

Table 14 Tensile test results mild steel

Force *F*, N	Elongation *Δl*, mm
0	0.0
51000	1.6
66000	2.3
72000	3.0
86400	3.5
66000	4.0
31000	4.6

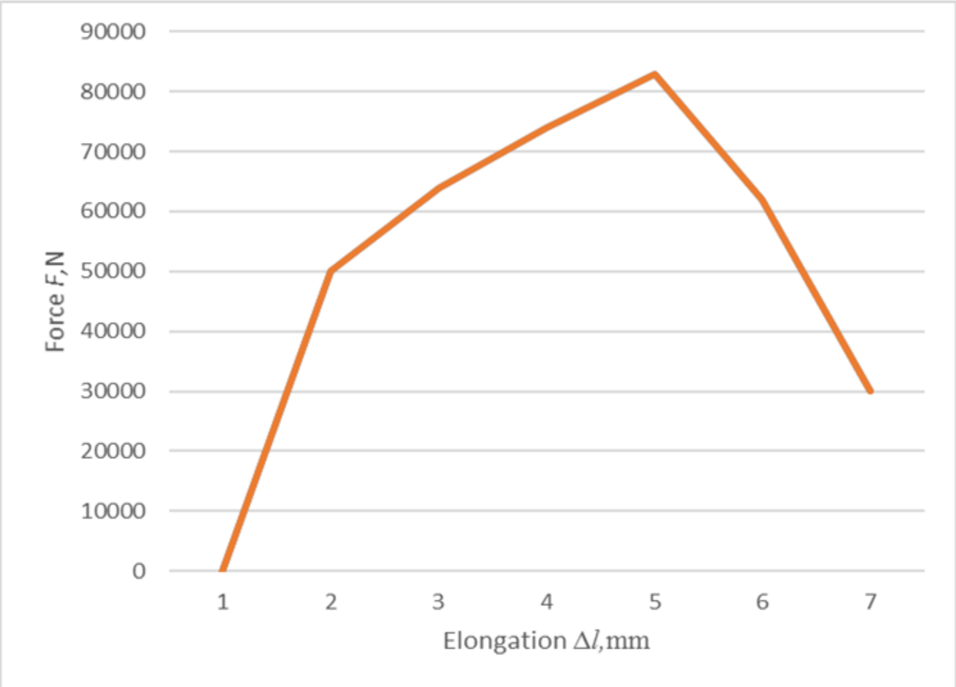


Figure 24 Engineering curve of welded specimen (stainless steel and mild steel combined)

The change in length of the specimen was also measured and shown in the Table 14. Similarly, for the welded specimen (mild steel) readings were taken shown in the Table 14. The force and length of the specimen data were used for the engineering curve shown in the figure 23.

The procedure is repeated for the seventh time to test the next welded specimen where stainless steel and mild steel welded together using the filler material 316l. The reading is taken and the graph is plotted. The strength and the mechanical properties of two different specimens is noted.

Table 15 Tensile test results stainless steel and mild steel combined

Force *F*, N	Elongation *Δl*, mm
0	0.0
50000	1.0
64000	1.8
74000	2.4
82800	3.1
62000	3.4
30000	4.1

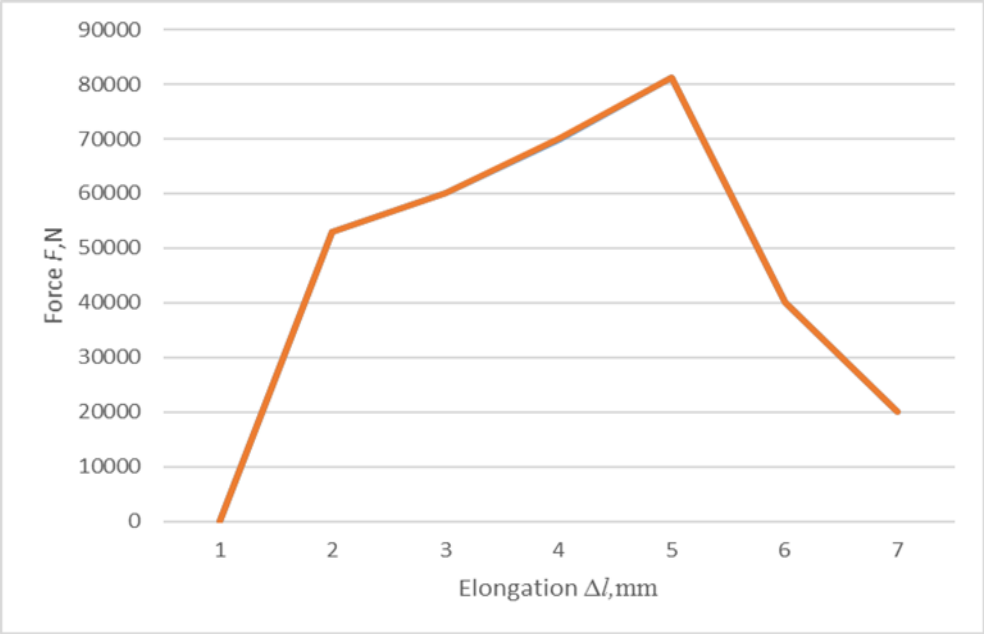


Figure 25 Engineering curve of welded specimen (Stainless steel)

The change in length of the specimen was also measured and shown in the Table15. Similarly, for the welded specimen (stainless steel and mild steel combined) readings were taken shown in the Table 15. The force and length of the specimen data were used for the engineering curve shown in the figure 24.

The procedure is repeated for the eight time to test the next welded specimen (Stainless steel). The filler material used here is 308. The reading is taken and the graph is plotted. The strength and the mechanical properties is noted.

Table 16 Tensile test results stainless steel

Force *F*, N	Elongation *Δl*, mm
0	0.0
53000	2.2
60000	3.5
70000	5.6
81200	6.3
40000	7.1
20000	8.3

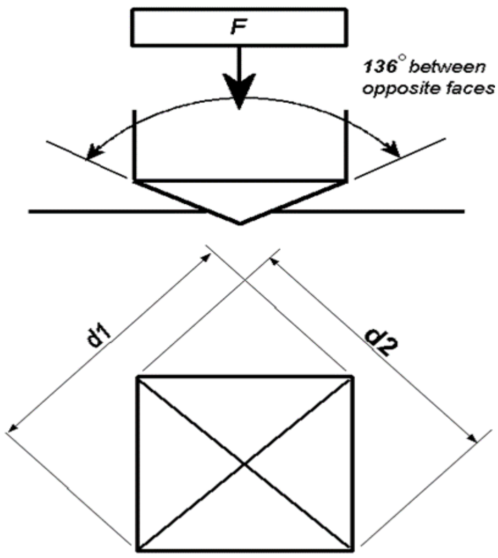
The change in length of the specimen was also measured and shown in the Table 16. Similarly, for the welded specimen (stainless steel) readings were taken shown in the Table 16. The force and length of the specimen data were used for the engineering curve shown in the figure 25.

10. Vickers hardness test

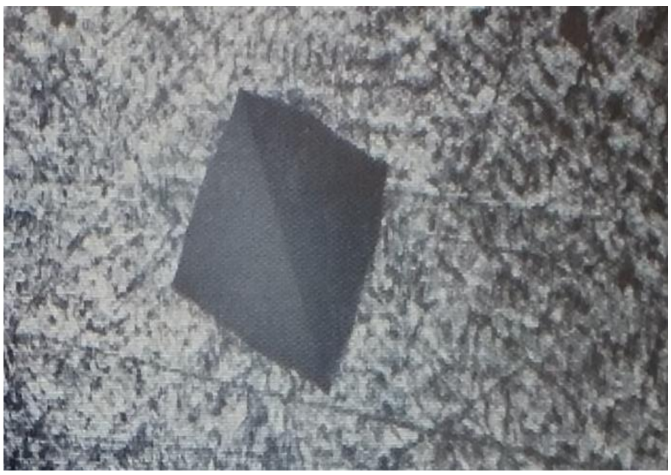
The Vickers hardness test is one of the hardness testing method like Brinell hardness testing method. In this method indenting the specimen or material using diamond shape indenter which has a square base, pyramid shape with opposite side facing with an angle subjected to 136 degree. The load generally applied on the specimen is between 1gf to 90kgf. In this test the force or the load is applied for 5 seconds to 10 seconds. The hard ness is obtained by dividing the area with the corresponding load applied [17,18]. The load applied here is smaller than that of Brinell hardness test. Vickers hardness test is versatile any type of materials. All types of victors' method can be tested since there is only one intender is present. Nondestructive can also be done, even for conducting other test methods the specimen can be used. The main disadvantage in the testing method is that the surface quality should be good and clean without any impurities otherwise it is very difficult for measuring the area of the intender where the load is applied [17,18].

The time taken to complete the test is slow when compared to Rockwell or Brinell hardness test because the cycles are between 25 to 60 seconds. But here when conducting the test the cycle was between 5 to

10 seconds. The force or load applied here was 5kgf for all the three specimens 1. Stainless steel 2. Mild steel 3. Stainless steel and mild steel combined which was sufficient load for obtaining the results for knowing the quality of weld.



a)



b)

Figure 26 a) Diamond shape intender and b) Microscopic view of the specimen

The time taken to complete the test is slow when compared to Rockwell or Brinell hardness test because the cycles are between 25 to 60 seconds. But here when conducting the test the cycle was between 5 to 10 seconds. The force or load applied here was 5kgf for all the three specimens 1. Stainless steel 2. Mild steel 3. Stainless steel and mild steel combined which was sufficient load for obtaining the results for knowing the quality of weld.

10.1 Procedure followed during the test

In Vickers testing it is very important to prepare and clean the specimen and no dust particles or impurities should be present.

1. An abrasive sheet should be used to rub the surface in order make it smoother.
2. The surface should be cleaned with chemical solution to remove the impurities
3. The specimen should be clamped precisely and tightly under the microscope for clear view of the specimen
4. During the test the machine should not be disturbed.

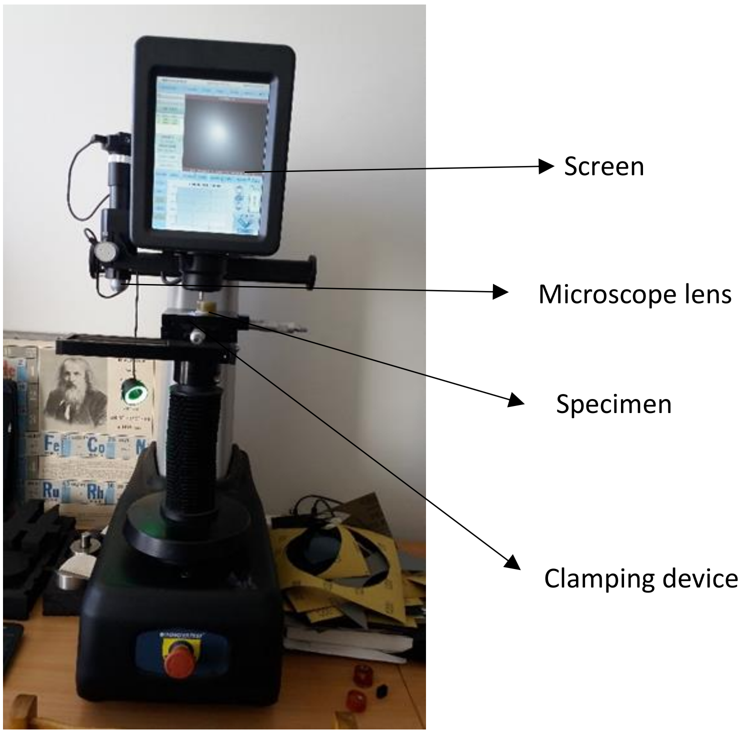


Figure 27 Vickers hardness testing machine

10.2 Hardness testing method

The specimen is rubbed against the abrasive sheet firmly for smooth surface. Then on top of the specimen certain chemicals are added to make the top view of the specimen clearer. Then the specimen is rubbed using cotton material to remove the dust and other impurities. The specimen is fixed firmly under a clamping device. The view of the specimen is magnified and adjusted per the view on the screen. The force applied here is 5kgf. After selecting the load the clamp is moved to the other end for testing the specimen. The start button is selected on the screen. The intender applies the load on the specimen for a cycle time of 5 seconds. After the load is applied on the specimen move the clamp to the other end for measuring the area. The adjustable screw is used to get a clear view of load applied. Using the key board select the area to calculate the hardness automatically. After the getting the hardness value the procedure is repeated for 20 intervals i.e. across the specimen. The test is completed and the graph is obtained for three different specimens.

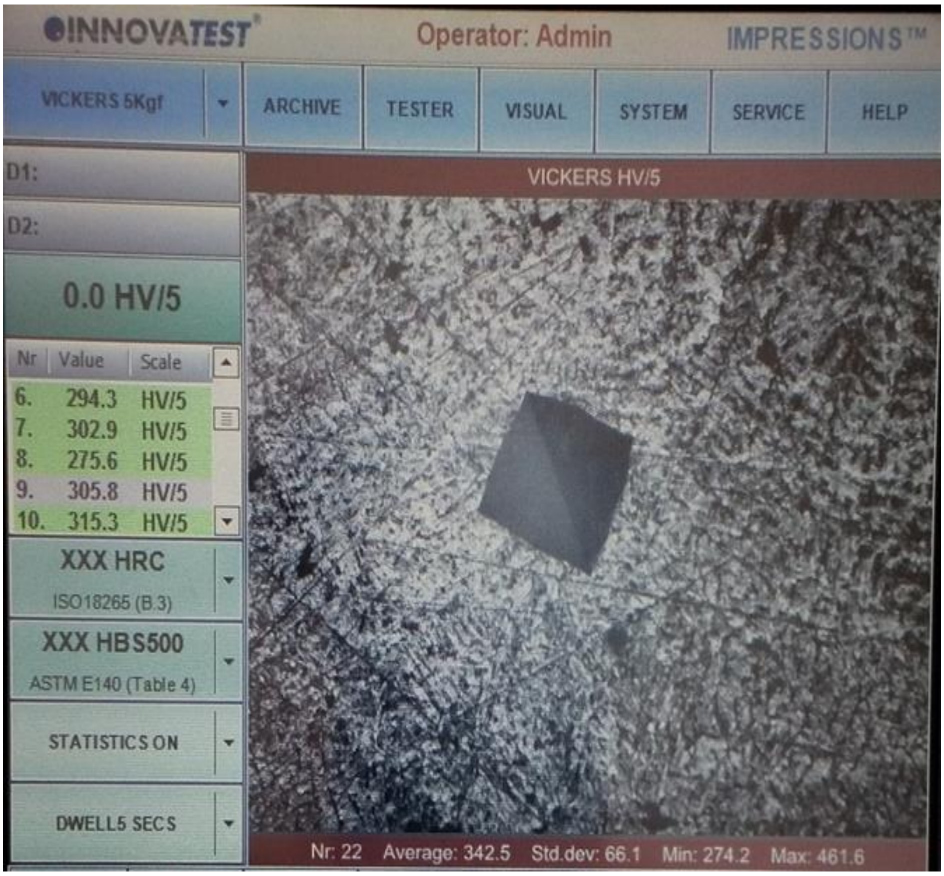


Figure 28 Vickers hard ness test result on the screen.

Since the hardness value is calculated automatically after measuring the size of the diamond intender as shown in the figure 28. For stain steel, welded specimen, the number of measurements taken was 21. The minimum hardness value was 277.3 and the maximum hardness value was 346.5 and average hardness value was 301.6. The standard deviation was 18.0. The diameter d1 and d2 for each measurement was taken and shown in the table 17. Graph was plotted and shown in the figure 29. For stainless steel and mild steel combined the minimum the hardness value was 243.7 and the maximum hardness value was 341.7. the standard deviation was 28.6. the diameter d1 and d2 was noted down and shown in the table 19. Graph was plotted using the values and shown in the figure 31. For mild steel the minimum and maximum value was 461.6 and 274.2. The average hardness value was 342.5. the corresponding values are shown in the table 18 and the graph is shown in the figure 30.

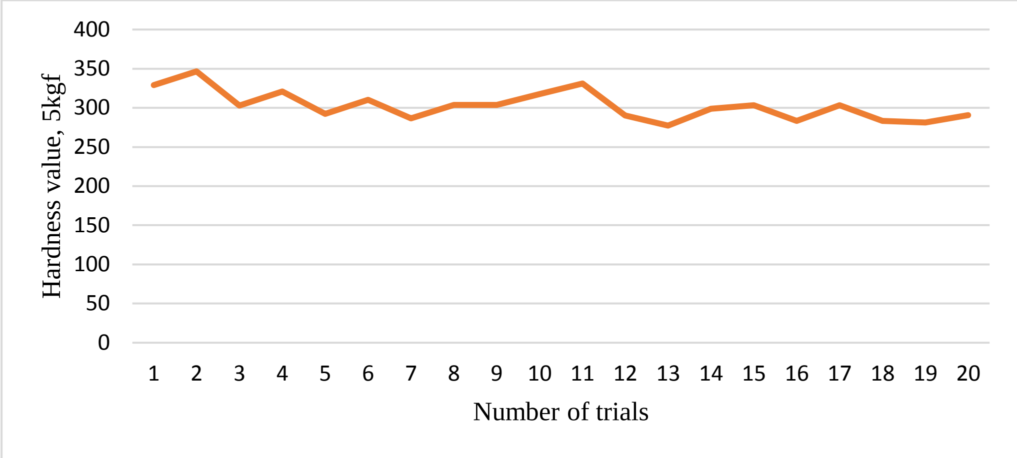


Figure 29 Hardness value- stainless steel

Table 17 Hardness value- stainless steel

No. of Trials	Hardness value, 5kgf	D1 (mm)	D2 (mm)
1	328.9	0.1779	0.1578
2	346.5	0.1617	0.1653
3	302.9	0.1751	0.1745
4	320.8	0.171	0.1689
5	292.2	0.183	0.1731
6	310.3	0.1664	0.1793
7	286.7	0.184	0.1756
8	303.8	0.1802	0.1692
9	303.9	0.1824	0.1669
10	317.5	0.173	0.168
11	330.9	0.1772	0.1576
12	290.2	0.1782	0.1792
13	277.3	0.1867	0.179
14	298.8	0.1774	0.1749
15	303.1	0.1652	0.1646

Hardness value of the welded region

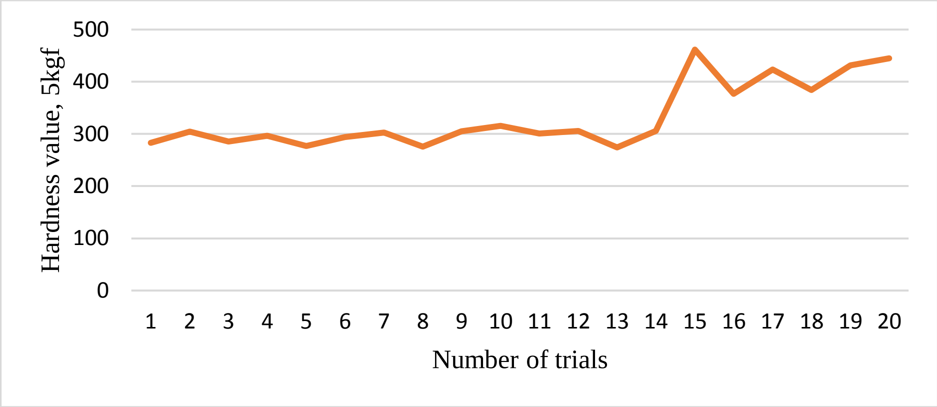


Figure 30 Hardness value- mild steel

Table 18 Hardness value- mild steel

No. of Trials	Hardness value, 5kgf	D1 (mm)	D2 (mm)
1	283.1	0.1773	0.188
2	304.7	0.1785	0.1704
3	285.7	0.1829	0.1774
4	296.5	0.1821	0.1716
5	277.1	0.1794	0.18
6	294.3	0.1748	0.1802
7	302.9	0.1717	0.1782
8	275.6	0.1816	0.1852
9	305	0.1746	0.1737
10	315.3	0.1717	0.1712
11	301.1	0.1736	0.1773
12	306	0.1736	0.1742
13	274.2	0.1852	0.1826
14	305.6	0.1751	0.1732
15	461.6	0.143	0.1405
16	376.7	0.157	0.1567
17	423.7	0.1469	0.149
18	384.3	0.1552	0.1554
19	431.5	0.1474	0.1457
20	445	0.1424	0.1463

Hardness value of the welded region

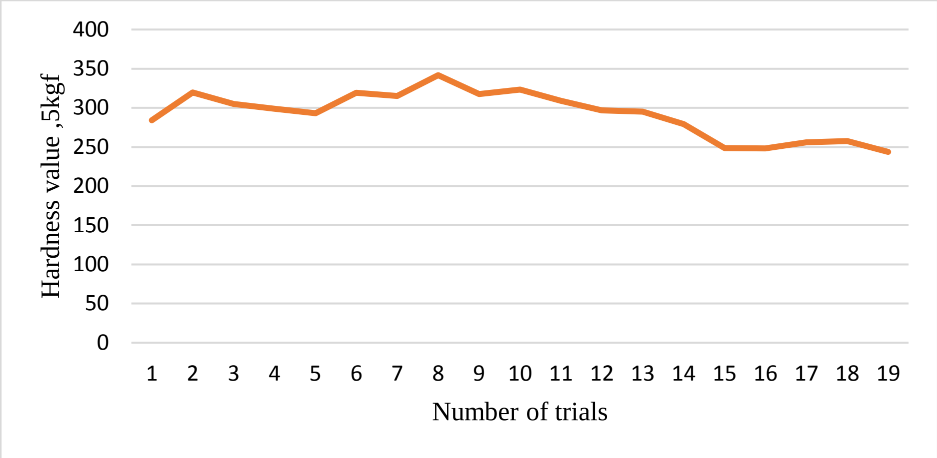


Figure 31Hardness value- stainless steel mild steel combined

Table 19 Hardness value- stainless steel mild steel combined

No. of trials	Hardness value, 5Kgf	D1 (mm)	D2 (mm)
1	284	0.1724	0.1889
2	319.5	0.1647	0.1759
3	305	0.1661	0.1826
4	298.9	0.1677	0.1845
5	293.2	0.1652	0.1904
6	319.1	0.1631	0.1778
7	315.1	0.1657	0.1773
8	341.7	0.1549	0.1746
9	317.5	0.1643	0.1775
10	323.4	0.1626	0.176
11	309.2	0.1648	0.1715
12	296.6	0.1651	0.1885
13	295.2	0.162	0.1925
14	279.4	0.1721	0.1921
15	248.7	0.183	0.2031
16	248.2	0.1783	0.2083
17	256	0.1768	0.2038
18	257.7	0.1802	0.1992

Hardness value of the welded

11. Micro structure analysis

The main purpose of microstructure analysis is to detect any defects in the material used for analysis. The relation between the material property and microstructure is determined by the defects in the microstructure. In this analysis, there are three sample materials namely mild steel, stainless steel and combination of mild steel and stainless steel. The main purpose this experiment is to visually inspect the grain structure of the specimen mainly in the weld region to understand the property of the material. For this microstructure analysis, electronic microscope was used to accurately inspect the microstructure visually and precisely [19,20].

11.1 Preparing the specimen

The from the tensile test the welded region of the specimen is cut into pieces using metal cutting machine and noted down. Then the specimen is placed in circular plastic cap covering it with the plastic cover. Each specimen from different material is placed inside the cap and filled with polythene solution and left to solidify as shown in the figure 32.

a) b) c)

Figure 32- Specimen for microstructure analysis a) stainless. b) mild steel c) stainless steel and mild steel combined

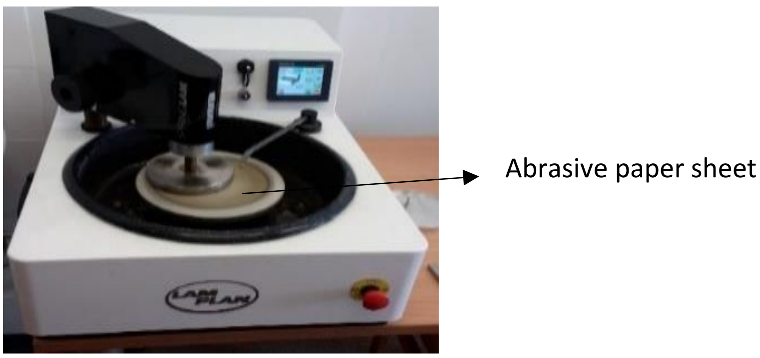


Figure 33 polishing machine

The specimen is solidified and taken for polishing for getting clear view. The three specimens are simultaneously fixed inside the polishing machine as shown in the figure 33. For polishing the specimen, three abrasive paper sheets were used. The specimens were cleaned with nitric acid which contains 3%

of spirit as shown in the figure 34. Then specimens are fixed in a clay for placing it in the microscope or analysis as shown in the figure.

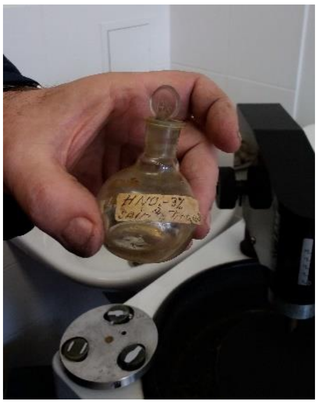


Figure 34 Nitric acid for cleaning the specimen

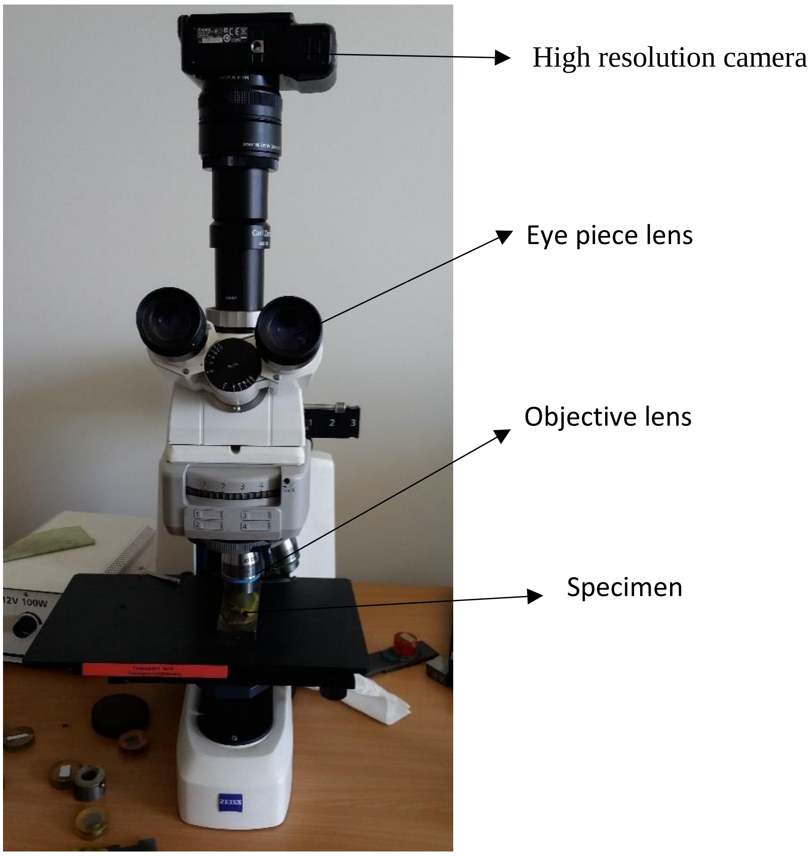
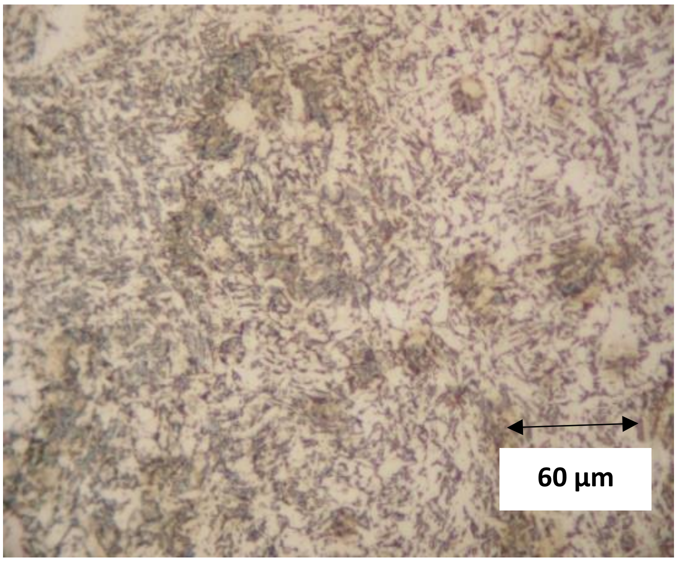


Figure 35 Electronic microscope

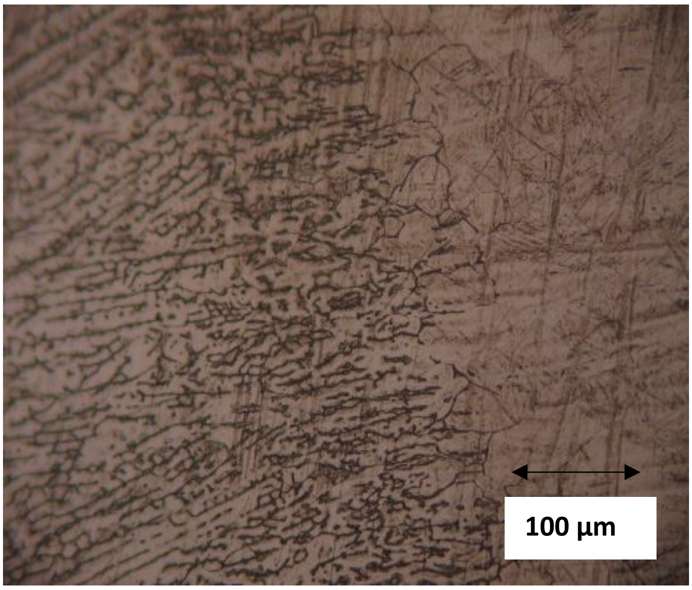
11.2 Experimental procedure

The specimen used here are stain- less steel, mild steel, stain less steel and mild steel combined and the equipment used to test these specimens are Electron microscope, specimen press and slide with clay to fix the specimen. The specimen is pressed firmly on the clay slides using the specimen presser and mounted on stand of the microscope to have an even horizontal level. The power supply is switched on to better brightness view on the specimen through the microscope. There are two knobs i.e. for fine and course adjustment for zooming the specimen and viewed simultaneously to get a better view through the microscope. Observation are made after getting a clear view through different magnifying lens. These images of the specimen are saved using high resolution camera shown in the figure 36, figure 37, figure 38. The microstructure of the specimen looked like shown on the figure of using different magnification lens.



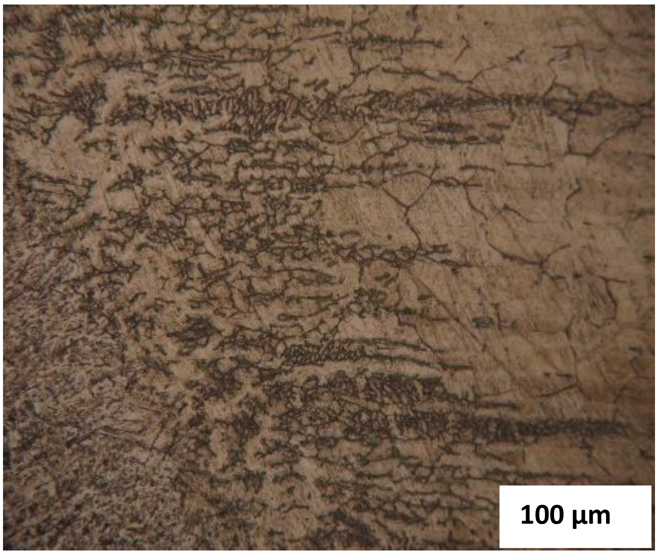
a)

Figure 36 Micro structure of stainless steel a) 50x-100 µm view of the microstructure.



a)

Figure 37 Microstructure of mild steel a) 20x -100 µm view of the microstructure -weld region.



a)

Figure 38 Microstructure of stainless steel and mild steel combined a) 20x- 100 µm view of the microstructure- weld region.

Discussion

The microstructure of the stainless steel is shown in the figure 36. This is a coarse-grained structure as shown in the figure 36-a. The heated effected zone is also seen in the figure 36- a where the magnification is 50 times than the other two images. The microstructure of the mild steel is shown in the figure 37. This is also coarse grained structure as shown in the figure 37-a. The microstructure of the weld region is well bonded with the parent material as shown in the figure 37-a. The bonding of the structure between the filler material and parent material is shown in the figure and is strong when compared to stainless steel and stainless steel- mild steel combined. The microstructure of the stainless steel and mild steel is shown in the figure 38. The bonding of the structure between the filler material and parent material is shown in the figure 38-a and is not strong when compared to stainless steel and mild steel.

Conclusion

1. The welding process in different materials and defects in exhaust pipes were analysed through patents, scientific articles, journals.

2. The finite element analysis showed, that in the mild steel specimen the maximum stress acting on the welded area is $\sigma_{\max} = 239.19$ and relatively high stress is occurring if compared to the other considered specimen model with different properties. The analysis showed, that maximum elastic strain in the mild steel and stainless steel combined specimens is $\varepsilon = 1.07e^{-03}$ and relatively large deformation is occurring if compared to the other considered specimen model with different properties.

3. The tensile test of the welded specimens, made of stainless steel and welded using 308l filler material, showed that breaking point was at 87500 N, 89400 N, 84900 N respectively. The welded specimens, made of mild steel using filler material E70s2 showed that breaking point was at 87000 N, 86700 N respectively and welded specimens made of stainless steel and mild steel combined using filler material 316 was at 86500 N, 84500 N, 82800 N respectively. From Experimental results confirmed that stainless steel specimen is stronger than the specimen, made of stainless steel and mild steel combined and mild steel alone. But when we compare all the value it shows the breaking point was between 82800 N and 89000 N therefore all the specimen made from different materials are considerably strong.

4. The material quality is determined by the hardness testing. The Vickers hardness test was conducted for three different specimen and results were obtained. The hardness value of mild steel was found to be high i.e. max value and min value was 461.6 and 274.2 and the average value was 342. The hardness value of stainless steel was 346.5 max and 277.3 min and average is found 301.6 and the lowest found to be stainless steel and mild steel combined tube maximum at 341.7 and min at 243.7 and average is 292.2. Therefore, mild steel and stainless steel will be suitable for performing intended application.

5. The microstructure of three different specimens were analysed. From the analyses the mild steel and stainless steel has coarse grained structure than stainless steel and mild steel combined. Therefore, these two specimens are tougher and stronger than the other material. i.e. stainless steel and mild steel combined.

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APPENDIXES

22nd International Scientific Conference "MECHANIKA-2017"

19 MAY 2017, BIRŠTONAS, LITHUANIA

CERTIFICATE

Chinnappa Shanmugam Vijayramachandhar

Kaunas University of Technology

attended the Conference

Kaunas University of Technology

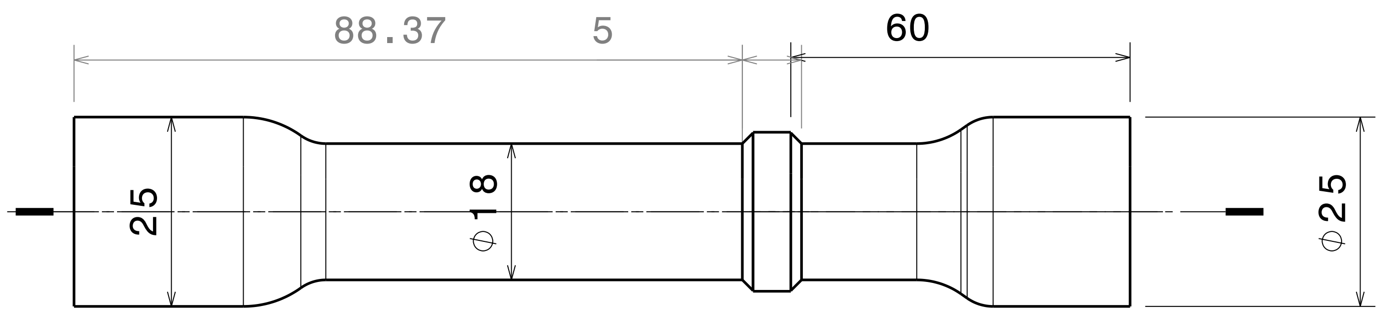
Lithuanian Academy of Science

IFToMM National Committee of Lithuania

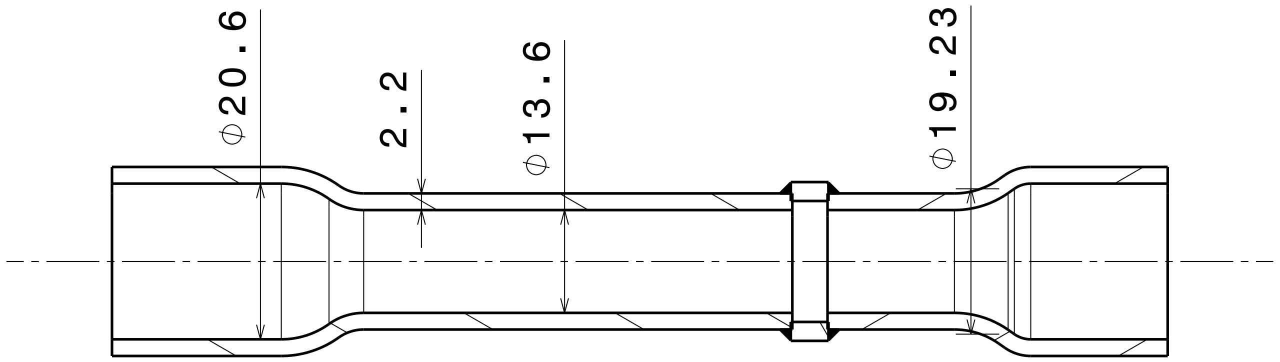
Baltic Association of Mechanical Engineering

Scientific Secretary of the Conference

Saulius Diliūnas



Front view
Scale: 1:1



Section view A-A
Scale: 1:1

SPECIMEN MODEL

MATERIAL- STAINLESS STEEL 304

MILD STEEL 1018

WALL THICKNESS = 2.2mm

TOLERANCE = +/_ 0.5mm