Analysis of fracture point of notched specimen of Aluminum 1050/T6 alloy using multiple parameters.

Author

ASIM LATIF

Regn Number

00000172283

Supervisor

Dr. HUSSAIN IMRAN

DEPARTMENT OF DESIGN AND MANUFACTURING ENGINEERING

SCHOOL OF MECHANICAL & MANUFACTURING ENGINEERING

NATIONAL UNIVERSITY OF SCIENCES AND TECHNOLOGY

ISLAMABAD

September, 2019


بسم الله الرحمن الرحيم

Analysis of fracture point of notched specimen of Aluminum 1050/T6 alloy using multiple parameters.

Author

ASIM LATIF

Regn Number

MS-DME-00000172283

A thesis submitted in partial fulfillment of the requirements for the degree of

MS Design and Manufacturing Engineering.

Thesis Supervisor:

Dr. HUSSAIN IMRAN

Thesis Supervisor's Signature: ________________________________

DEPARTMENT OF DESIGN AND MANUFACTURING ENGINEERING

SCHOOL OF MECHANICAL & MANUFACTURING ENGINEERING

NATIONAL UNIVERSITY OF SCIENCES AND TECHNOLOGY,

ISLAMABAD

THESIS ACCEPTANCE CERTIFICATE

Certified that final copy of MS/MPhil thesis Written by Mr. Asim Latif (Registration No: 00000172283), of SMME (School of Mechanical and Manufacturing Engineering) has been vetted by undersigned, found complete is all respects as per NUST Statutes/ Regulations, is free of plagiarism, errors and mistakes and is accepted as partial fulfillment for award of MS/MPhil Degree. It is further certified that necessary amendments as pointed out by GEC members have also been incorporated in this dissertation.

Signature: ________________________________

Name of the supervisor: Dr. Hussain Imran

Dated: _________________

Signature (HOD): __________________________

Dated: ____________________

Signature (Principal): _______________________

Dated: __________________

FORM TH-4

MASTER THESIS WORK

We hereby recommend that the dissertation prepared under our supervision by: Asim Latif 00000172283 Titled: "Analysis of fracture point of notched specimen of Aluminum 1050 alloy using multiple parameters" be accepted in partial fulfillment of the requirements for the award of MS Design and Manufacturing Engineering degree with (…….) grade.

Examination Committee Members

1. Name Dr.Mushtaq Khan Signature:________________

2. Name: DrShahidIkramUllah Signature:________________

3. Name: Engr. M. Naveed Hassan (MRC) Signature:________________

Supervisor's name: Dr. Hussain Imran Signature:________________

Date:____________________

____________________ Date:____________________

Head of Department

COUNTER SIGNED

____

Date:___________ Dean/Principal

Declaration

It is certify that this research work titled "*Analysis of fracture point of notched specimen of Aluminum 1050/T6 alloy using multiple parameters*" is my own work. The work has not been presented elsewhere for assessment. The material that has been used from other sources. It has been properly acknowledged / referred.

Signature of Student

ASIM LATIF.

2016-NUST-MS-DME-00000172283.

Plagiarism Certificate

It is certified that MS Thesis Titled "*Analysis of Fracture point of notched specimen of Aluminum 1050/T6 alloy using multiple parameter.*" by Asim Latif has been examined by us. We undertake the follows:

a) Thesis has significant new work/knowledge as compared already published or are under consideration to be published elsewhere. No sentence, equation, diagram, table, paragraph or section has been copied verbatim from previous work unless it is placed under quotation marks and duly referenced.

b) The work presented is original and own work of the author (i.e. there is no plagiarism). No ideas, processes, results or words of others have been presented as Author own work.

c) There is no fabrication of data or results which have been compiled/analyzed.

d) There is no falsification by manipulating research materials, equipment or processes, or changing or omitting data or results such that the research is not accurately represented in the research record.

e) The thesis has been checked using TURNITIN (copy of originality report attached) and found within limits as per HEC plagiarism Policy and instructions issued from time to time.

Signature of Student

Asim Latif

2016-MS-DME-00000172283

Signature of Supervisor

Copyright Statement

Acknowledgements

First and foremost, I would like to thank Allah Almighty who always helped me throughout my life and to get through this research degree and thesis.

I am grateful to my loving parents for all their support and the way they brought me up and made me able to handle all kinds of pressure and helped me through thick and thin. I would like to pay my earnest and honest gratitude to my sister (Late) for her unconditional support, encouragement and prayers.

I would also like to pay debt of gratitude to my advisor Dr. Hussain Imran, for his profound guidance, valuable time, motivation, personal support and encouragement, to complete this research work. Also, extremely grateful to the committee members, Dr. Mushtaq khan (DME), Dr Shahid Ikram Ullah and Engr. Muhammad Naveed Hassan (MRC) for their sincere guidance to complete this research work.

Dedicated to my family especially my sister (Late) whose tremendous support and cooperation led me to this wonderful accomplish.

Abstract

This study examines the fracture point of aluminum alloy samples using multiple parameters conducting tensile test. Suitable base material is selected on the basis of previous studies and tensile test carried on each sample according the Taguchi design of experiments (DOE)using Minitab software. This study also includes the EDS test results which shows the different spectrums and elemental classification of the base material. Double notched specimen was used for examination. Different diameters of holes were designed on each sample according to design of experiment(DOE) so their effect on fracture point and strength can been analyze.

Keywords: Aluminum 1050/T6,EDS Elemental analysis, DOE Taguchi Technique, ASTM Standard, EDM wire cut, CNC machining, blunt notch, tensile testing, UTS value, ANOVA.

Table of Contents

List of Figures

List of Tables

Nomenclature

Symbol	Abbreviation	Symbol	Abbreviation
EDS	Energy dispersal x-ray spectroscopy	K	Potassium
CNC	Computer Numeric Control	Fe	Iron
EDM	Electro discharge machining	x	Horizontal distance of hole from notch.
UTS	Ultimate Tensile Stress	y	Vertical distance of hole from notch.
mm	Millimeter	d	Diameter of hole
µm	Micrometer	P	Number of factors
Al	Aluminum	L	Number of levels
DOF	Degree of freedom	rpm	Revolution per minute
mm/min	Millimeter per minute	A	Ampere
DOE	Design of Experiment	G	Gauge Length
Mg	Magnesium	W	Width
ASTM	American society for testing and materials	C	Width of grip section
MPa	Mega Pascal	B	Length of grip section
HV	High Voltage	T	Thickness
Gpa	Giga Pascal	KN	Kilo Newton
Ωm	Ohm meter	mm/sec	Millimeter per second
SEM	Scanning Electron Microscope	N/mm^2	Newton per millimeter square
WD	Work Displacement	Seq SS	Sequential sum of squares
BI	Beam Intensity	Adj SS	Adjusted sum of squares
C	Carbon	Adj MS	Adjusted Mean square
O	Oxygen	Si	Silicon

CHAPTER 1:

INTRODUCTION

1.1 Overview :

Fracture point and crack initiation behavior is evaluated in order to prevent the early failure of machine parts, for examples ships and aero planes parts are designed after focusing the crack initiation. It is very important for the maintenance, reliability of machine elements and for the strength of materials.

Various methods has been used for examining the fracture point and crack propagation by researchers [1-5] like method of arresting crack propagation by drilling holes at crack tips [1-3], cold working methods [6-8], and brinell-type indentation to retard the crack propagation [9-10].

In this study the fracture point and timing of failure due to different set of parameters has been examined. Necessary set of parameters are required to reliability for machine elements and crack arresting has been examined using the tensile testing techniques.

Several set of parameters were selected as input and Taguchi DOE (Design of experiment) was used for experiment. According to Design of Experiments, samples were designed for further testing which is discussed below in the Design and Machining chapter.

Aluminum 1050/T6 alloy has been chosen for the experiment as base material because it is widely used in commercial area like ship and marine machine elements, lamp reflectors, cable sheathing, architectural flashing, food industry containers and in many more fields because it is known for the excellent resistance to corrosion and It has high ductility and highly reflective finishing. It contains comparatively low mechanical strength than more significantly alloyed metals. It can be strengthened only by cold working.

1.2 Objectives:

My research work includes

- To analyze the elemental classification of material conducting EDS test.
- To examine the fracture point of material and timing of failure of sample due to crack towards the different arrangement holes.
- To examine a set of parameters, which are reliable for machine elements and crack propagation.

1.3 Approach lead to analysis:

A desired result of an experiment needs a reasoning approach. Approach used in this study is given below at a glance.

According to this approach to conduct an experiment, there were core phases like conducting EDS test of material to analyze the elemental classification of material. EDS test was conducted in USP CASEN, NUST.

Similarly getting design of experiment using Taguchi method. For that purpose, Minitab software was used with different parameter as input and got the Design of Experiment (DOE) which contains an orthogonal L9 array to describe the set of experiment, which describes that, nine samples will be required for the examining the effect of all parameters and differentiating as well.

After that, designing phase was started in which Nine samples were machined according to the ASTM international standard for designating each set of parameters on different samples. Samples were sliced from a plain square sheet of aluminum having thickness of 3 mm using CNC machine in BZU Multan at constant parameters (Spindle speed, feed rate and depth of cut).

After that, notches were made using EDM machine in the MRC-NUST keeping constant parameters (Pulse on time, Pulse off time, Current and wire speed) and then holes were designed according to Design of Experiment as described in orthogonal array got by Taguchi approach using Minitab software.

After designing all samples according to Design of Experiment, Tensile testing was conducted on Universal testing machine in SCME-NUST keeping the testing parameter constant (strain rate and gauge length) in order to compare the Fracture point, Strength and crack information about each sample. After getting results, ANOVA was performed keeping the UTS as response value and best set of parameters and worst set of parameters was analyzed.

After Analysis of variable and comparing with each other, this study eventually came to conclusion about which set of parameter is effective regarding fracture point and reliability for a sample.

Below given each chapter contain core information about each step of used approach.

CHAPTER 2:

COMPOSITION AND EDS TESTING OF MATERIAL

2.1 Characteristics of Aluminum 1050/T6:

Aluminum 1050/T6 is very commonly used in the industrial sector usually formed by extrusion or rolling. It is used in chemical and electric field because it has high electrical conductivity, corrosion resistance, and workability. It is also used for the manufacturing of heat sinks because it has a higher thermal conductivity than other alloys. It is used in commercial sector because it has low mechanical strength compared to other metals.

2.2 Mechanical Properties:

Table 2-1: Mechanical Properties of Aluminum 1050/T6.

Proof Strength	85 MPa
Tensile Strength	100 MPa
Elongation	12%
Shear Strength	60 MPa
Hardness Vickers	30 HV

2.3 Physical Properties:

Table 2-2: Physical Properties of Aluminum 1050/T6.

Density	2.71 Kg/m^3
Melting Point	650 °C
Thermal Expansion	24 x 10^{-6} /K
Modulus of Elasticity	71 GPa
Thermal Conductivity	222W/m.K
Electrical Resistivity	0.0282 x 10^{-6} Ω .m

2.4 EDS Testing and Results:

2.4.1 Testing:

Firstly, EDS test was conducted to analyze the elemental classification of Test material. The test was conducted at the USP CASEN in National institute of science and technology using following devices:

- SE detector for imaging in SEM.
- Vega 3 (LMU) TESCAN.
- EDS detector instrument,(x-act) PantaFetPria.

Table 2-3 describe the parameters, used for the conducting of EDS test:

Table 2-3: Parameters for EDS testing.

Parameter	Value
WD	15mm
HV	20kv
BI	11
Spot size	1mm

2.4.2 Results:

Figure 2.1 and Figure 2.2 describe the spectrum of Aluminum 1050 generated by EDS scanning.

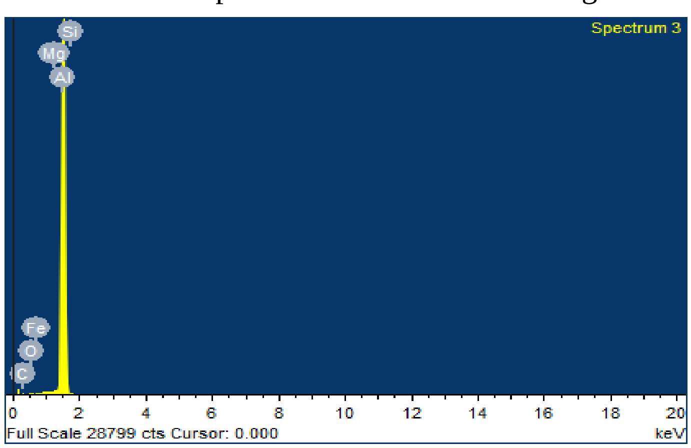

Figure 2.1: Spectrum of Aluminum 1050.

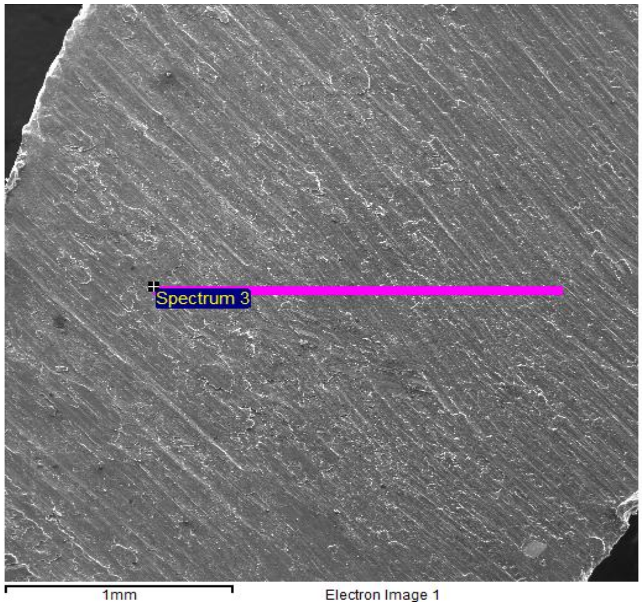

Figure 2.2: Spectrum of Aluminum 1050.

Following table describe the elemental classification of aluminum alloy analyzed by EDS test.

Table 2-4: Elemental classification of Aluminum 1050.

Element	**Weight %**	**Atomic %**
C	14.83	27.61
O	3.82	5.34
Mg	0.48	0.44
Al	**79.37**	**65.77**
Si	0.58	0.46
K	0.09	0.05
Fe	0.84	0.34
Total	100	100

CHAPTER 3

DESIGNING, MACHINING AND TESTING OF SAMPLES

3.1 Design:

As It is stated that this work is on the basis of the research paper [11] in which aluminum was used to examine the fracture point and crack arresting using fatigue testing machine. In this study same approach was used, but it is examined by conducting tensile test using “Universal Testing machine” in SCME-NUST. Double sided notch specimen was used and different arrangement of holes were created according the “Design of Experiment” which obtained using multiple parameters as input in Minitab software by applying Taguchi approach.

According to the ASTM international, (American society for testing and materials) the samples have been designed with the help of CNC milling machine in BZU Multan.

Length of the specimen is 190 mm, width is 25 mm and thickness is 3mm, U shaped Notch height of 5mm with 0-degree angle and 1mm radius is created at the center of the longitudinal sides of the specimen. All the dimensions were according to the ASTM international, (American System of Testing and Materials).

Figure 3-1 shows the base specimen.

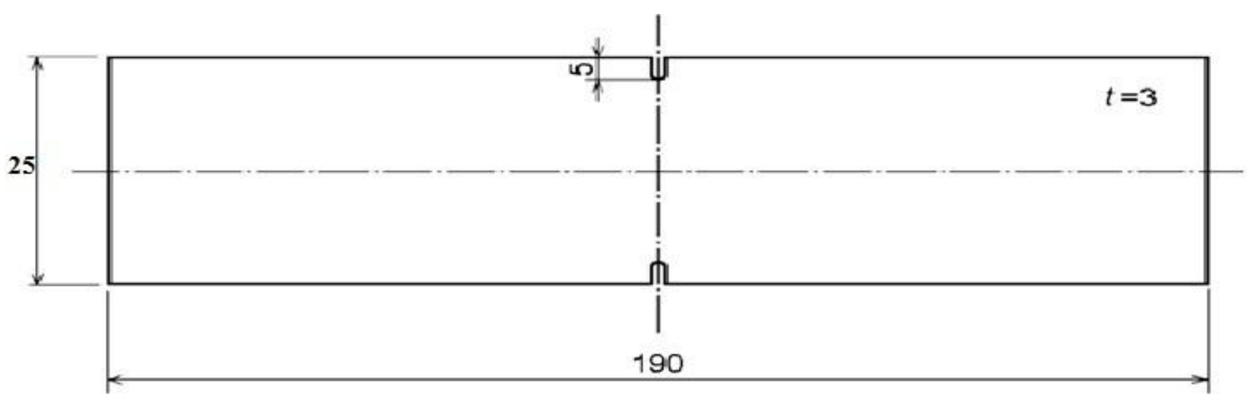

Figure 3-1: Dimension of base sample.

3.2 DOE and Parameters:

Taguchi approach was applied to investigate the effect of multiple parameters. Taguchi method has been widely used in engineering analysis. It is a powerful tool to design a high quality system. It employs a special design of orthogonal array in order to investigate the effect of complete parameters. By using Taguchi method, time and number of conducting experiment are significantly reduced and it is effective to investigate the effects of multiple parameters in the experiment.

3.2.1 Steps involved in Taguchi DOE technique:

Basic Steps that were involved in Taguchi DOE technique are:

1-Determination of the quality characteristic and our objective function which was “Sample with highest UTS value”.

2-Identifying the control factors and their alternative levels:

- Horizontal distance of hole from notch (x)
- Vertical distance of hole from notch (y)
- Different diameters of hole.(d)

3-Identifying the noise factors and test conditions:

- Experimentation Condition.
- Operator skills.

Step 4- Orthogonal array selection

- L9 array has been used to satisfy this step.

Step 5 -Conduct Experimentation:

- Experiments are performed as per orthogonal array

3.2.2 Parameters used for DOE:

Following parameter were used as input to obtain DOE.

- **X** (horizontal distance from center of hole to notch),
- **Y** (vertical distance from center of hole to notch).
- **D** (Diameter of the hole).

Three parameters were used with three sub levels of above given parameters. Table 3-1 describes the parameters with sub level.

Table 3-1: Input parameters for DOE

Factor	Level 1	Level 2	Level 3
X (mm)	5	10	15
Y (mm)	-1.5	0	1.5
D (mm)	2	4	6

3.2.3 Orthogonal Array Selection:

The minimum number of experiments to be conducted is to be fixed based on the table below:

Table 3-2: Selection of an orthogonal Array.

Levels	**Number of parameters**								
	2	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
2	L4	L4	L8	L8	L8	L8	L12	L12	L12
3	L9	L9	L9	L18	L18	L18	L18	L27	L27
4	L16	L16	L16	L16	L32	L32	L32	L32	L32
5	L25	L25	L25	L25	L25	L50	L50	L50	L50

According to literature review :

DOF = P*(L – 1)

- DOF = degree of freedom
- P = number of factors = 3
- L = number of levels = 3

(DOF)R = 3(3 – 1) = 6

As the total DOF of the orthogonal array should be equal or greater than the total DOF required for the experiment. Thus L9 orthogonal array was selected to perform the experiments, which is described in Table 3-3.

Table 3-3: L9 orthogonal array.

Sr No.	X (mm)	Y (mm)	D(mm)
1	5	-1.5	2
2	5	0.0	4
3	5	1.5	6
4	10	-1.5	4
5	10	0.0	6
6	10	1.5	2
7	15	-1.5	6
8	15	0.0	2
9	15	1.5	4

3.3 Machining and creating the holes:

CNC machine was used to machine the outer boundary of the samples keeping constant parameters. Table 3-4 describe the parameters for CNC machining.

Table 3-4 :CNC machining parameters.

Parameters	**Value**
Spindle speed	2000 rpm
Cutting feed	200mm/min
Depth of cut	1.0 mm

The fracture properties of any material can be determined by using blunt notch or sharp crack at the tip of the notch. When we used blunt notch, the crack initiation energies are higher but when a sharp notch is used, the energy necessary to initiate a crack is small. In a blunt notch case, both crazing and shear yielding mechanisms may operate simultaneously. This study focused the blunt notched specimen.

After machining the base samples according to the ASTM E8/E8M 16-a [12] double notches of 5mmwere created using the EDM wire cut in Manufacturing resource center (NUST).Machine used was JIANGSU SANXING MACHINERY model DK77- 32AZ having table travel of 320x400mm which used molybdenum wire having the diameter of 0.1mm. All the machine parameters were constant. Table 3-5 describe the parameters used in the EDM.

Table 3-5: EDM machining parameters.

Parameters	**Value**
Pulse on	16 µsec
Pulse off	8 µsec
Current	2A.
Wire speed	50.

Figures 3.2 and 3.3 show the working on EDM wire cutting machine.

Figure 3.2: Parameters of EDM for creating notches

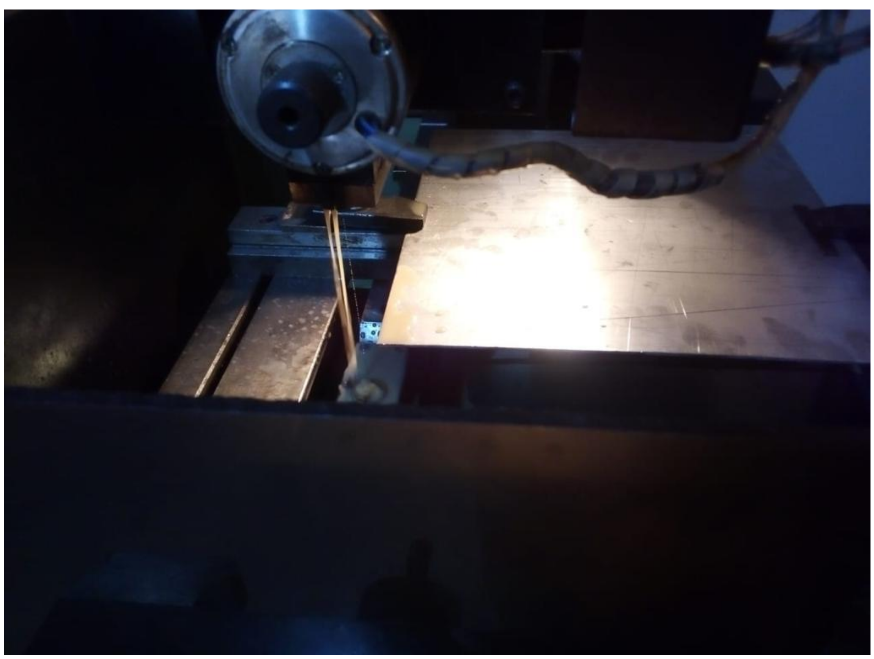

Figure 3.3: EDM creating notches

After creating the notches on both sides of the specimens, holes were created in MRC, NUST according to Design of experiments.

After making the samples, each sample has been designated with unique sample name, i-e (sample 1,2,3,4,5….) so it can be further convenient to differentiate after the tensile test.

According to ASTM international, E8/E8 M, 16-A dimensions of specimen are following:

- G-Gauge length= 50 mm.
- W-Width=15mm
- C-Width of Grip section =25mm
- B-Length of Grip Section =75mm
- T-Thickness= 3mm

Figure 3.4 shows the specimen according to ASTM Standard.

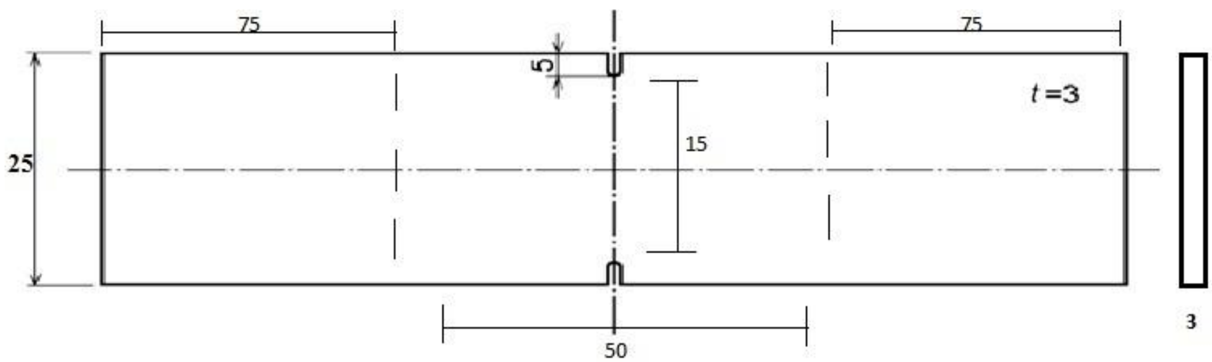

Figure 3.4: Specimen according to ASTM standard

Figure 3.5 shows the actual view of samples. These samples were made after multiple steps of machining, which were discussed before. All samples have their unique name so it can be further differentiate in order to conclude our result.

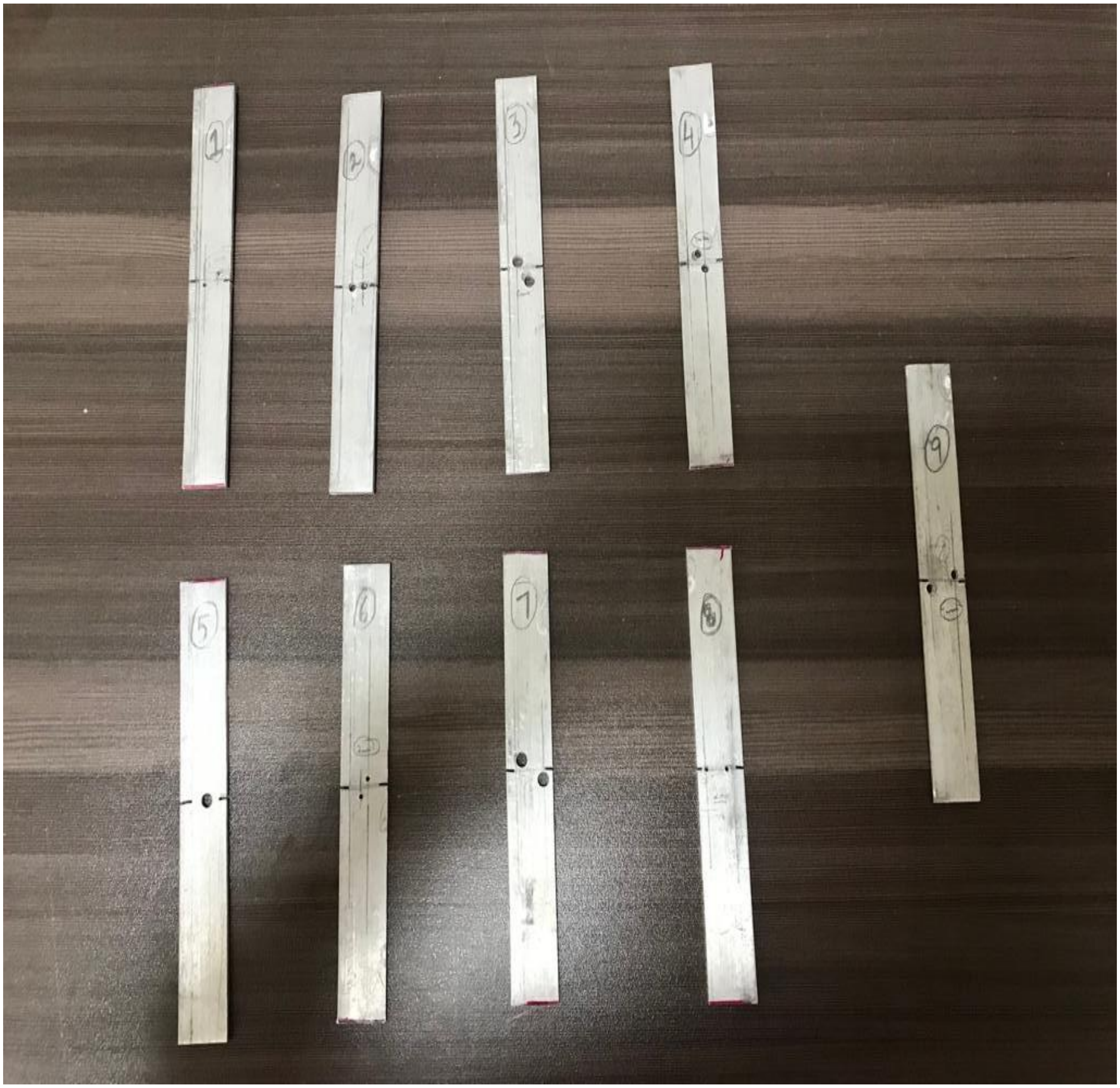

Figure 3.5: Actual view of samples

3.4 Testing of samples:

Tensile test is one of the most fundamental and common types of mechanical testing. A tensile test applies tensile (pulling) force to a material and measures the specimen's response to the stress. By doing this, tensile tests determine how strong a material is, its fracture point and ductility level.

Tensile test of the samples was conducted on the floor model Universal testing machine. Machine used was SHIMAZDU AG-X Plus having maximum load capacity is 20KN,by keeping the gauge length of 50 mm for each sample and strain rate of 1mm/sec on each sample, so result can be differentiable. Samples had been set vertically in both hydraulic jaws of the machine and test was conducted according to above given parameters keeping the force and position value at zero.

Following is the pictorial view of the sample on which tensile forces are exerted.

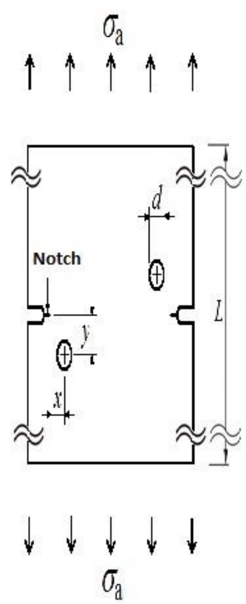

Figure 3.6 :Tensile loading concept

As test started, upper hydraulic jaw of the machine started expanding and lower jaws of the machine stayed at rest exerting a tensile force on the specimen and consequently force and position values were gradually increasing and presenting in the digital panels. Graph was gradually generated on the screen of the computer equipped with the Universal testing machine.

Computer screen also displayed the value of Stress, Strain, Force, Time and Displacement value of samples which were continuously varying till complete fracture.

The graph on the computer screen presented following specification of each sample:

- Maximum force calculation.
- Maximum stress calculation.
- Maximum displacement value.
- Maximum time.
- Maximum strain calculation.
- Break force sensitivity.
- Break strain sensitivity.
- Break stress sensitivity.
- Break displacement sensitivity.
- Break time sensitivity.

As the force was applying on the samples, above given values of each sample were gradually recording according to the strength of sample. Each value is mentioned in the cells, designed on the graphical result sheet. Values of above given parameters are unique for each sample. On the basis of above given values, results were compared and analyzed the best sample regarding the fracture point, strength and crack propagation.

Layout of testing of materials is given below:

Figure 3.7: Hydraulic jaws holding sample

Figure 3.8: Side view of sample in hydraulic jaws

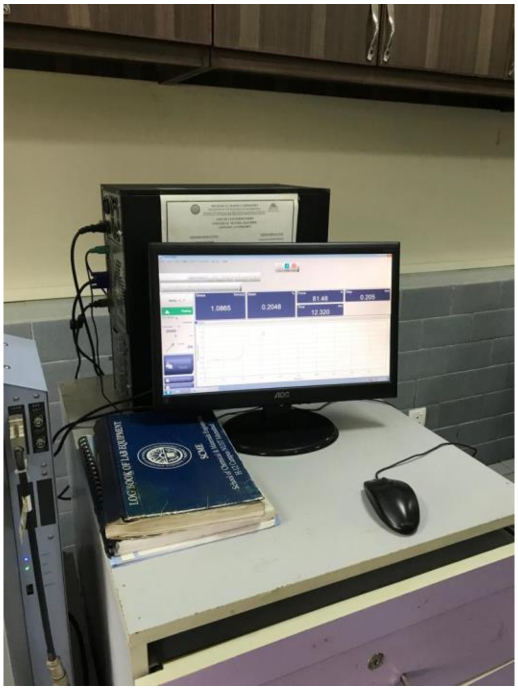

Figure 3.9: Computer generating graphical result

CHAPTER 4:

RESULTS AND DISCUSSION

4.1 Testing Results:

The result of testing is a graph of stress (load on y-axis) vs strain (amount of displacement on x-axis). Amount of load needed to stretch or change the material depends on the size of the material and of course the properties of the material.

Tensile specimens were loaded into the mechanical load frame and pulled at constant cross head speeds. It carried 2 to 3 minutes to fracture each sample completely and to developing a visual representation. Universal testing machine tested each sample very effectively and presented graphic base result accurately with showing value of multiple parameters like stress, strain, force, time, break time, break force, break sensitivity, stress sensitivity and strain sensitivity. After getting results and graphs, it was noticed that every parameter of each sample is varying and due to these values and graphical view, result has been concluded.

There are nine graphical result sheets, Each graphical result shows the unique name of sample on the left top corner, so it can be easily recognize. Figures below present the graphical result of each samples developed by Universal testing machine expressing the core values of the sample.

4.1.1 Sample 1:

Key Word		Product Name	
Test File Name	1.xtak	Method File Name	Method File of aluminium 1050.xmak
Report Date	7/23/2019	Test Date	7/23/2019
Test Mode	Single	Test Type	Tensile
Speed	1mm/min	Shape	Plate
No of Batches:	1	Qty/Batch:	1

Name Parameters Unit	Max_Force Calc. at Entire Areas N	Max_Stress Calc. at Entire Areas N/mm2	Max_Disp. Calc. at Entire Areas mm	Max_Strain Calc. at Entire Areas %
1 _ 1	8002.55	106.701	2.65960	2.65960

Name Parameters Unit	Max_Time Calc. at Entire Areas sec	Break_Force Sensitivity: 10 N	Break_Stress Sensitivity: 10 N/mm2	Break_Disp. Sensitivity: 10 mm
1 _ 1	159.610	7058.93	94.1190	2.98083

Name Parameters Unit	Break_Strain Sensitivity: 10 %	Break_Time Sensitivity: 10 sec
1 _ 1	2.98083	178.880

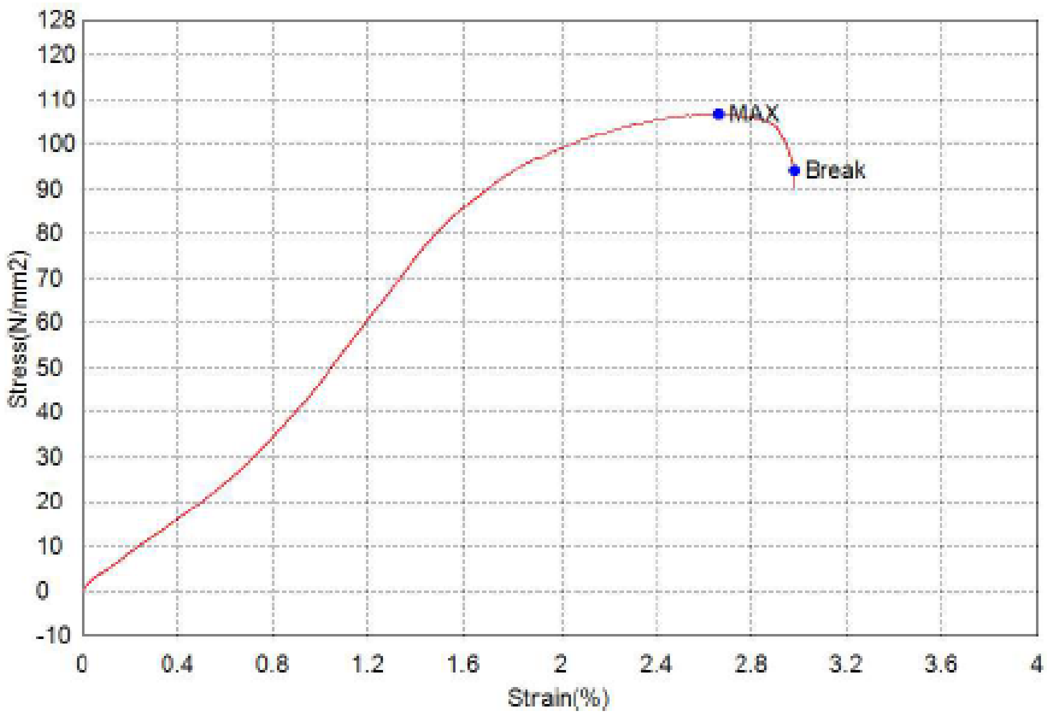

Figure 4.1: Tensile testing result of sample 1

Comments:

The value of UTS of sample 1 is 106.701N/mm^2 which gives corresponding 2.65960% strain rate ate entire area. Sample tolerated maximum 8002.55 N force to reach the fracture point. It took 178.880 sec to complete breaking. It has the highest break force sensitivity among all samples i-e 7058.93 N. It also has the highest break stress sensitivity 94.1190 N/mm^2.

4.1.2 Sample 2:

Key Word		Product Name	
Test File Name	2.xtak	Method File Name	Method File of aluminium 1050.xmak
Report Date	7/23/2019	Test Date	7/23/2019
Test Mode	Single	Test Type	Tensile
Speed	1mm/min	Shape	Plate
No of Batches:	1	Qty/Batch:	1

Name Parameters Unit	Max_Force Calc. at Entire Areas N	Max_Stress Calc. at Entire Areas N/mm2	Max_Disp. Calc. at Entire Areas mm	Max_Strain Calc. at Entire Areas %
1 _ 1	4750.61	63.3414	1.59658	1.59658

Name Parameters Unit	Max_Time Calc. at Entire Areas sec	Break_Force Sensitivity: 10 N	Break_Stress Sensitivity: 10 N/mm2	Break_Disp. Sensitivity: 10 mm
1 _ 1	95.8300	4482.37	59.7650	1.71546

Name Parameters Unit	Break_Strain Sensitivity: 10 %	Break_Time Sensitivity: 10 sec
1 _ 1	1.71546	102.960

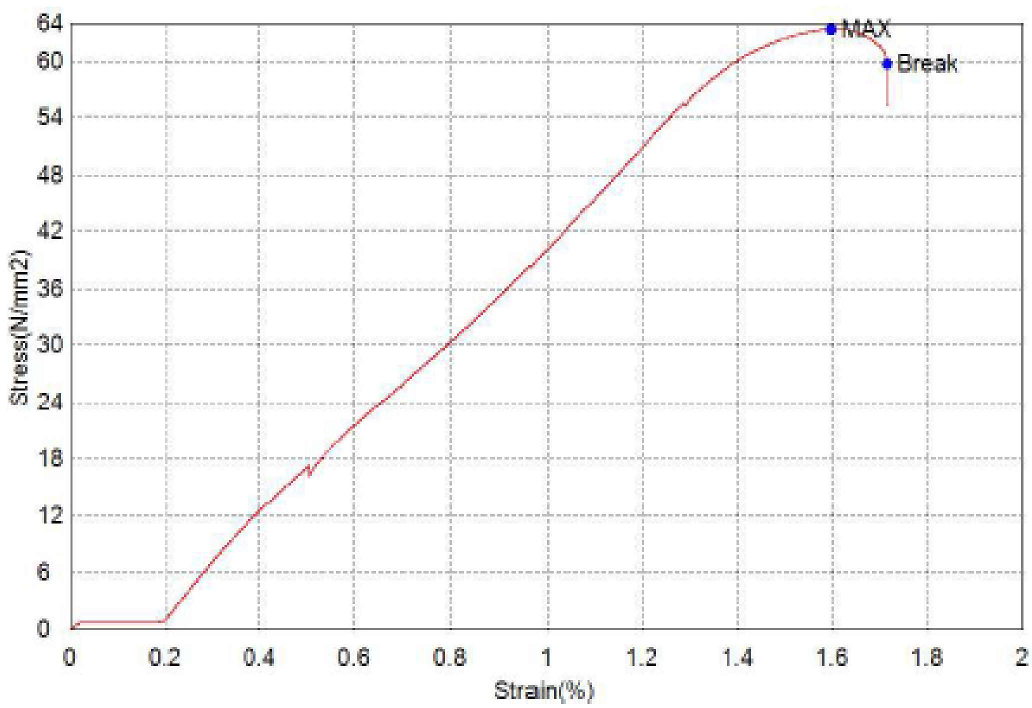

Figure 4.2: Tensile testing result of sample 2

Comments:

UTS value of sample 2 is 63.3414 N/mm^{2}which give 1.59658% corresponding strain calculation at entire area .It tolerated maximum 4750.61 N force and took 102.960 sec to complete breaking. Its plastic phase start at 1.2% strain calculation at entire area.

4.1.3 Sample 3:

Key Word		Product Name	
Test File Name	3.xtak	Method File Name	Method File of aluminium 1050.xmak
Report Date	7/23/2019	Test Date	7/23/2019
Test Mode	Single	Test Type	Tensile
Speed	1mm/min	Shape	Plate
No of Batches:	1	Qty/Batch:	1

Name Parameters Unit	Max_Force Calc. at Entire Areas N	Max_Stress Calc. at Entire Areas N/mm2	Max_Disp. Calc. at Entire Areas mm	Max_Strain Calc. at Entire Areas %
1 _ 1	5430.86	72.4115	1.99515	1.99515

Name Parameters Unit	Max_Time Calc. at Entire Areas sec	Break_Force Sensitivity: 10 N	Break_Stress Sensitivity: 10 N/mm2	Break_Disp. Sensitivity: 10 mm
1 _ 1	119.740	4282.36	57.0982	2.20213

Name Parameters Unit	Break_Strain Sensitivity: 10 %	Break_Time Sensitivity: 10 sec
1 _ 1	2.20213	132.160

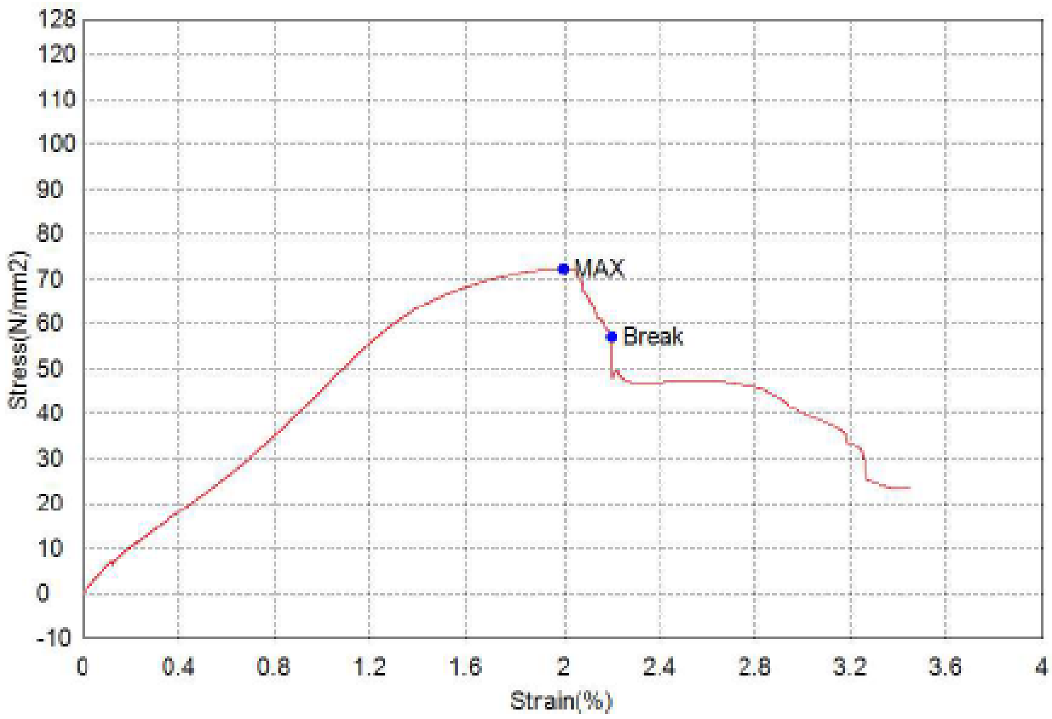

Figure 4.3: Tensile testing result of sample 3

Comments:

UTS value of sample 3 reached at 72.4115 N/mm^2 giving corresponding strain calculation is 1.99515% at entire area. It took 132.160 sec to reached at fracture point and tolerated maximum force of 5430.86 N.Plastic phase of sample 3 has started at 58N/mm^2.

4.1.4 Sample 4:

Key Word		Product Name	
Test File Name	4.xtak	Method File Name	Method File of aluminium 1050.xmak
Report Date	7/23/2019	Test Date	7/23/2019
Test Mode	Single	Test Type	Tensile
Speed	1mm/min	Shape	Plate
No of Batches:	1	Qty/Batch:	1

Name	Max_Force	Max_Stress	Max_Disp.	Max_Strain
Parameters	Calc. at Entire Areas	Calc. at Entire Areas	Calc. at Entire Areas	Calc. at Entire Areas
Unit	N	N/mm2	mm	%
1 _ 1	6014.34	80.1913	2.12458	2.12458

Name	Max_Time	Break_Force	Break_Stress	Break_Disp.
Parameters	Calc. at Entire Areas	Sensitivity: 10	Sensitivity: 10	Sensitivity: 10
Unit	sec	N	N/mm2	mm
1 _ 1	127.510	4076.38	54.3517	2.47708

Name	Break_Strain	Break_Time
Parameters	Sensitivity: 10	Sensitivity: 10
Unit	%	sec
1 _ 1	2.47708	148.660

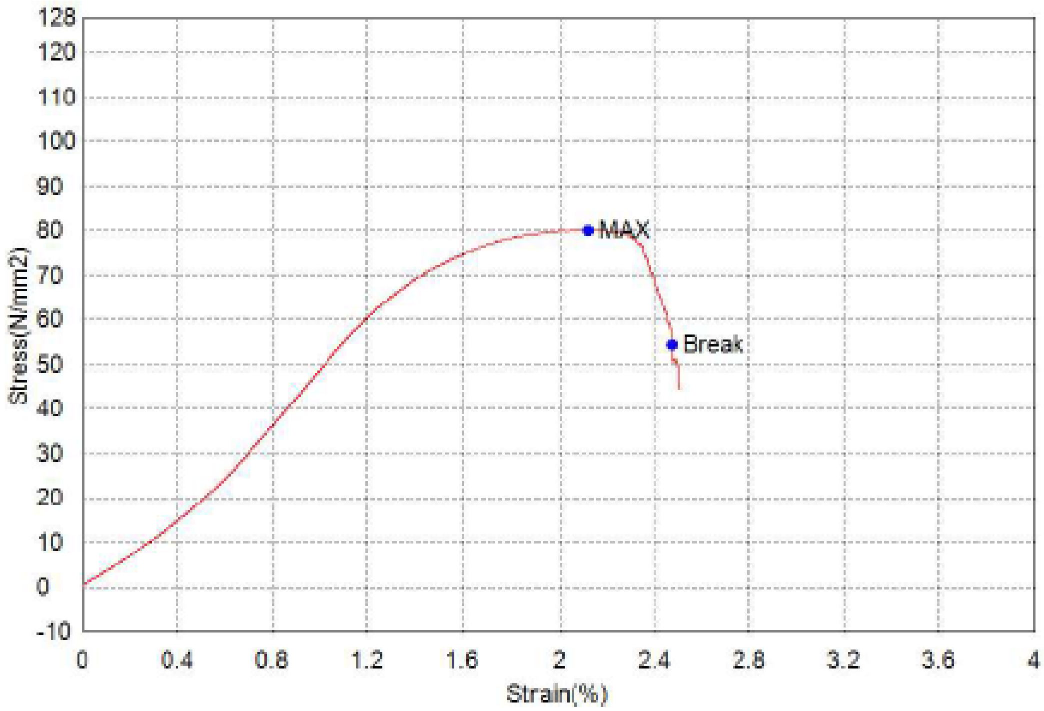

Figure 4.4: Tensile testing result of sample 4

Comments:

UTS value of sample 4 is 80.1913N/mm^2 giving strain calculation is 2.12458%. It tolerated maximum 6014.34 N force to reach the fracture point and took 148.660 sec till complete failure. Its plastic phase started at 60 N/mm^2 stress value.

4.1.5 Sample 5:

Key Word		Product Name	
Test File Name	5.xtak	Method File Name	Method File of aluminium 1050.xmak
Report Date	7/23/2019	Test Date	7/23/2019
Test Mode	Single	Test Type	Tensile
Speed	1mm/min	Shape	Plate
No of Batches:	1	Qty/Batch:	1

Name Parameters Unit	Max_Force Calc. at Entire Areas N	Max_Stress Calc. at Entire Areas N/mm2	Max_Disp. Calc. at Entire Areas mm	Max_Strain Calc. at Entire Areas %
1 _ 1	3568.21	47.5761	1.32958	1.32958

Name Parameters Unit	Max_Time Calc. at Entire Areas sec	Break_Force Sensitivity: 10 N	Break_Stress Sensitivity: 10 N/mm2	Break_Disp. Sensitivity: 10 mm
1 _ 1	79.8100	3085.85	41.1446	1.65513

Name Parameters Unit	Break_Strain Sensitivity: 10 %	Break_Time Sensitivity: 10 sec
1 _ 1	1.65513	99.3400

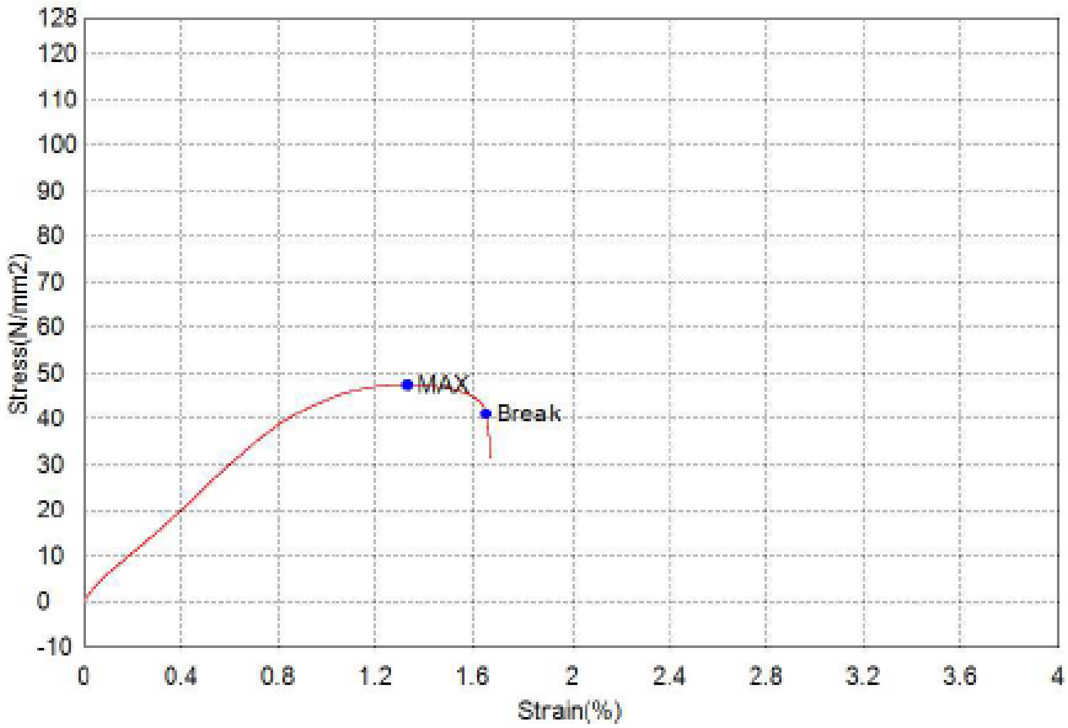

Figure 4.5: Tensile testing result of sample 5

Comments:

UTS of sample 5 is 47.576 $N/mm^2$with corresponding 1.32958% strain calculation at entire area. It took 99.3400 sec to reach rapture point with maximum tolerated 3568.21 N force. All of the above recorded values are minimum among all samples.

The sample 5 is considered as worst sample among all due to minimum UTS value, so it means that the set of parameters of this sample is not reliable. Sample contain x, y and d parameter which is the horizontal distance of hole from notch, vertical distance of hole from notch and diameter of the hole respectively. X has the value of 10 mm, y has the 0.0 mm and d is 6 mm, which is the highest diameter of the hole.

It shows that a sample with highest diameter and no vertical distance from notch make a sample not reliable and less tolerable.

4.1.6 Sample 6:

Key Word		Product Name	
Test File Name	6.xtak	Method File Name	Method File of aluminium 1050.xmak
Report Date	7/23/2019	Test Date	7/23/2019
Test Mode	Single	Test Type	Tensile
Speed	1mm/min	Shape	Plate
No of Batches:	1	Qty/Batch:	1

Name Parameters Unit	Max_Force Calc. at Entire Areas N	Max_Stress Calc. at Entire Areas N/mm2	Max_Disp. Calc. at Entire Areas mm	Max_Strain Calc. at Entire Areas %
1 _ 1	8115.58	108.208	2.95508	2.95508

Name Parameters Unit	Max_Time Calc. at Entire Areas sec	Break_Force Sensitivity: 10 N	Break_Stress Sensitivity: 10 N/mm2	Break_Disp. Sensitivity: 10 mm
1 _ 1	177.340	6025.76	80.3435	3.28994

Name Parameters Unit	Break_Strain Sensitivity: 10 %	Break_Time Sensitivity: 10 sec
1 _ 1	3.28994	197.430

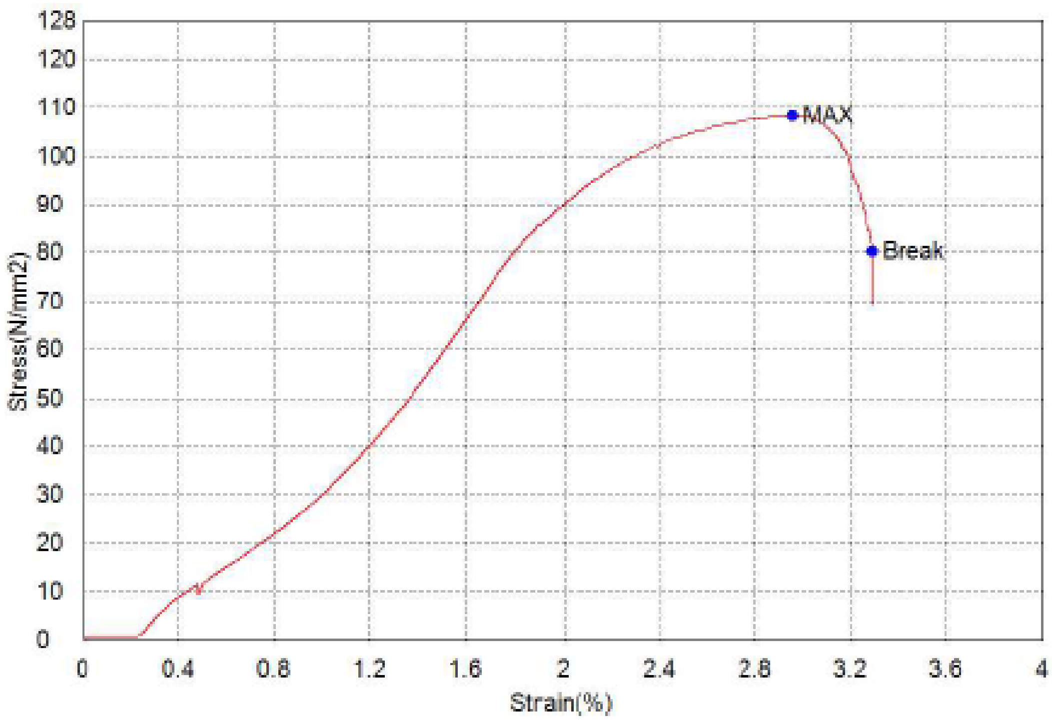

Figure 4.6: Tensile testing result of sample 6

Comments:

Sample 6 has the UTS value is 108.208 N/mm^2, which is the highest among all samples. It gives corresponding 2.95508% strain calculation at entire area. It tolerated 8115.58 N force to reached UTS and took 197.430 sec to reached fracture point.

Its plastic phase started at the 85N/mm^2 .Sample 6 tolerated highest force at entire area among all the samples.

As it has the highest value of UTS, it is considered as strong and reliable sample among all. Sample contain x, y and d parameter which is the horizontal distance of hole from notch, vertical distance of hole from notch and diameter of the hole respectively. X has the value of 10 mm, y has the 1.5 mm and d is 2 mm, which is the lowest diameter of the hole.

According to this we can say that a sample having lowest diameter with moderate horizontal and vertical distance from the notch make the material reliable.

4.1.7 Sample 7:

Key Word		Product Name	
Test File Name	7.xtak	Method File Name	Method File of aluminium 1050.xmak
Report Date	7/23/2019	Test Date	7/23/2019
Test Mode	Single	Test Type	Tensile
Speed	1mm/min	Shape	Plate
No of Batches:	1	Qty/Batch:	1

Name	Max_Force	Max_Stress	Max_Disp.	Max_Strain
Parameters	Calc. at Entire Areas	Calc. at Entire Areas	Calc. at Entire Areas	Calc. at Entire Areas
Unit	N	N/mm2	mm	%
1 _ 1	5241.61	69.8881	2.37708	2.37708

Name	Max_Time	Break_Force	Break_Stress	Break_Disp.
Parameters	Calc. at Entire Areas	Sensitivity: 10	Sensitivity: 10	Sensitivity: 10
Unit	sec	N	N/mm2	mm
1 _ 1	142.660	4490.72	59.8763	2.56563

Name	Break_Strain	Break_Time
Parameters	Sensitivity: 10	Sensitivity: 10
Unit	%	sec
1 _ 1	2.56563	153.970

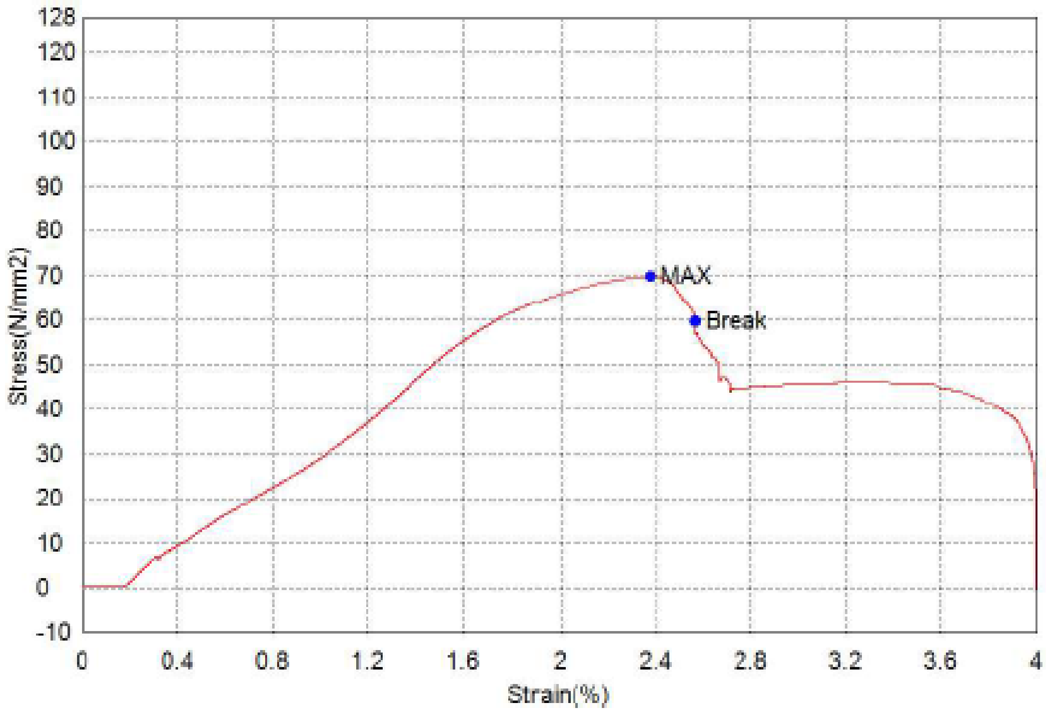

Figure 4.7: Tensile testing result of sample 7

Comments:

UTS value of sample 7 is 69.8881 N/mm^2 with giving corresponding 2.37708% strain calculation at entire area. It took 153.970 sec to reached fracture point with bearing of maximum 5241.61N. Plastic phase of sample 6 started at 50 N/mm^2.

4.1.8 Sample 8:

Key Word		Product Name	
Test File Name	8.xtak	Method File Name	Method File of aluminium 1050.xmak
Report Date	7/23/2019	Test Date	7/23/2019
Test Mode	Single	Test Type	Tensile
Speed	1mm/min	Shape	Plate
No of Batches:	1	Qty/Batch:	1

Name Parameters Unit	Max_Force Calc. at Entire Areas N	Max_Stress Calc. at Entire Areas N/mm2	Max_Disp. Calc. at Entire Areas mm	Max_Strain Calc. at Entire Areas %
1 _ 1	7886.15	105.149	2.35758	2.35758

Name Parameters Unit	Max_Time Calc. at Entire Areas sec	Break_Force Sensitivity: 10 N	Break_Stress Sensitivity: 10 N/mm2	Break_Disp. Sensitivity: 10 mm
1 _ 1	141.490	6475.19	86.3358	2.65577

Name Parameters Unit	Break_Strain Sensitivity: 10 %	Break_Time Sensitivity: 10 sec
1 _ 1	2.65577	159.380

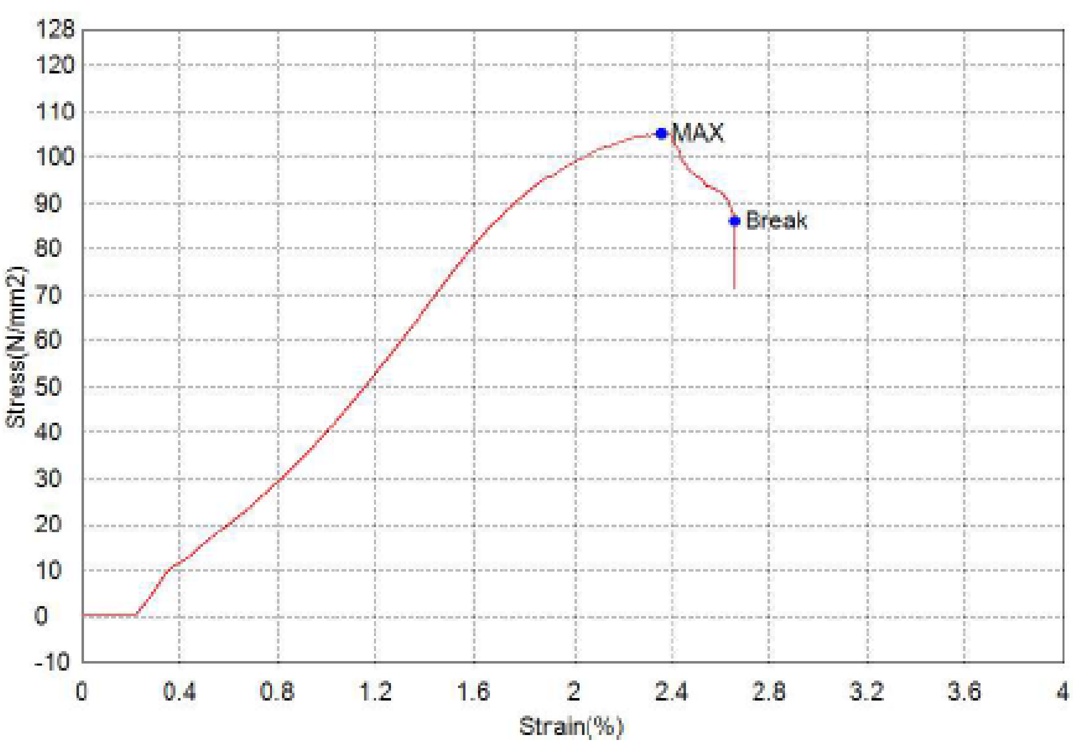

Figure 4.8: Tensile testing result of sample 8

Comments:

Sample 8 has the UTS value 105.149 N/mm^2 with corresponding 2.35758% strain calculation at entire area. It took 159.380 sec to reach fracture point. Plastic phase of sample 8 has started at 80 N/mm^2. It tolerated maximum 788615 N force to break completely.

4.1.9 Sample 9:

Key Word		Product Name	
Test File Name	9.xtak	Method File Name	Method File of aluminium 1050.xmak
Report Date	7/23/2019	Test Date	7/23/2019
Test Mode	Single	Test Type	Tensile
Speed	1mm/min	Shape	Plate
No of Batches:	1	Qty/Batch:	1

Name	Max_Force	Max_Stress	Max_Disp.	Max_Strain
Parameters	Calc. at Entire Areas	Calc. at Entire Areas	Calc. at Entire Areas	Calc. at Entire Areas
Unit	N	N/mm2	mm	%
1 _ 1	6081.94	81.0925	1.80373	1.80373

Name	Max_Time	Break_Force	Break_Stress	Break_Disp.
Parameters	Calc. at Entire Areas	Sensitivity: 10	Sensitivity: 10	Sensitivity: 10
Unit	sec	N	N/mm2	mm
1 _ 1	108.260	1368.33	18.2444	3.44117

Name	Break_Strain	Break_Time
Parameters	Sensitivity: 10	Sensitivity: 10
Unit	%	sec
1 _ 1	3.44117	206.500

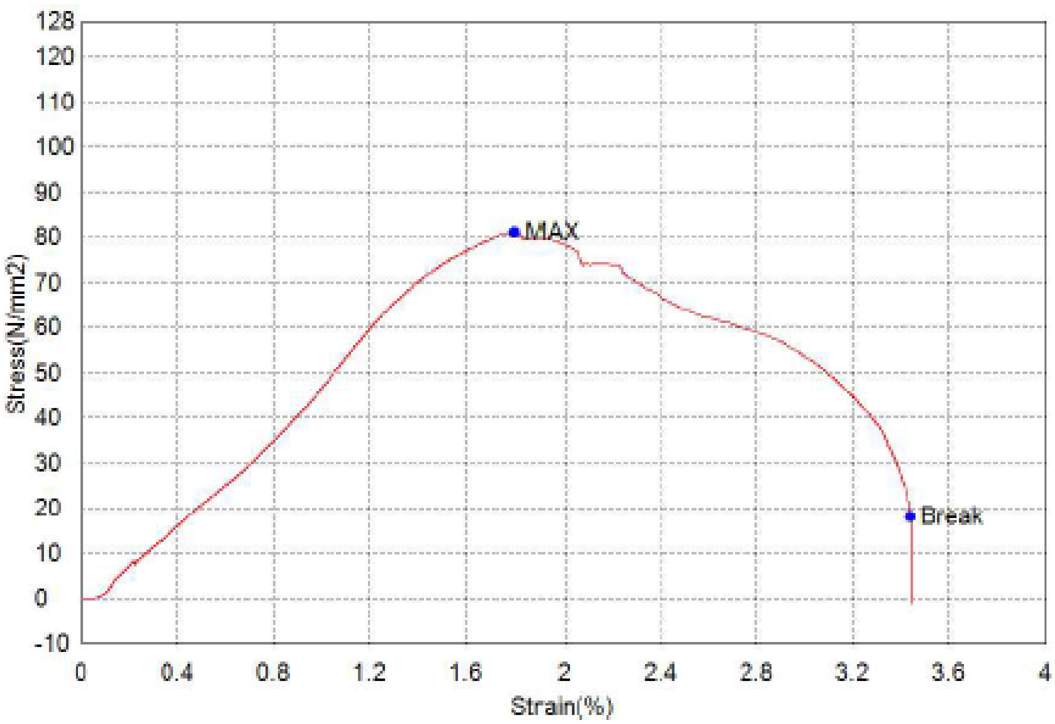

Figure 4.9: Tensile testing result of sample 9

Comments:

UTS value of sample is 81.0925 N/mm^2 giving corresponding 1.80373% strain calculation at entire area. Its plastic phase started at 60 N/mm^2. Its break force sensitivity is 1368.33N which is the minimum among all samples. Sample 9 has the maximum value of break strain among all samples. i-e 3.44117 mm.

It has the maximum horizontal and vertical distance from notch as x=15 mm, y=1.5 mm and diameter is 4 mm which is moderate. These extreme parameters are responsible for maximum break strain sensitivity.

4.2 Breaking of Samples:

Figure 4.10 shows the breaking of all samples after performing tensile test.

Figure 4.10: Breaking of samples after tensile testing

After complete breaking of samples, it was observed that angle of breaking is different for each sample. This difference was due to sets of multiple parameters and different arrangement of holes leads to propagation of cracks in different paths.

4.3Analysis of Variable (ANOVA):

Analysis of Variable is the statistical approach used to check if the means of two or more groups are significantly different from each other. It analyzes the impact of one or more factors by comparing the means of different samples.

After experimentation phase, ANOVA was applied taking the UTS value as response and x(horizontal distance of hole from notch), y(vertical distance of hole from notch) and d(diameter of hole) as factors using Minitab software. Table 4-1 describes the values of factors and response.

Table 4-1: Factors and Response values.

Sample Names	X (mm)	Y (mm)	d (mm)	UTS
1	5	-1.5	2	106.701
2	5	0.0	4	63.341
3	5	1.5	6	72.412
4	10	-1.5	4	80.191
5	10	0.0	6	47.576
6	10	1.5	2	108.208
7	15	-1.5	6	69.888
8	15	0.0	2	105.149
9	15	1.5	4	81.093

According to the above given values of factors and response, ANOVA represented the result which includes the value of Degree of Freedom (DF), Sequential sum of squares (SeqSS), Percentage contribution, Adjusted sum of squares (Adj SS),Adjusted Mean square (Adj MS),F-value and P-value. Table 4-2 displays the result of ANOVA.

Table 4-2: ANOVA results.

Source	DF	Seq SS	%Contribution	Adj SS	Adj MS	F	P
X (mm)	**2**	**70.58**	**1.96%**	**70.58**	**35.29**	**0.79**	**0.559**
Y (mm)	**2**	**418.38**	**11.60%**	**418.38**	**209.19**	**4.68**	**0.176**
d (mm)	**2**	**3029.15**	**83.97%**	**3029.15**	**1514.58**	**33.91**	**0.029**
Error	**2**	**89.33**	**2.48%**	**89.33**	**44.66**		
Total	**8**	**3607.44**	**100.00%**				

According to above given results d (diameter of hole) has the 83.97% contribution. y(vertical distance of hole from notch) has the 11.60% and x(horizontal distance of hole from notch) has the 1.96% contribution. Result shows that diameter of holes have the highest contribution in the UTS values and x parameter has the lowest contribution against UTS.

4.3.1 Main Effect Plot:

ANOVA represented Main effect plot for means according to the results. Figure 4-11 shows the main effect plots for means.

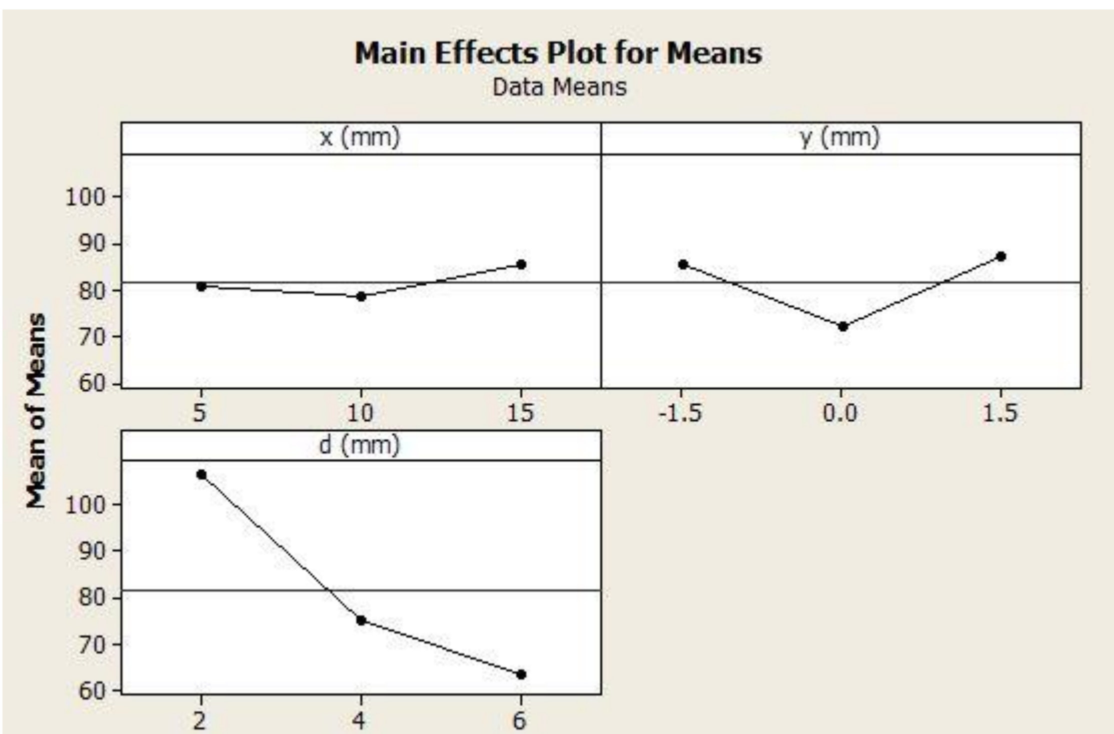

Figure 4.11: Main Effect Plot

According to Main Effect Plot, UTS value and diameter of hole is inversely proportional to each other. Its mean that smaller diameter of hole gained highest value of UTS and lowest value of UTS for larger diameter. Similarly, UTS value and x parameter is directly proportional to each other, if horizontal distance of hole from notch is increases, it gained higher UTS value and vice versa. UTS value and y parameter is directly proportional to each other If vertical distance of hole from notch is increasing, then it also gained the higher UTS value and vice versa.

4.3.2 Best and Worst:

Sample 6 considered as the best sample, as main effect plots shows that a smaller diameter of hole and more vertical and distance from notch undergoes the higher UTS value.

Sample 5 considered as the worst sample, because according to the graph, a higher diameter hole and lowest vertical distance from notch undergoes the lowest UTS value.

CHAPTER 5:

DISCUSSION AND CONCLUSION

5.1 Discussion and Comparisons:

After comparing the results, we came to know that **sample 6** (x=10mm,y=1.5 and holes dia=2mm) give the highest inclined line starting from initial point indicating the linear relationship between stress and strain, so it undergoes highest elastic phase under stress-strain diagram therefore, it reached highest ultimate stress point with highest Stress point 108.208 N/mm^2. Due to all of these, it tolerated highest maximum force at entire area, which is 8115.58 N. It gives 2.95508 % strain rate at entire area. Break strain sensitivity of sample 6 is recorded as 3.28994%. These factors of sample 6 are responsible to reach its Ultimate stress point. By comparing with another samples behavior, it is noticeable that sample 6 stored maximum energy before reaching the point of rapture.

In contrast, **sample 5** (x=10mm,y=0.0 mm and holes dia=6mm) possess the minimum UTS value among all samples, i-e 47.561f $N/mm^{2.}$ It tolerated force of 3568.21N to reach the UTS. It also has the minimum strain calculation on entire area among all samples that is 1.32958%. Among all specimens, its break strain sensitivity is lowest which is 1.65513mm. Due to all these lowest parameters, it took lowest time of 79.81 sec to reach at UTS point. Its break time reduced to 99.34 sec, which is also lowest among all samples. Sample 5 has the minimum elastic phase and it jumped to plastic phase after more force applying on it and it stored minimum energy applied on it.

Sample 9 (x= 15, y=1.5, holes dia=4mm) has the lowest break force sensitivity i-e 1368.3N among all the sample and it has lowest stress sensitivity 18.244 N/mm that’s why It has the highest strain sensitivity i-e 3.4417 % and highest break time sensitivity that is 206.5 sec.

5.2 Conclusion:

After comparing the above given results, we can conclude that smaller the diameter of hole and maximum horizontal and vertical distance from notch is optimum for the sample regarding propagation of crack and failure of object under tensile loading. It undergoes highest elastic phase and then goes to plastic phase and after that necking starts by applying more force on it. It is noticed that crack has been propagate from notch in each case. Smaller the diameter with moderate x and y distance from notches undergoes more force as compared to large diameter which is drilled in front of the notches.

Similarly, lowest horizontal distance value, zero vertical distance value from notch and larger diameter make the sample weak. It has small break strain sensitivity and it shows the lowest Ultimate stress point and minimum strain calculation under tensile loading. It undergoes small elastic phase and goes to plastic phase very quickly after applying small value of force on it.

It was observed that the UTS showed linear increase with the natural logarithm of strain rate. The stress intensity factors under blunt notch and sharp crack conditions also increased linearly with gradually increasing force and extension of hydraulic jaws of the machine.

According to ANOVA a hole has a maximum contribution. A specimen is stronger or reliable, if we use smaller diameter of hole respective to crack or notch. As we increasing the horizontal and vertical distance of hole from notch, a specimen become more reliable.

References:

[1] Murdani A, Makabe C, Saimoto A, Kondo R. A crack-growth arresting technique in aluminum alloy. Eng Fail Anal 2008;15(4):302–10.

[2] Domazet Z. Comparison of fatigue crack retardation methods. Eng Fail Anal 1996;3(2):137–47.

[3] Song PS, Shieh YL. Stop drilling procedure for fatigue life improvement. Int J Fatigue 2004;26:1333–9.

[4] Shin CS, Wang CM, Song PS. Fatigue damage repair: a comparison of some possible methods. Int J Fatigue 1996;18(8):535–46.

[5] Vulic´ N, Jecic´ S, Grubišic´ V. Validation of crack arrest technique by numerical modeling. Int J Fatigue 1997;19(4):283–91.

[6] Shkarayev S. Theoretical modeling of crack arrest by inserting interference-fit fastener. Int J Fatigue 2003;25:317–24.

[7] Ghfiri R, Shi H, Guo R, Mesmacque G. Effects of expanded and non-expanded hole on the delay of arresting crack propagation for aluminum alloys.

Mater SciEng A 2000;286:244–9.

[8] Ghfiri R, Amrouche A, Imad A, Mesmacque G. Fatigue life estimation after crack repair in 6005 AT-6 aluminium alloy using the cold expansion hole

technique. Fatigue FractEng Mater Struct2000;23:911–6.

[9] Goto M, Miyagawa H, Nisitani H. Crack growth arresting property of a hole and Brinell-type dimple. Fatigue FractEngng Mater Struct

1996;19(1):39–49.

[10] Nishimura T. Experimental and numerical evaluation of crack arresting capability due to a dimple. Trans ASME 2005;127.

[11] Crack-growth arrest by redirecting crack growth by drilling stop holes

and inserting pins into them. ChobinMakabea,*, AnggitMurdani b, Kazuo Kuniyoshi c, YoshikiIrei b, Akihide Saimoto d

[12]ASTM international standard Test Methods forTension Testing of Metallic Materials,E8/E8M,16-A.

volume 1: properties and selection: irons, steels, and highperformance

alloys ASM handbook Committee; 1990. p. 673–88.

[13]Cracks, dunce caps and a new way to stop cracks. Fatigue FractEng Mater Struct2009;32:484–92.Mattheck C, Bethge K, Sauer A, Orensen JS, Wissner C, Kraft O by Mattheck C, Bethge K, Sauer A, Orensen JS, Wissner C, Kraft O..

[14] Fatigue crack growth rate under condition of biaxialstress field and elevated temperature. PhD, Pennsylvania stateUniversity; May, 1976. By Shabara M.

[15]. On the prediction of the residual fatigue life of cracked structures repaired by the stop-hole method. Int J Fatigue 2010;32:670–7 by Wua H, Imad A, Benseddiq N, Tupiassu J, de Castro P,Meggiolaro MA.

[16]. A crack-growth arresting technique in aluminum alloy. Eng Failure Anal 2008;15:302–10 by Murdani A, Makabe C, Saimoto A, Kondou R.

[17] Numerical analysis of the influenceof stopping holes in the crack growth. J Aero Space SciTechnol JAST March 2007;4(1):9–16.by Khoshravan MR, Hamidi A.

[18] Shah R. Investigate the delay of crack using stop drilled holes on mild steel. Faculty of Mechanical Engineering, Universiti Malaysia Pahang; November 2009.

[19] Stress concentration at stop-drilled holes and additional holes by Murdani A, Makabe C, Saimoto A, Irei Y, Miyazaki T.

ORIGINALITY REPORT

11%	6%	6%	9%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

1	www.thyssenkrupp-materials.co.uk Internet Source	1%
2	Chobin Makabe, Anggit Murdani, Kazuo Kuniyoshi, Yoshiki Irei, Akihide Saimoto. "Crack-growth arrest by redirecting crack growth by drilling stop holes and inserting pins into them", Engineering Failure Analysis, 2009 Publication	1%
3	Submitted to University of Westminster Student Paper	1%
4	Katiyar, Jitendra Kumar, Nikhil Yadav, Nitu Singh, and Vijay Kumar Pal. "Investigating the Effects of Varying Proportions of Waxes in Wax Mix on Surface Roughness and Optimization by Taguchi Method", Applied Mechanics and Materials, 2011. Publication	1%
5	bioresources.cnr.ncsu.edu Internet Source	1%
	iraqjournals.com	

6	Internet Source	1%
7	Submitted to Skyline High School Student Paper	<1%
8	Submitted to Institute of Research & Postgraduate Studies, Universiti Kuala Lumpur Student Paper	<1%
9	Submitted to Coventry University Student Paper	<1%
10	P.A. Vaghela, J.M. Prajapati. "Hybridization of Taguchi and Genetic Algorithm to minimize iteration for optimization of solution", MethodsX, 2019 Publication	<1%
11	Kneas, F.N.. "Tests on the full size model arches in the Franklin Institute Museum", Journal of the Franklin Institute, 193503 Publication	<1%
12	Submitted to Universiti Teknikal Malaysia Melaka Student Paper	<1%
13	Claus V. von Koch. "Evidence of Plasmons in Secondary Electron Emission Spectra", Physical Review Letters, 09/1970 Publication	<1%

14	www.writing.engr.psu.edu Internet Source	<1%
15	infoscience.epfl.ch Internet Source	<1%
16	proceedings.asmedigitalcollection.asme.org Internet Source	<1%
17	digi.lib.ttu.ee Internet Source	<1%
18	Submitted to Bharati Vidyapeeth Deemed University College Of Engineering Student Paper	<1%
19	spotidoc.com Internet Source	<1%
20	Submitted to National University of Singapore Student Paper	<1%
21	Submitted to Madan Mohan Malaviya University of Technology Student Paper	<1%
22	Submitted to The University of Manchester Student Paper	<1%
23	Submitted to University Tun Hussein Onn Malaysia Student Paper	<1%
24	www.tandfonline.com	

Internet Source

<1%

25 Sobih, Mohamed, Zuhair Elseddig, Khalid Almazy, Amro Youssef, and Mohamed Sallam. "Optimization of EBW Parameters for 2219 AL-Alloy Using Grey Relation Method", Advanced Materials Research, 2012.
Publication

<1%

26 Submitted to University of Sheffield
Student Paper

<1%

27 Şefika Kasman, I. Etem Saklakoglu. "Determination of process parameters in the laser micromilling application using Taguchi method: A case study for AISI H13 tool steel", The International Journal of Advanced Manufacturing Technology, 2011
Publication

<1%

Exclude quotes	On	Exclude matches	Off
Exclude bibliography	On		