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Simulation Analysis of Riveted Joint Specimen with Parameter of Working Pressure and Hole Clearance Using Semi-Automatic Riveting Tool

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Abstract

Squeeze force, rivet length, rivet diameter, and hole clearance are the factors that affect the riveting procedure and the effectiveness or result of the rivets. In this riveting simulation, the riveting parameters are determined using a semi-automatic riveting tool. The semi-automatic riveting tool's working pressure is the parameter set, and the hole clearance is created during the drilling process on sheet metal. The results of riveting simulation show that the working pressure of the rivet gun and the hole clearance directly impact the rivets' shear strength. The shear strength of the rivets will increase with higher operating pressure of the rivet gun and larger hole clearance. Due to the strain hardening that occurs when rivets are hit with a rivet gun during the riveting process, the shear strength of rivets has increased.

Keywords: Rivet Gun Pressure, Hole Clearance, Shear Strength, Rivets, Sheet Metal.

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INTRODUCTION

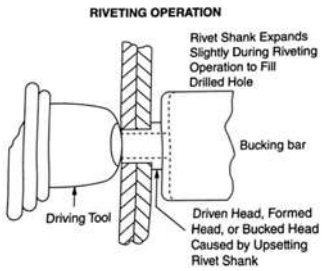
The manufacturing of aircraft relies heavily on the use of sheet metal for a variety of components. Riveting is used to join virtually all of the sheet metal components that go into making aircraft [1]. The rivet is the result of the development of manufacturing technology in the field of joining techniques utilizing a variety of materials [2]. As a result, rivets continue to be the best option for use in manufacturing and the maintenance of aircraft.

Failure of rivets or damage to them is a factor that can play a role in the occurrence of fatalities and accidents involving aircraft [3]. There are a few different outcomes that could result from rivets causing damage to sheet metal joint connections. For instance, the investigation into the crash of Aloha Airlines Flight 243 in 1998 found that the cause of the crash could be traced back to damage that occurred to one of the rivet holes, which then spread to affect the entire joint. The failure of rivet joints in airframes can be attributed to a combination of three factors: induced stress, thermal fatigue, and vibration [4][2]. Induced stress is the only one of these three factors that can be controlled, which means that it is also the only factor that can be used to reduce the risk of rivet joint failure [5][3][6]. The stress that occurs as a result of the operation of an airplane is referred to as "induce stress."

When compared to spot-welded joints, riveted joints are more resistant to corrosion and have a better impact on improving crashworthiness and fatigue performance [7]. Rivets have a good impact on improving crashworthiness and fatigue performance [8][9][10]. According to the findings of a study by Cheraghi titled "Effect of variations in the riveting process on the quality of riveted joints," [3]there are several parameters related to the riveting process that are related to the quality or results of rivets. These parameters include squeeze force, rivet length, rivet diameter, and rivet hole diameter tolerance. in the process of determining how variations in riveting parameters, such as squeezing force or impact force, rivet structure, countersunk hole structure, countersunk diameter, plate thickness, and clamping force, affect the quality of the rivet connection. The simulation illustrates the connection that exists between the riveting parameters and the pattern of variation in the quality of the rivet connection. It was discovered that the amount of force applied during the squeezing process is an important factor in determining the rate at which rivet joints are produced [3][11][12].

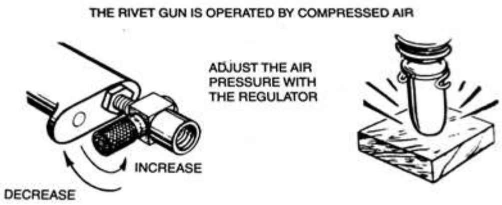
The act of riveting necessitates the completion of multiple steps, including the selection of the type of rivet to be used, the creation of holes, the establishment of the length of the rivet, the modification of the working pressure of the rivet, and finally, the actual riveting of the rivet. Some of these procedures are what people usually mean when they talk about riveting parameters.

Figure 1. Riveting Operation



Source: Standart Aircraft Handbook for Mechanics and Thecnicians 7th Edition

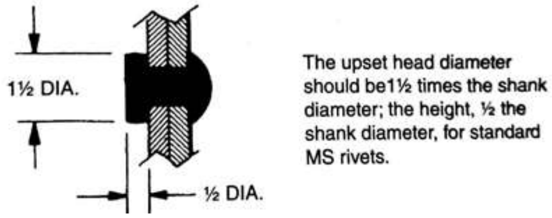
Figure 2. Adjusting Air Pressure



Source: Standart Aircraft Handbook for Mechanics and Thecnicians 7th Edition

Figure 1. is a picture that illustrates the process of riveting, and Figure 2. is a picture that illustrates how to adjust the working pressure of the rivet gun. Let's say that the correct amount of time is spent riveting and that the operating pressure of the rivet gun is just right. In that case, the standards that have been predetermined will produce the best results when riveting [13][14][15]. The standardization of rivet sizes is depicted in Figure 3. which can be found below.

Figure 3. The standardized shape of the shop head rivet



Source: Standart Aircraft Handbook for Mechanics and Thecnicians 7th Edition

In his journal, J. Mucha mentions that the DIN standards (DIN 8593-0:2003, 2003a; DIN 8593-5:2003, 2003b) present the classification of rivet connections made by pressing. Other international standards, such as DIN EN ISO 14272, 2005, and EN1993-1-8, 2005, as well as ISO/DIS 12996, 2013, detail the specimen dimensions, testing conditions, and joint failures. The aforementioned standards contain a listing of the properties of lap joints, and the ISO 2013 standard [11][16][17] contains an explicit listing of the structural analysis of joints.

When testing the tensile strength of a plate, if two pieces of sheet metal are connected with rivets, the plate will have a tendency to bend, and as a result, the shear strength will not be measured accurately. This is one of the phenomena that was discovered during the course of the research. The following diagram explains this phenomenon that was observed by J. Mucha.

Figure 4. Single Shear Phenomenon

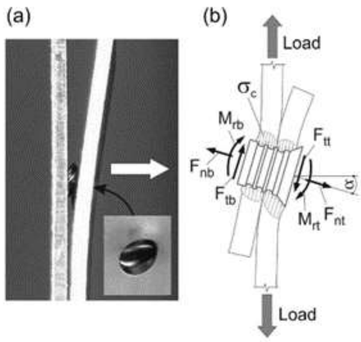
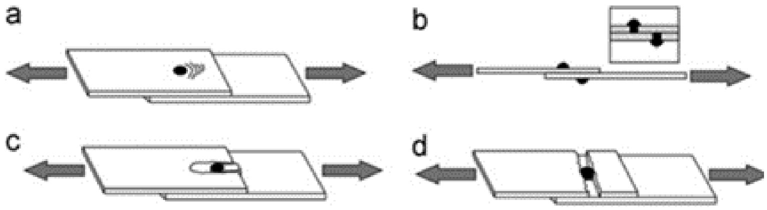


Figure 5. Fracture phenomenon in shear testing



In light of the preceding information regarding the background and the literature review, the purpose of this experiment is to determine the shear strength of rivets that are produced as a result of the riveting process using the parameters of rivet gun working pressure and hole clearance [18][5].

Because the fracture that is produced is not a pure shear phenomenon but rather a combined shear phenomenon [19] [20] , the results of the sample shear test that was done on rivets using a single shear test method need to be done in specific calculations in order to account for this fact. This was discussed previously in Figure 4. and Figure 5.

METHOD

This study, to simulate the shear strength of specimen by determine the working pressure parameters of the rivet gun, is to engineer an automation system that can control the air pressure entering the rivet gun [21]. The Solidworks Simulation is used as the controlling system, graphical below shows an overview of simulation of the riveting process using a semi-automatic tool.

Stages of Static Analysis

a) Structural Modeling in 3D

Figure 6. Specimen Mesh

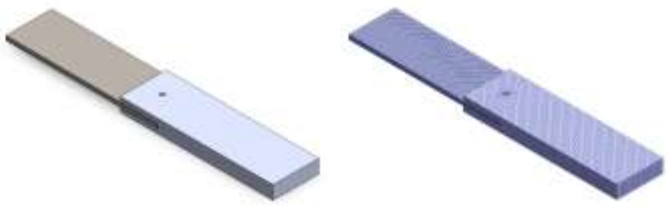
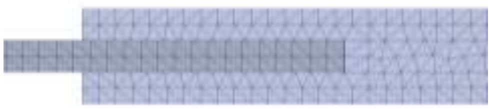


Figure 7. Specimen Mesh



The rivet shear strength test specimen is designed as shown below in Figure 8. The rivet used is a type of solid rivet with a diameter of 3mm Al 1100/plain series, which is used to connect ST37 steel plates or low carbon steel equivalent to AISI 1045 standard or with a strength of 37 kg/mm2 [22][23][24].

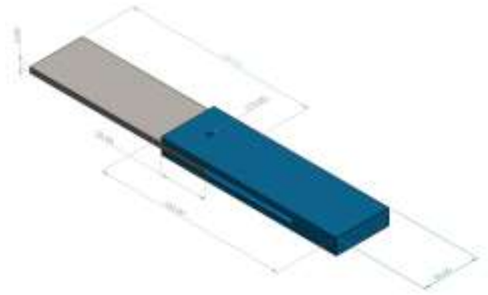


Figure 9. Rivet type of Al1100

b) Input and determine of Working Pressure and Hole Clearance

The variables that will be varied in this study are as follows on Table 1.

Table 1 Table of riveting parameters variation

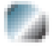
Variation	
Pressure (bar)	**Hole Clearance (mm)**
1	0
1.5	0.1
2	0.2

c) Creating Mesh
d) Start Static Analysis

After conducting the shear test, plotting the test data to determine the character of the shear strength of the rivets resulting from the rivet is necessary. Based on the table of material properties of plain-type rivets with 1100 series is as follows on Table 2 [25][26].

Table 2 Material properties of 1100 series rivets

Material Properties of Rivet				
Material	**Head Marking**	**AN430 Round Head**	**AN470 Universal Head**	**Shear Strength (psi)**

1100	Plain 			10.000

The Figure 10. below shows the size of the diameter of the shop head and the shop height of the riveting results, where good riveting is riveting by the standards of the Standard Aircraft Handbook [14][27].

$$D_{SH} = 1.5 \times D_r$$
$$H_{SH} = 0.5 \times D_r \qquad (1)$$

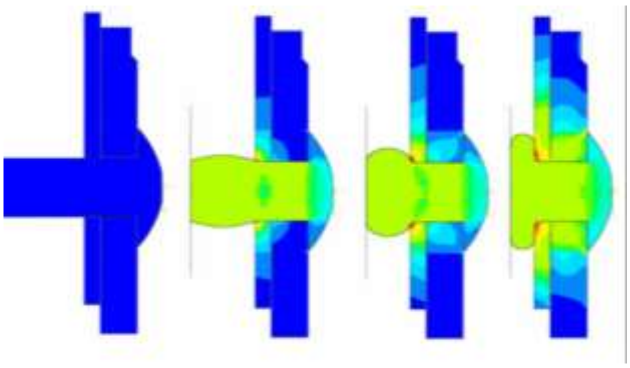
Where :

D_{SH} = Shop head diameter
H_{SH} = Height of shop head
D_r = Rivet Diameter

So the optimal size of rivets with a diameter of 3 mm is

$D_{SH} = 1.5 \times 3$ $\qquad$ $H_{SH} = 0.5 \times 3$
$D_{SH} = 4.5$ mm $\qquad$ $H_{SH} = 1.5$ mm

Figure 10. Riveting Process



Source : [28]

To ascertain the nature of the shear strength of the rivets that are sheared using the predetermined parameters, it is also required to evaluate the shear strength after performing and examining the shearing results. It is important to perform calculations using the formula in order to calculate the charting of the stress-strain graph since the variables that are measured during the tensile testing procedure are mass (F) and length increase (ΔL) [12][29].

$$\sigma = \frac{F}{A}$$

Then,

$$\sigma = \frac{4F}{\pi D^2}$$

Where :

σ = Stress (Mpa)

F = Tensile Force (N)

D = Rivet Diameter (mm)

RESULT AND DISCUSSION

Modeling of Testing Specimen

Figure 11. Riveting Specimen

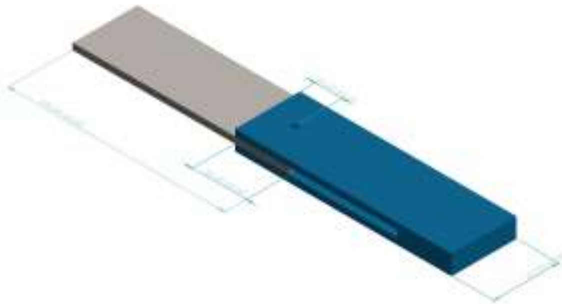
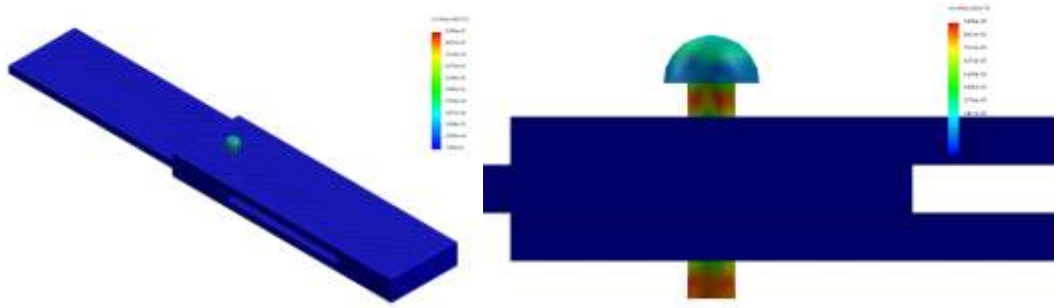
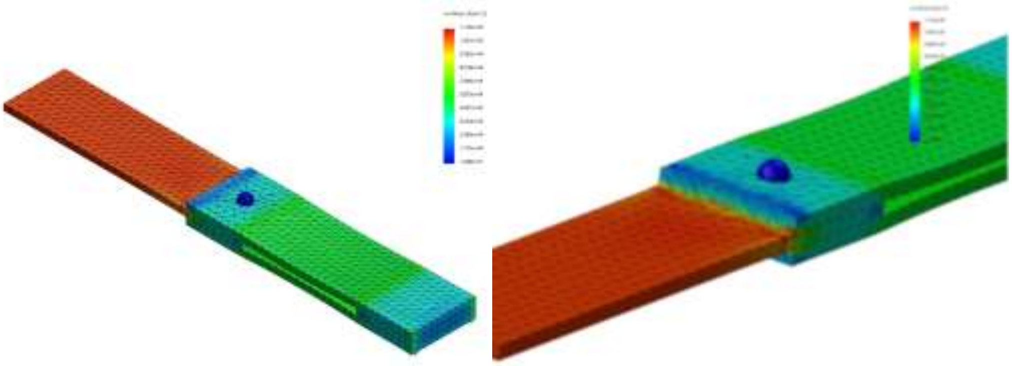


Figure 11. Riveting Process



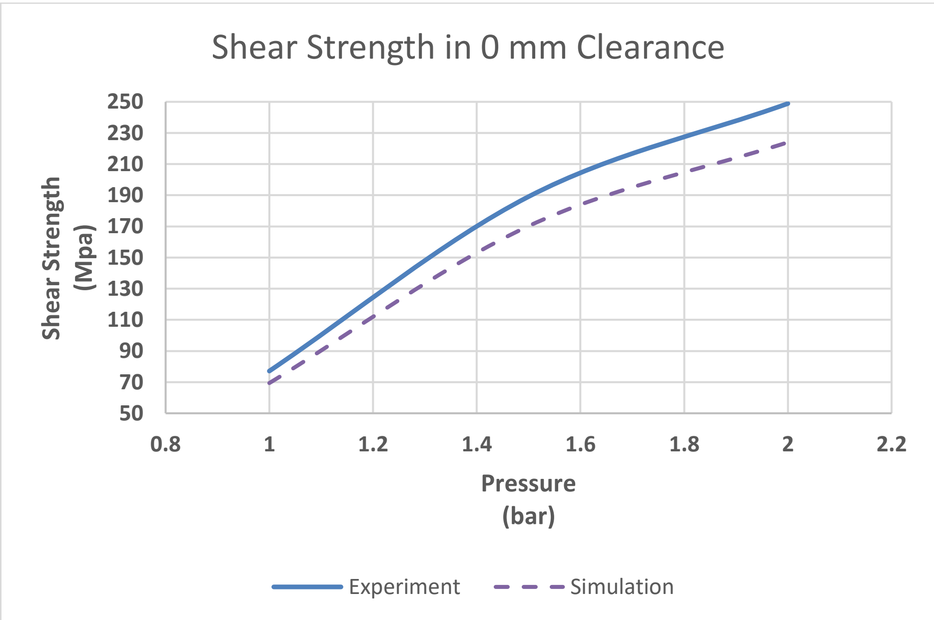
The specimen size is depicted in Figure 11 above. Shear testing will be conducted using a simulation from Solidworks in the following step.

Figure 12. Specimen Tensile Test



According to the literature, the rivetgun pressure is the most important parameter; its variations have a substantial effect on the residual stress field surrounding the hole and, as a result, on the fatigue behavior of the joint. The technician adjusts the pressure valve on a hydraulic/pneumatic riveting machine to manage the squeeze force. The squeeze force is used until the rivet geometry is appropriately distorted. The Standard Aircraft Handbook [14] specifies the dimension range of the upset height within which riveting operations are valid.

Figure 13. Stress vs strain graph at pressures of 1, 1.5, and 2 bar at 0 mm hole clearance



As the working pressure of the rivet gun rises, Figure 13 above illustrates an increase in the shear strength of rivets. With a shear strength of 248.92 Mpa and a rivet gun pressure of 2 bar, the highest shear strength of rivets may be produced. The graph's trend indicates that the shear strength of the rivet grows noticeably as operating pressure on the rivet gun increases[30][31].

Due to the strain hardening process that takes place during the impact of the rivet set with the rivet shop head, the shear strength of rivets improves dramatically as the rivet gun working pressure increases [32]. Dislocations will migrate and interact with other dislocations while the shop head riveting configuration is in place. As a result of the interaction between the dislocations, the material's density will rise, making dislocation movement more challenging. The shear strength of the material on rivets is inversely proportional to the difficulty of dislocation motion [33][6][34].

Figure 14. Stress vs strain graph at pressures of 1, 1.5, and 2 bar at 0.1 mm hole clearance

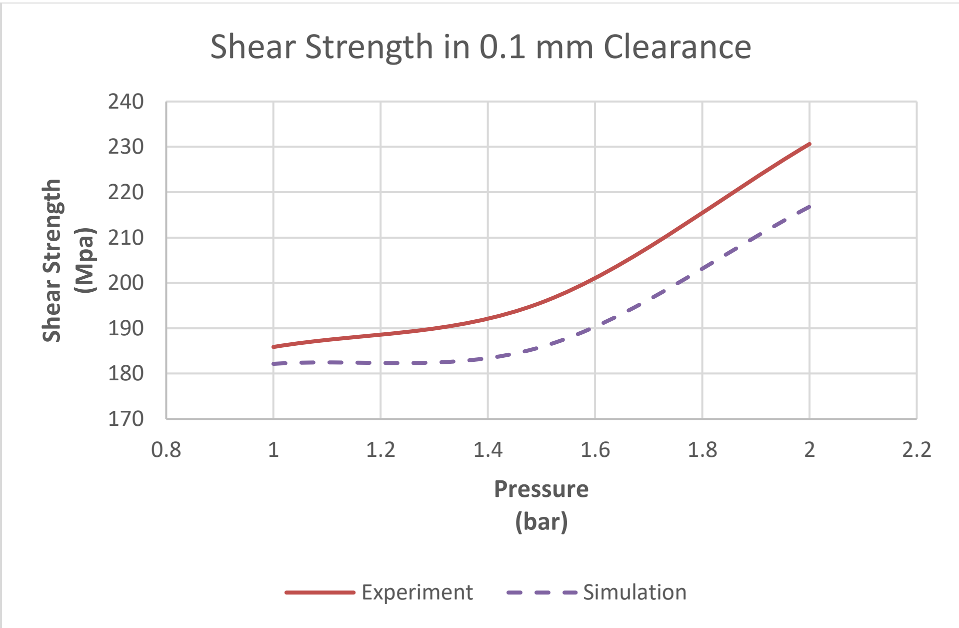


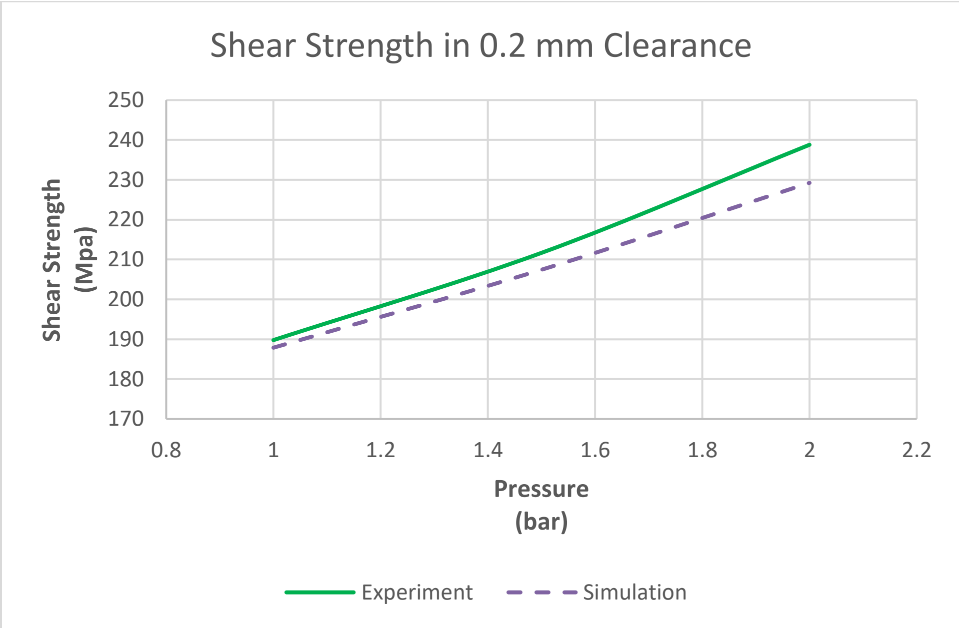
Figure 3.5 demonstrates how the shear strength of rivets improves as the working pressure of the rivet gun increases. The highest shear strength of rivets is attained while riveting with a rivet gun pressure of 2 bar and a shear strength of 230.63 Mpa. The graph's trend indicates that the higher the working pressure of the rivet gun, the greater the shear strength of the rivet [35][30].

The strain hardening process that takes place during the contact of the rivet set with the rivet shop head is what causes the substantial rise in rivet shear strength that happens as the rivet gun working pressure increases [32]. Dislocations will move and interact with one another while constructing shop head rivets. The density of the material will rise as a result of the interaction between the dislocations, making dislocation movement more challenging. The shear strength of the material on rivets and the difficulty of dislocation motion are both correlated [6][33][36][37].

The findings presented above are comparable to study by A. Manes published in a publication titled "Effect of riveting process parameters on the local stress field of a

T-joint," where pressure or squeeze force is the most important factor in determining the shear strength of rivets [28].

Figure 15. Stress vs strain graph at pressures of 1, 1.5, and 2 bar at 0.2 mm hole clearance



As the operating pressure of the rivet gun rises, the shear strength of the rivets increases (see Figure 15 above). When riveting with a rivet gun pressure of 2 bar and a shear strength of 238.79 Mpa, the shear strength of rivets can be increased to the utmost level. By analyzing the graph's trend, it can be deduced that the shear strength of the rivet greatly increases with increasing working pressure of the rivet gun [35][30].

The strain hardening process that occurs during the contact of the rivet set with the rivet shop head is responsible for the substantial rise in shear strength of rivets as the rivet gun working pressure increases [30][12][24]. Dislocations will move and interact with other dislocations during the process of manufacturing shop head rivets; this interaction between dislocations will raise the density of the material, making dislocation movement more difficult. The difficulty of dislocation motion is proportional to the material's shear strength on rivets [28].

Variations of Hole Clearance

From the simulation results that have been carried out, the shear strength test data of the rivets are shown in the following table.

Table 3. Rivet shear strength recap table

w		**Shear Strength (Mpa)**		
Hole Clearance (mm)	**Pressure (bar)**	**1st Test**	**2nd Test**	**3rd Test**
0	1	103.76	98.76	77.12

0.1	1	185.87	212.66	247.94
0.2	1	255.78	249.25	189.79
0	1.5	229.65	257.09	189.14
0.1	1.5	195.67	244.02	208.09
0.2	1.5	211.68	244.35	245.98
0	2	273.75	228.92	250.23
0.1	2	234.87	230.63	234.55
0.2	2	244.02	247.29	238.79

After recapitulating the UTS value, the lowest UTS value is chosen in the tensile testing procedure for the safety factor so that the lowest shear stress value can be found in the 0 mm hole clearance parameter at a pressure of 1 bar, specifically in the second test with the minimum shear stress value of 98.76 Mpa. In contrast, the riveting technique generates the largest shear stress in the third test, with a maximum shear stress value of 238.79 Mpa, and a hole clearance parameter of 0.2 mm at a pressure of 2 bar.

Figure 16. Hole clearance vs shear strength graph

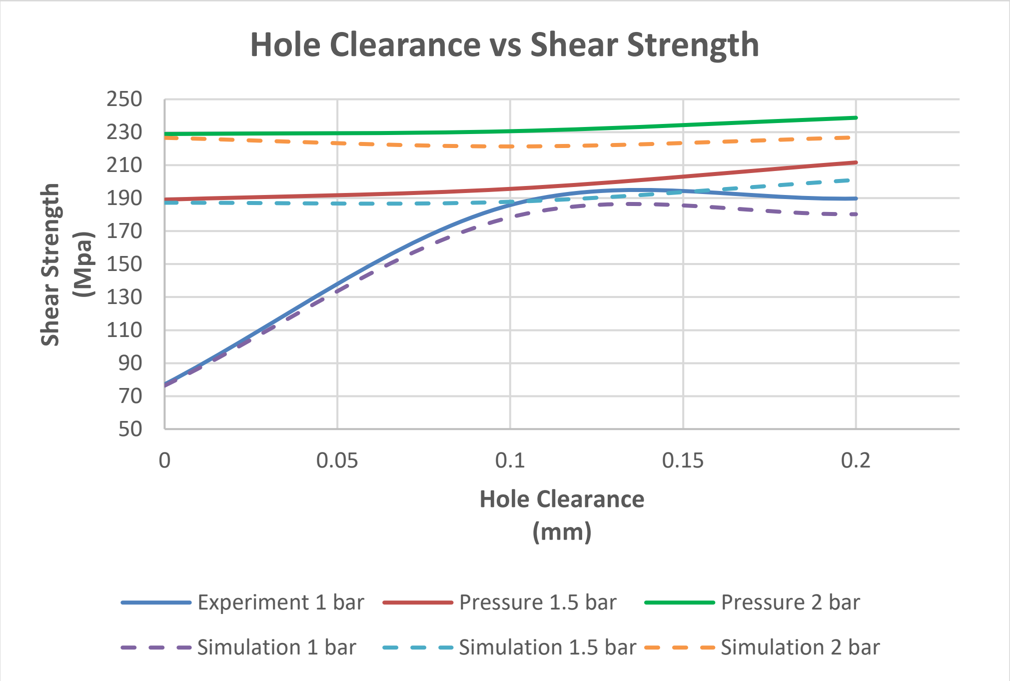


Figure 16 demonstrates a rise in shear strength of rivets as the pressure of the hole clearance dimension increases. The highest shear strength of rivets is obtained while riveting with a hole clearance of 0.2 mm at a pressure of 2 bar and a shear strength of 238.79 Mpa. The graph's trend shows that the bigger the hole clearance, the greater the shear strength of the rivet [28][35][30].

The strain hardening process that occurs during the impact of the rivet set with the rivet shop head is responsible for the considerable increase in shear strength of rivets as the hole clearance dimension increases [6][29].

CONCLUSION

This simulation's findings demonstrate how rivet shear strength is greatly influenced by the riveting parameters. The shear strength of the rivets, on the other hand, increases along with the rivet gun working pressure parameter. As the hole clearance dimension rises, the rivets' shear strength results in a similarly noticeable increase, as seen by the hole clearance parameter. During the riveting process, the strain hardening event affects how much the rivets' shear strength increases.

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