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Evaluation of Aluminium, Copper and Aluminium-30% Copper Alloy Rivets

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Abstract

This work studied the failure of rivets made from different material compositions; Aluminium, copper, and aluminium-copper alloy under the same working condition. The strength to weight ratio and other properties of these materials make them ideal materials for rivet design. Six different rivets were produced each using pure aluminium ingot, pure copper ingot and aluminium copper alloy and each of the rivet was used to join mild steel together using the same pressing force of 50 kN. Each of the joint was subjected to impact test to measure the amount of impact energy they can absorb before failure. The impact test analysis showed that copper rivets had the highest impact resistance as only partial failure occurred. Impact test analysis of aluminium rivet resulted in fracture, thereby making it a weak material for riveting when it comes to components that requires high loading force. Also, Al-30%Cu alloy has high impact resistance, but less than that pure copper. Thus, it is concluded that for application with expected impact energy < 12J, rivet made from pure copper is recommended. For application with expected impact energy < 10J, rivet made from Al-30% Cu alloy is recommended, while for application with very low impact energy < 5J, rivet made from pure aluminium is recommended.

Keywords: Rivet joint, aluminium-copper alloy, pressing force, failure test, Impact energy

1. Introduction

A mechanical joint is a part of a machine where two or more components are assembled together. Choosing the right type of mechanical joint for specific application has always remained a challenge in designing and fabricating processes. A riveted joint is a permanent joint which uses rivets to fasten two components. A rivet is a structure that has a hemispherical head on one side and a cylindrical shaft on the other. Rivet can be made from different metals and alloy like aluminium, copper, steel etc. The rivet joints have a wide range of applications ranging from aircraft bodies to high pressure boilers.

In riveted joints, depending on the amount of expected load, one or more rivet may be applied to fasten the components. When more than one rivet is applied, the rivets are positioned in a specific array that is either parallel to each other or runs in a zigzag manner. Riveted joints are strong and can handle high stress, especially in shear. However they can also fail with a high value of tension force is applied.

Aluminium and its alloy are strong, durable and light weight. In today's energy conscious society, these three basic properties combine to make the metal and its alloy the preferred material of construction for transport applications. Products like automobiles, aircraft, ships, conductors, and trains are all obvious examples. Furthermore, the light weight of aluminium and its alloy makes them a suitable rivet material (Surappa 2003). Similarly, copper metal has high ductility which makes it important for industrial application. It is the third most widely used metal in industries next to aluminium and iron. Copper has high heat dissipation and can withstand corrosion, that's why it is commonly used in ship building, steam engine firebox. For these reasons, copper are also being used as a rivet material. However, copper are more expensive than aluminium and have higher weight to strength ratio.

Numerous researchers have worked on rivet joint design, application and its failure analysis. Fitzgerald and Cohen (1994) used experimental method to investigate the riveting process. A model was developed for rivet design to achieve a very good strength. A new method was likewise developed to measure the residual stresses in and around rivets in clad aluminium plates. For this purpose, X-Ray diffraction method was employed. Residual stress values (radial and tangential components) were obtained on and near the rivet head and tail before and after riveting state. Residual stress field created by cold expansion was experimentally obtained by using the X-Ray technique. It was concluded that cold working of rivet holes is a technique which can improves the fatigue life of riveted joints. Geoffrey *et al*. (2001) evaluated the guide to design criteria for bolted and riveted joint. The study showed design criteria for riveting joints, different types of riveted joints, connections, loading conditions and design procedures. Langrand *et al.* (2002) carried out experimental studies to investigate the riveting process and to improve the design of riveted joints. They stated that complex riveting joints are considered as the sum of single riveted joints (simply 2 plates-One rivet joints).

Atre and Johnson (2004) summarized the fatigue test results for riveted lap joints with critical manufacturing process variables. The influence of under-driven and over-driven rivets, hole quality and sealant effects on the fatigue life of the joints were investigated. Test results showed under-driven lap joints to have the least fatigue strength. It was concluded that fatigue life increased with increasing rivet interference. Fung and Smart (2005) obtained the residual stress from riveting process by using thermal expansion method. By selecting different coefficients of thermal expansion of the rivet shank, height of the rivet shank was reduced and diameter of the rivet shank was increased. Reducing height of the rivet shank corresponds to the clamping force in riveting process.

D'Aniello *et al.* (2011) carried out experiment to investigate shear behaviour of riveted connection in the steel structure. The experimental investigation allowed the influence of various parameters on the response of the connection to be assessed, such as load eccentricity, variation in net area, plate width and number of rivets. The experimental results and predicted shear stress were compared in order to evaluate the reliability of the work. It was also highlighted that shear behaviour is strictly dependent on the geometry of the joints and loading conditions.

However, there is a need to explore more different material compositions for production of rivets. In view of this, this study investigated the failure of aluminium metal rivet, copper metal rivet and aluminium-copper alloy rivets under the same working condition of applying force. The work was limited to the use of mild steel as the work piece samples fastened with the rivets. Furthermore, only aluminium-copper alloy of composition Al-30% Cu only was considered.

2 Materials and method

2.1 Materials

The materials used to carry out the above procedures and their functions are outlined as follows:

- Pure aluminium metal ingot: This is used to produced Produce aluminium made rivet
- Pure copper metal ingot: This is used to produce copper made rivet. The aluminium and copper metal are also mixed in ratio 7:3 and cast to produce Al- 30% Cu alloy.

- Vanier Callipers: This is used to measure the diameter of the head and the length of the shank of the rivet.
- Weighing Scale: This is used to measure the weight of the copper, aluminium and the alloy produced.
- Cast Furnace: The casting process is carried out in the furnace.
- Machine Press: A force of 5 metric ton (50,000N) is applied to each of the rivet to join the mild steel together using the press.
- Impact Test machine: The shear stress at which each of the rivet joint failed is measured by applying an impact force from the impact test machine.
- Some journals and paper on Al-Cu alloys: Some paper, research work, previous thesis and useful textbook are consulted to know the state of knowledge on the subject matter.
- Computer numerical control lathe machine: This machine is used to produce the rivet from each of the material.
- A personal computer.

3.2 Method

The rivets were produced and used to join mild steel work piece samples of the same dimension together. A pressing force of 5 metric Ton (50,000N) was used to produce each of the rivets using a machine press. A charpy impact tester was used to apply shear stress on each of the rivet joint. The amount of force or energy absorbed by each of the rivet joint is measured and recorded. The following steps were employed in carrying out the work.

- Casting of aluminium-copper alloy ingot. The composition of alloy used is aluminium-30%copper alloy.
- Furnace charging: The composition was fed into furnace for melting and casting.
- Sand-Casting.
- Production of pure Aluminium, Copper and aluminium-copper alloy rivets.
- Rivet Design
- Impact analysis testing

3.2.1 Geometry of a rivet

The design parameters in a riveted joint are diameter of the head, the sum of length of the tail, the shank and the margin. Figure 3.1 shows the geometry of a rivet design in this work.

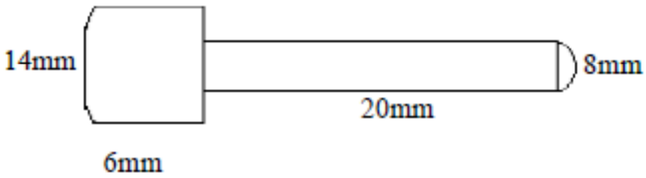

Figure 3.1. The geometry of the fabricated rivet

3.2.2 Installation of rivets

The riveting process consists of inserting the rivet in matching holes of the work piece to be joined and subsequently forming a head on the protruding end of the shank. The diameter of the hole on the mild steel is 8mm and greater than the nominal diameter of undriven rivet. The head is formed by continuous pressing using a shop press, then fastened to work piece. Figures 3.2a and 3.2b show the rivets and the work piece samples fastened using the three rivets. Figure 3.3 shows the press machine used for fastening rivets.

Copper Rivet   Aluminium Rivet   Aluminium Alloy Rivet

Figure 3.2a. Fabricated Rivets

Figure 3.2b Fastened work piece samples with the three rivets

Figure 3.3: Press machine

3.3 Rivet failure test

A riveted joint may fail in several ways. The following are the common modes of failures of a riveted joint:

- Tearing of the plate
- Shearing of the rivet
- Crushing of rivet
- Tearing of the plate at edge

In this work, failure of rivet by crushing was considered in which a crushing energy of 10 Joule (5division) on the impact testing machine was applied.

Impact testing procedure

3.4 Testing Procedure:

- Place the pendulum in the upper position.
- Move the pointer to the zero position
- Ensure that no one is in danger and then release the pendulum
- Repeat the above two or more times until the pointer ceases to move.
- Record the pointer reading from the 10ft.1b. scale
- Place the specimen in the vice as shown in figure
- Place the pendulum in the upper position
- Move the pointer to 101bs.
- When it is safe to do so, release the pendulum. Check reading.
- Mount sample, release pendulum and record the pointer reading.

Figure 3.4 shows the Charpy impact testing machine and figure 3.5 shows the sample of the work piece with the rivet tested of impact energy.

Figure 3.8: Charpy Impact Testing Machine

Figure 3.9: Sample of the work piece after Impact Test

3 Results and Discussion

3.1 Results of Impact Test

The result of the impact test from the experiment of each of the rivet materials (Aluminium, Copper, and Al-Cu alloy) is shown as follows after running series of test on; three copper riveting joints, three aluminium riveting joints, three Al-30%Cu riveting joints respectively.

3.1.1 Rivet from Copper Only

6 division on charpy Impact Testing Machine, which is equivalent to 12 Joule of Impact energy resulted in joint, giving way for bending stress (partial failure)

3.1.2 Rivet from Aluminium Only

5 division on charpy impact testing machine, which is equivalent to 10 Joule of impact energy, resulted in Total failure (Fracture)

3.1.3 Rivet from Al-30%Cu Alloy

5 division on charpy Impact Testing Machine, which is equivalent to 10 Joule of Impact energy, resulted in the joint, giving way for partial failure.

3.2 Discussion

From the result of the impact test analysis, copper rivets showed the high impact resistance as only partial failure occurred. Impact test analysis of aluminium rivet resulted in fracture, thereby making it a weak material for riveting when it comes to components that requires high loading force.

Al-30%Cu alloy has high impact resistance, making it the best material among the other two specimen (copper and aluminium rivet). Al-Cu alloy rivets are light in weight compared to that of copper rivets and in terms of mass production this is most suitable.

4 Conclusions

At the end of the experiment, the following conclusions relating to the impact test of each of the rivets are made:

- For application with expected impact energy < 12J, rivet made from pure copper is recommended.
- For application with expected impact energy < 10J, rivet made from Al-30%Cu alloy is recommended.
- For application with very low impact energy < 5J, rivet made from pure aluminium is recommended.

For cost effective production, Al-Cu alloy is best suitable for the production of rivets, because it is relatively affordable and lighter in weight than copper and its strength to resist impact force is higher compared to aluminium.

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