Influence of Mesh Sizes and Orientations on Expanded Aluminium Sheets on Tensile Performances

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Abstract. Nowadays, the demand of usage for aluminium mesh has increased in many types of applications. As a result of this trend, studies on the mesh conditions of these materials are becoming increasingly important. Based on this information, this study investigates the effect of mesh sizes and orientation of Aluminium expanded mesh sheets on their tensile properties. The experiment is carried out by using three types of Aluminium expanded mesh sheets with different mesh sizes: fine mesh (2.0 x 3.5mm), medium mesh (3.0 x 4.0mm) and coarse mesh (8.0 x 12.0mm). There are two types of mesh orientation involved for each mesh size: the original orientation (30°) and its rotated orientation (60°). According to the results of the experiment, specimens with fine mesh have higher tensile stress, which is 44.90 MPa for fine mesh specimens with a 30° orientation, compared to medium and coarse mesh sizes, which have the lowest strength, which is 7.06 MPa for coarse mesh specimens with a 60° orientation. In terms of orientation, the specimens with 60° orientation have smaller tensile stress than those with 30° orientation. However, the strain values were higher for specimens with 60° orientation than specimens with 30° orientation.

INTRODUCTION

Aluminium is the most prevalent structural metal because it makes up 8% of the earth's crust. Since its first discovery in 1808, it has been widely researched by scientists and has become one of the most used metals in the whole world [1]. The advantages of Aluminium, such as lighter weight and high ductility, have made it one of the materials used widely in many industries such as electric, construction and automotive industries [2-4]. While sheet and wire type of Aluminium is widely used for many applications, several types of aluminium design have been introduced to fulfil the industry's need. An aluminium sheet with a mesh or holes is one of the types of design introduced. Compared to typical metal sheets, woven wire mesh is a metallic fabric with considerable advantages such as lightweight, unique mechanical and thermal qualities, and the possibility for multi-functional applications. Flexible, anisotropic, inhomogeneous, and porous is a woven wire mesh criterion that exhibits different interactions between its constituent wires. Due to these distinctive properties, wire mesh behaves fundamentally differently from other engineered materials [5].

The aluminium mesh has been used in many applications nowadays, especially in engineering-based applications. The application includes reinforcing materials in composite laminates [6], thermal dissipation structure [7], hydrogen explosion suppression structure [8-10], reinforcement in concrete [11,12], etc. It is more suitable when there is a need to combine the materials or known as hybrid materials, as the mesh will enhance the bonding interface between different materials types [6,13,14].

Aluminium mesh is usually divided into expanded mesh sheet metal, perforated sheet metal, and welded/woven wire mesh. An expanded mesh metal sheet is created by splitting the sheet many times and extending it. Stretching results in a one-of-a-kind diamond pattern opening throughout the sheet and can strengthen the product structurally. Aluminium expanded metal is utilized for various industrial applications, including partitions, window guards, and various production and maintenance applications. One advantage of expanded metal manufacture is that the sheet preserves its structural integrity because it has not been stressed by being punched with forms as a perforated sheet does. The mesh-like pattern also does not unravel like woven mesh. Expanded metal is formed by stretching rather than punching, which reduces scrap metal waste and makes it more cost-effective. Besides that, there is a finding that the different mesh sizes and orientations will have different tensile behaviour, especially if combined with other materials [15,16].

As the usage of aluminium mesh is more and more popular in demand, the fundamental study focusing on the mechanical properties of these materials is as important. It has been observed that very few studies have been carried out on the effect of different mesh sizes and orientation on the tensile properties of Aluminium mesh primarily related to expanded mesh type. Based on this info, this research is conducted to study the tensile performances of Aluminium filter sheet expanded mesh due to different mesh sizes and mesh orientation.

MATERIALS AND METHOD

Materials

For this study, the materials used were Aluminium filter sheet expanded mesh with three different mesh sizes. Each of the specimens had an original orientation of 30° or a rotated orientation of 60° from the axial load. Commonly used Aluminium expanded mesh in the industry was selected for this study. The materials were obtained from Kingstore, China. Table 1 shows the material details, while Figure 1 shows the example of the expanded mesh sheet used for this study.

TABLE 1. The hole sizes of mesh for Aluminium filter sheet expanded mesh

Type	**Hole sizes (mm) SWD x LWD**	**Strand sizes (mm)**	
		Thick, d	Width, w
Fine mesh	2.0 x 3.5	0.5	0.4
	3.5 x 2.0		
Medium mesh	3.0 x 4.0	0.8	0.6
	4.0 x 3.0		
Course mesh	8.0 x 12.0	1.9	1.2
	12.0 x 8.0		

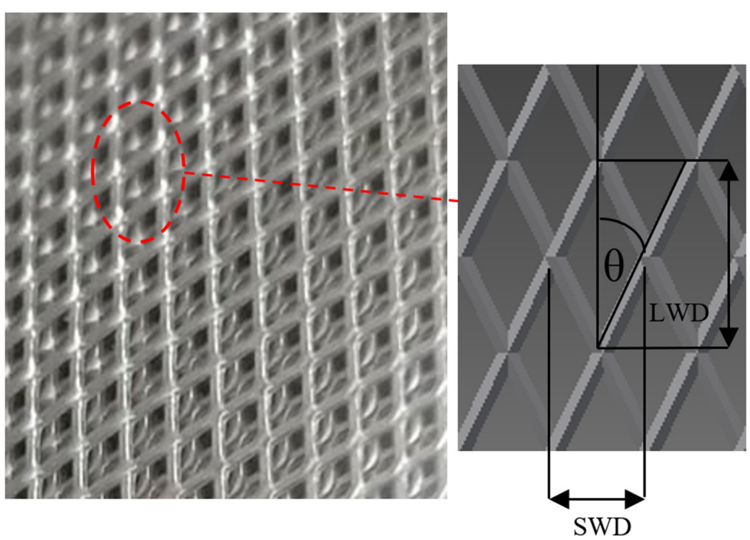


FIGURE 1. Details of Aluminium filter sheet expanded mesh.

Experimental Setup – Tensile Strength Test

Specimens were cut to the dumbbell shape following the ASTM E8 standard. There are six specimens involved in this test with three different mesh sizes: the fine, medium and coarse sizes, as stated in Table 1 and two types of mesh orientation of 30° and 60°. Table 2 shows the details of the specimen involved in this test. The gauge length between the two clamps was set at 90 mm, and an extensometer with a gauge length of 50 mm was employed to measure the elongation of the specimens accurately. This test was carried out by using Universal Testing Machine (UTM), model no. L.R. 30KPlus Lloyd Instruments LTD, located at Textile Testing Laboratory, UTHM. Figure 2 shows the specimens' experimental setup at the UTM for further understanding. Nexigen 4.1 software was used to obtain accurate readings throughout the test run. Five identical test setups were repeated for each set of specimens code to validate the result. Tensile strength, strain and young modulus were the value that was obtained and discussed from this test. From the test carried out, tensile strength can be calculated as Equation 1:

$$\sigma = P/A \tag{1}$$

Where σ is the tensile strength in MPa, P is the maximum load carried by the specimen during the tension test in N and A is the average cross-sectional area of the specimen in mm2. Tensile strain can be calculated using Equation 2.

$$\varepsilon = \delta/L \tag{2}$$

Where ε is the tensile strain, δ is the extensometer displacement at the lth data point in mm and L is the extensometer gauge length in mm.

TABLE 2. Details of specimens for the tensile test

Specimens code	Description
S30	A fine expanded mesh size of 2.0mm x 3.5mm. The orientation of the mesh is 30°
S60	A fine expanded mesh size of 3.5mm x 2.0mm. The orientation of the mesh is 60°
M30	A medium expanded mesh size of 3.0mm x 4.0mm. The orientation of the mesh is 30°
M60	A medium expanded mesh size of 4.0mm x 3.0mm. The orientation of the mesh is 60°
B30	A coarse expanded mesh size of 8.0mm x 12.0mm. The orientation of the mesh is 30°
B60	A coarse expanded mesh size of 12.0mm x 8.0mm. The orientation of the mesh is 60°

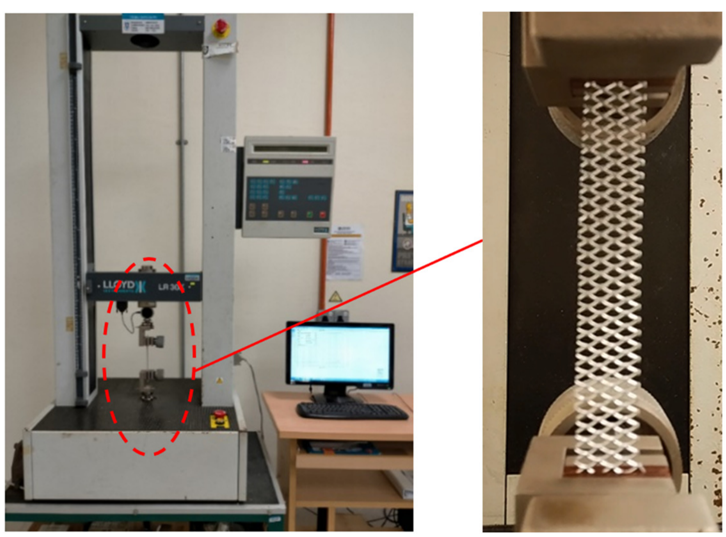


FIGURE 2. Experimental setup of tensile strength test

RESULTS AND DISCUSSION

Tensile Behaviour

Figure 3 shows the stress-strain curve for all specimens. Based on the graph, it can be concluded that the specimen with a 30° orientation has a higher stress value than the specimen with a 60° orientation. However, the stress value for specimen 30 rapidly increases and fails suddenly when it hits the maximum stress value.

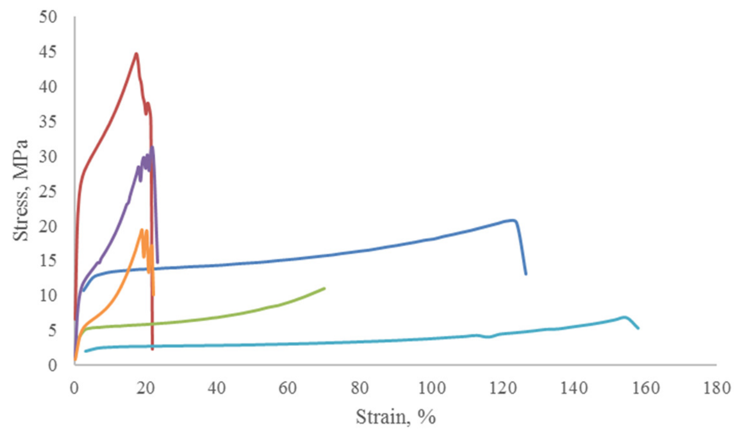
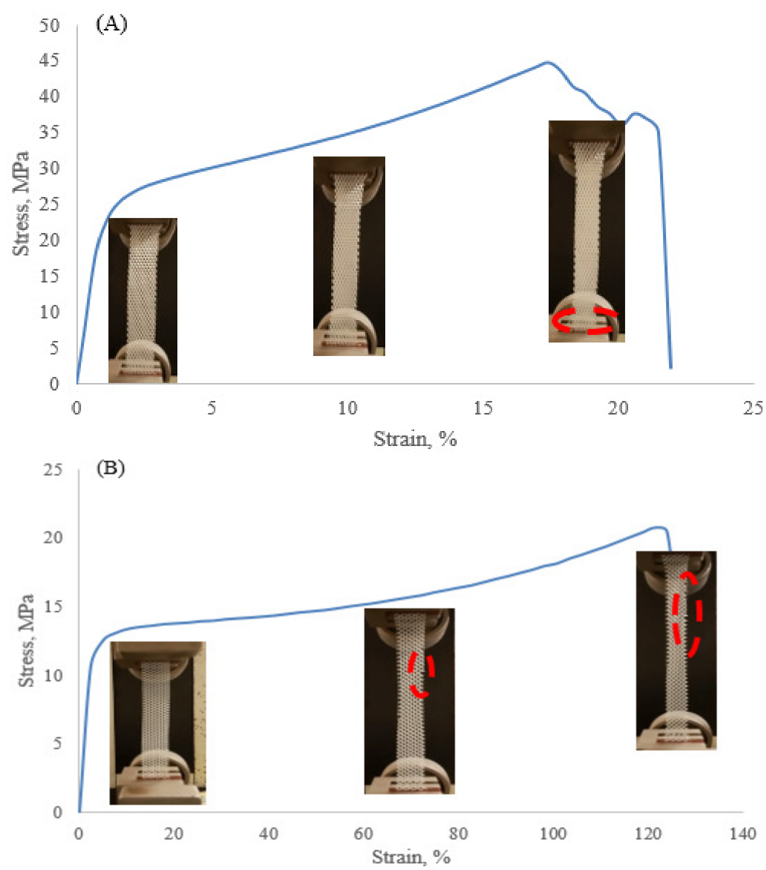


FIGURE 3. Stress-strain behaviour of all specimens.



s

FIGURE 4. Stress-strain curve and specimens elongation during tensile test (A) S30 (B) S60.

In contrast, a specimen with a 60° orientation slowly elongates depending on the load applied until it reaches maximum tension, as depicted in Figure 4. Although the stress value for this specimen is lower than the 30° orientation specimen, the nature of the material with a more excellent strain value permits it to be employed for applications requiring significant energy absorption. Based on observations, it was found that specimens with 60 degrees of orientation began to experience failure from the wire-breaking process at the edges of the specimens. The more it was pulled, the strand was broken slowly, one by one. The breaking behaviour of this specimen is different compared to the specimen with a 30° orientation, where the breaking usually starts at the necking strand between the mesh and causes the sudden break of the specimens after fewer strand breaking, as shown in Figure 4. All the specimens under different mesh sizes also showed the same breaking behaviour as the fine mesh size specimens, as shown in Figure 5. The significant SWD value for specimens with 60° orientation also causes the time taken for the displacement process to be long before failure takes place. The failure was caused by the maximum strain along the loading width that was achieved until the specimens broke. The failure scenario also had been found in past studies [17]. This combination results in a higher strain to failure, which is advantageous in structural engineering applications where large deformations are present as strain to failure is more critical than strength [18].

Tensile Performance

Figure 6 illustrates the value of stress, strain, and tensile modulus for all fabricated specimens. The graph in Figure 6(a) and Figure 6(c) shows that the specimen with a 30° orientation has higher stress and tensile modulus than specimens with a 60° orientation with 44.90MPa and 3.54GPa for specimens S30 compared to specimens B60 with a stress value 7.06MPa and 0.07GPa of tensile modulus. However, the strain in Figure 6(b) is better for the specimens with a 60° orientation. The difference in the strain value between specimens with 30° orientation and 60° orientation is up to 8 times higher. The highest tensile strain is recorded at 1.59 for B60, while the lowest of 0.17 is recorded for S30.

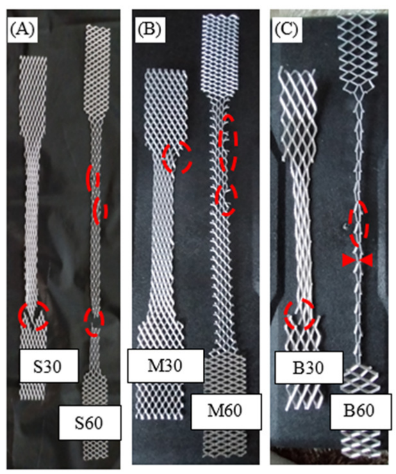


FIGURE 5. Difference of breaking behaviour of specimen with 30° and 60° orientation (A) fine mesh - S code (B) medium-mesh – M code (C) coarse mesh – B code.

CONCLUSIONS

In this experiment, six types of specimens with different mesh sizes and orientations were tested under the tensile strength test. From the result obtained from the test conducted, the findings can be summarized as follow:

a) The specimens with fine mesh size have a higher stress value compared to medium and coarse mesh sizes.
b) Specimens with a 30° orientation had higher tensile strength and tensile modulus than specimens with a 60° orientation. However, specimens with 60° orientation have higher tensile strain than specimens with 30° orientation. This phenomenon was rather valuable as the specimens will take more time to fail than specimens with 30° orientation.

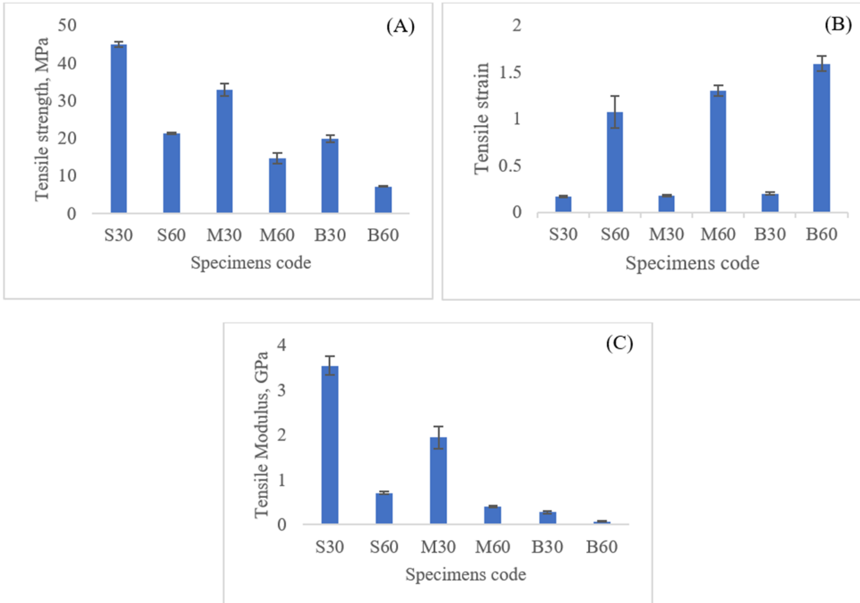


FIGURE 6. Tensile value for all specimens (A) Strength (B) Strain (C) Modulus

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