Reinforcement with natural fibers instead of perlon in the manufacture of prostheticsockets

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Abstract
This research focuses on replacing perlon with natural materials in the manufacture of prostheses, which are more comfortable, less expensive, and available in local markets. The manufactured model was used in the Rehabilitation Center for the Disabled and Prosthetic Limbs in the city of Kut, group B (4 perlon, 1 carbon fiber, 4 perlon), as the basis for comparison with the proposed model, group W (4 burlap, 1 carbon fiber, 4 burlap), and comparison of the two groups with sockets made of polypropylene. Tensile testing was used to determine the mechanical characteristics of the sockets. The B group has a yield stress of 36.5 MPa, an ultimate strength of 45.11 MPa, and an elastic modulus of 9.19 GPa, respectively, while for the W group, these values were 35 MPa, 43.78 MPa, and 5.74 GPa. The fatigue test was used to evaluate the failure characteristics of the socket. An F-socket was utilized to test the interface pressure between the residual limb and the socket. Tekscan sensor The pressure in the medial region is 350 kPa, while the pressure in the posterior region is 330 kPa. The failure safety agent for the composite material for group B was 2.38, while the fatigue safety factor for the composite material for group W was 2.33. It is all considered safe and successful for design purposes. The maximum stress, safety factor, and total deformation were observed using the finite element technique (ANSYS Workbench 14.5) to analyze and evaluate the fatigue characteristics.

Keywords: prosthetic sockets, Burlap, (BK) amputation, Perlon

1.Introduction

In the past, walkers, wheelchairs, wooden pegs, and crutches were the available alternatives for those who had lost a lower leg. Individuals with this handicap can now profit from medical research and technological breakthroughs by using smart lower limbs. [1,2]. Accidents or limb disorders are common causes of lower limb amputations. The main purpose of a prosthetic socket, leg, and foot is to restore missing bone framework, function, and muscles of the foot, ankle, and patellar muscles, as well as the structure and muscles of the ankle, pylon, and foot. [3]. Recent years have witnessed a remarkable development in the manufacture of prostheses and the quality of the materials used in their manufacture. In this research, the focus was on the artificial socket, where Prolon, which is an industrial material that may have side effects on the patient's health or comfort from wearing the prosthesis, was replaced by burlap, which is a natural material with acceptable properties and classified as natural polymers, as the results proved it was a successful alternative. The best materials are polymer composites because they have excellent mechanical characteristics and are simple to produce. The idea of creating hybrids out of polymers and inorganic or organic elements has drawn a lot of interest [4, 5]. Composites are commonly known as the collection of a matrix and fillers that have at least one material with special properties different from those of the individual ingredients [6]. The substance that has been infused into the matrix to provide the composite with its benefit (often strength) is known as the filler. Carbon fiber, glass beads, sand, or ceramic can all be used as fillers. [7].

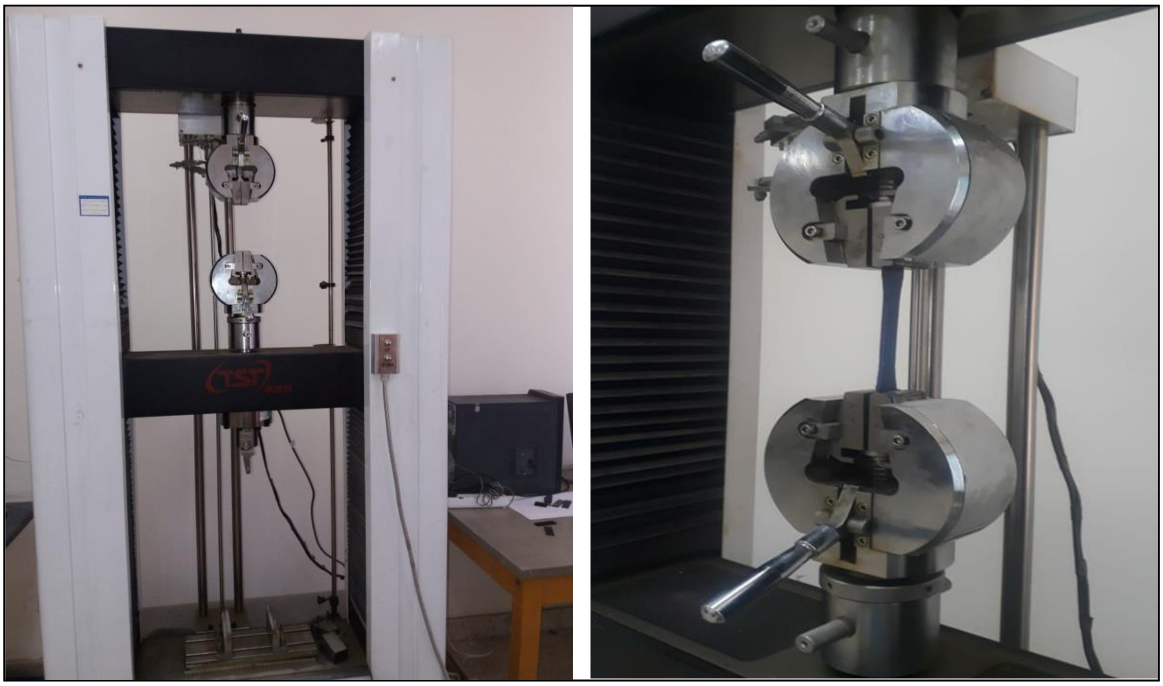
2. EXPERIMENTAL STEPS

2.1. Materials

The prosthetic socket that is the subject of this research is made from matrix lamination resin 80:20 (polyurethane) reinforced with burlap, carbon fiber, and perlon, and solidified using hardening powder. The test samples are prepared using a vacuum apparatus and polyvinyl alcohol (PVA).

2.2. Tensile and Fatigue Test Samples

The tensile test was performed on the samples under test in order to know their mechanical properties. The test was conducted using the WDW-100 test machine shown in Figure 1, where the modulus of elasticity, yield strain, and ultimate stress of the materials utilized in the manufacture of prosthetic limb sockets were calculated. used a computer-numerical control machine (CNC). To cut it [8] for each sample according to ASTM D638(I) dimensions [9], The samples were tooled as shown in figure 2. A tensile test was carried out on the samples at room temperature at a speed of 1 mm/min by means of a tensioning machine with a load capacity of 5 N. [10]



(a) Testing machine. . (b) During test

Figure 1: Mechanical testing machine.

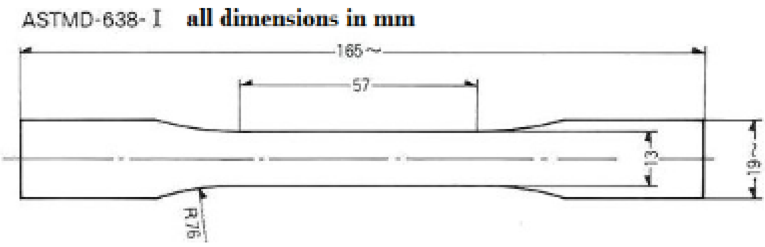


Figure 2. Specimen for tensile test.

The fatigue test is performed on five samples for each laminate [11]. These samples have lengths of 100mm and widths of 10mm, with thicknesses varying according to the layup. The fatigue sample is depicted in Figure 3.

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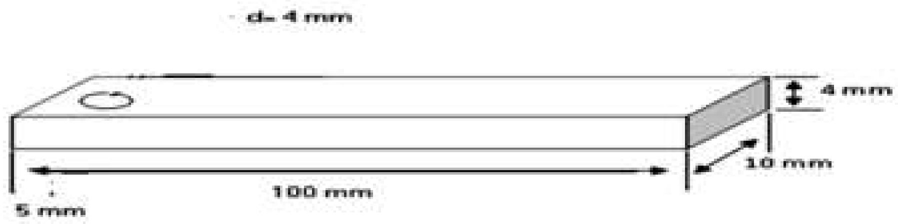

Figure 3: Dimensions of the fatigue test specimen.

Fatigue testing machine Figure 4 shows an application of alternating bending stress with constant amplitude. The specimens are subject to deflection columnar to the axis of the specimens on one side, and the other side is clamped, resulting in the occurrence of bending stresses. [12]

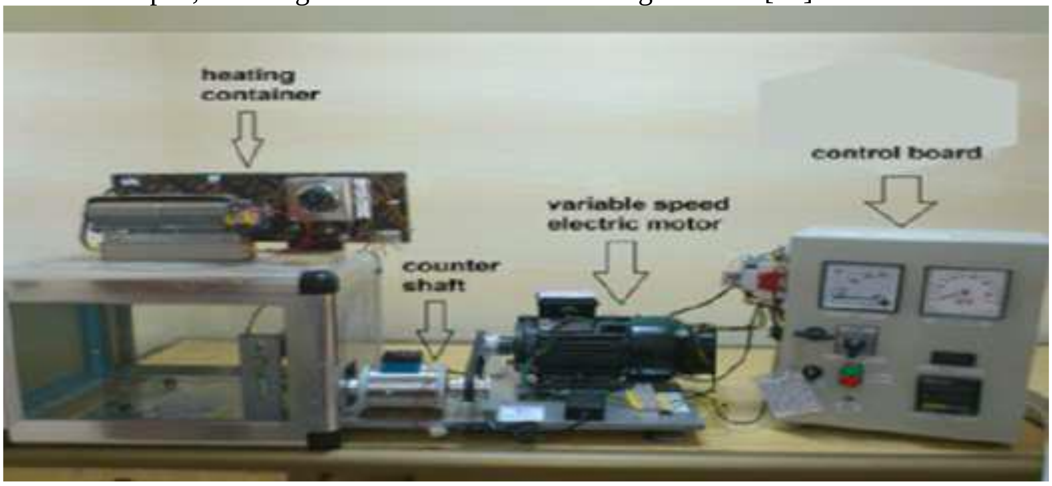

Figure4: Fatigue device

2.3. Fabrication process for the specimens.

The samples were manufactured in a manner similar to that used in making prosthetic sockets, using the vacuum technique to prevent defects and cavities, in order to calculate the mechanical characteristics of the materials under study, which are made of composite materials. The first step is to make a gypsum template with measurements of 20, 10, and 10 cm. A thin layer of polyvinyl alcohol (PVA) is then applied to the mold and drawn against the mold by a vacuum. Then multiple reinforcing layers are applied in the next stage. A second PVA coating is applied to the mold, which has an upper inlet for liquid plastic. Next, 80:20 polyurethane lamination resin with hardener is added. After curing with resin, cubic composite materials are obtained. And then it will be cut to the required dimensions of the samples.

2.4.The F -Socket Test

One of the most popular methods for determining the pressure inter the socket and the residue limb is the piezoelectric F-socket interface compression monitoring device. [13] The assessment of the interface pressure inter the residual limb and the socket utilizing the F-Socket is thought to be of utmost significance. This evaluation is a key barometer of amputees' contentment and comfort. [14]. acting with F-Socket includes:

1. As illustrated in Fig. 5 [15], the sensors are initially placed on the patient's stump (the anterior portion) or within the prosthetic socket.
2. The apparatus begins to record the patient's movement as soon as they begin to move. The apparatus is tracking the applied pressure as the patient moves.
3. re-testing, but this time placing the sensors on the other three sides of the leg (lateral,medial, and posterior). The distribution of interface pressure was measured by partitioning the residue limb into three sections, as reported by Convery et al. [16]. A test was taken at Al-Nahrain University.

Figure 5 Patient with Tekscan sensor

3. Results and Discussions

3.1. Results for Tensile Properties

The predetermined mechanical characteristics of the laminations utilized are offered in Table 1. The stress-strain graph for all lamination is depicted in Figure 6. The results show that the attributes of group (w), when employing one layer of carbon fiber in the middle with four layers of burlap on both sides,raise yield strength by 28.67% and ultimate tensile strength by around 17.4%, and increase E by 363% when compared to the control group (Group pp). But using one layer of carbon fiber with four layers of perlon on both sides of group (b) results in an increase in yield strength of 34.2%, the ultimate tensile strength of 20.9%, and a 641% increase in E. These mechanical properties for sampls vary due to the inclusion of carbon fibers with distinctive properties, as well as burlap and perlon.

Table 1: Evaluation of mechanical characteristics using stress-strain curves

Groups Name	**Reinforcement**	**Yield Stress** Mpa	**Ultimate Strength** Mpa	**Modulus Gpa**	**Thickness (mm)**
White W	4Bu 1Cf 4Bu	35	43.7821	5.743	6
Blue B	4p 1Cf 4p	36.5	45.1128	9.193	3.3
Polypropylene [17]**(pp)**	Sheet	27.2	37.3	1.24	6.**0**

Burlap (Bu)

Perlon (Pr)

Carbon fiber (Cf)

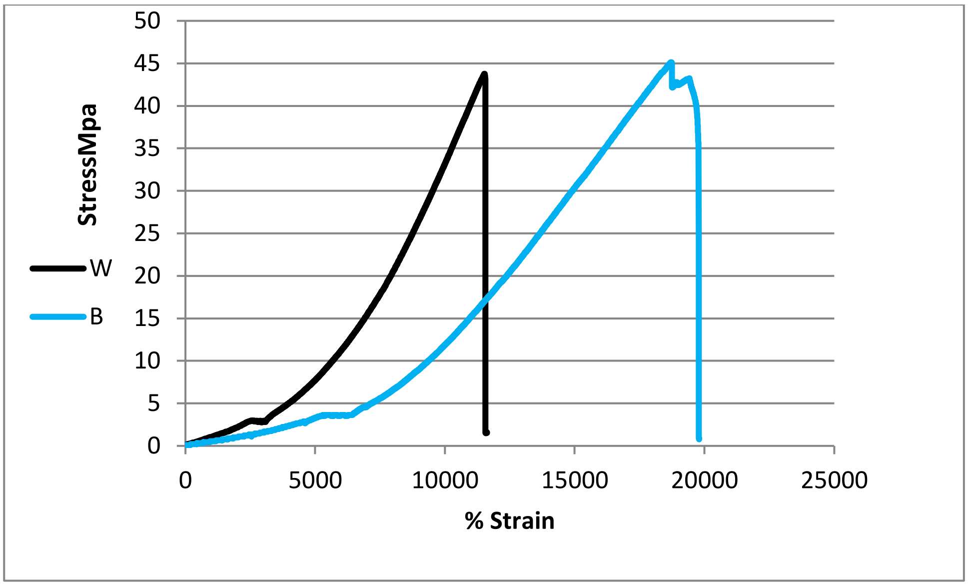

Figure 6-Each lamination's stress-strain curve

3.2. Results of Fatigue Properties

Flat-sample stress failure can occur when the sample is smashed under periodic stress. The results of the fatigue tester revealed the number of cycles during which the samples were broken. Figure 7 shows the S–N graphs for each specimen from all laminations. Reduces failure stresses while increasing the number of failure cycles. at the same temperature.

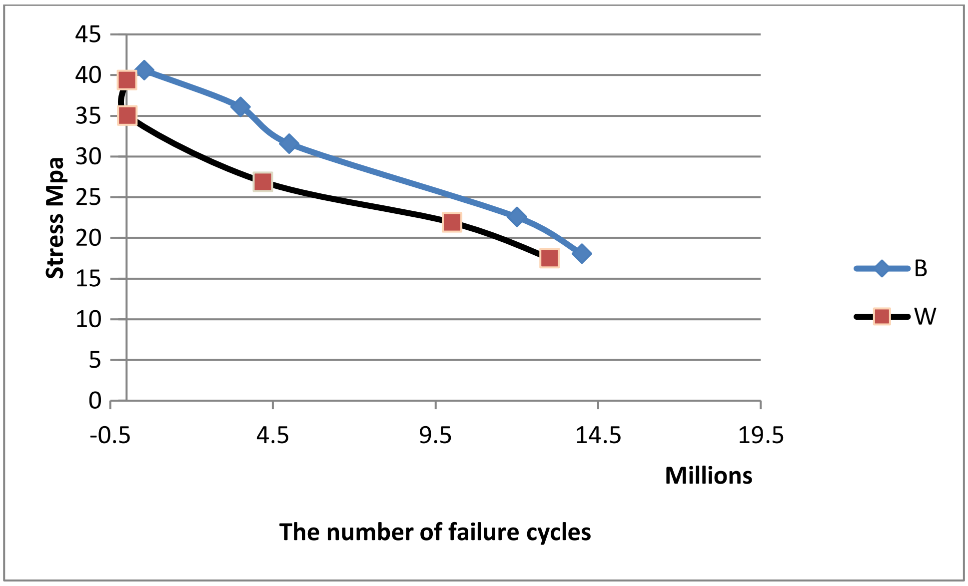

Figure 7 For each lamination, S-N curves

3.3. Result of Interface Pressure

The F Socket Sensor may be used to gauge the pressure at the interface between the patient's stump and the socket. To measure the applied pressure curve, a computer program called F-Scan drives the sensor. As seen in Figures 8–11, the sensor was placed on the stump's anterior, lateral, medial, and posterior surfaces. Table 2 provides specifics on the placements and pressure levels on the socket. 350 kPa of higher pressure is rising in the medial area, while 330 kPa is emerging in the posterior region. The reason for this is that when the patient moves, the medial and posterior muscles are more active, which prevents pressure from building up at the tibia's anterior and lateral areas.

Table 2 Interface pressure values for prosthetic sockets .

Region	**Interface Pressure Distribution (KPa)**	Socket Group
Anterior	220	Upper
	180	Middle
	155	lower
Lateral	155	Upper
	150	Middle
	110	lower
Medial	215	Upper
	350	Middle
	290	lower
Posterior	330	Upper
	250	Middle
	225	lower

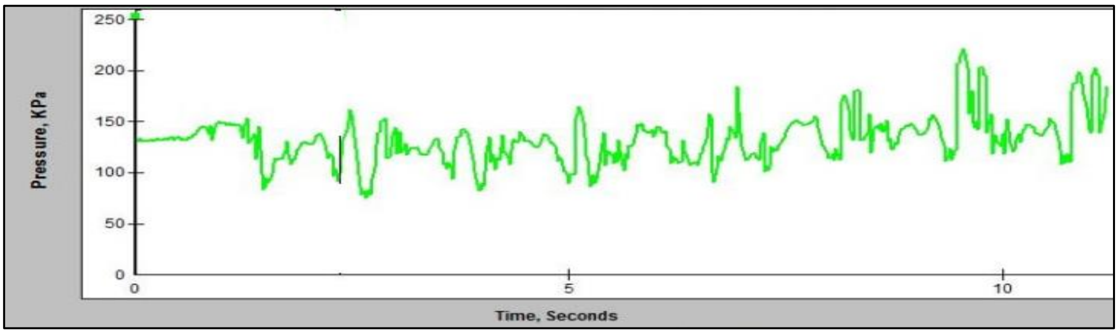

Figure 8 The Interface pressure at anterior region of the socket vs. Time

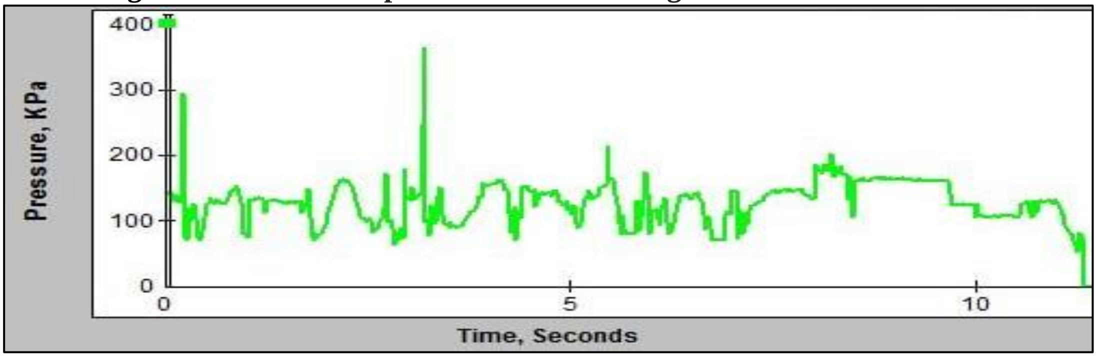

Figure 9 The Interface pressure at medial region of the socket vs. Time

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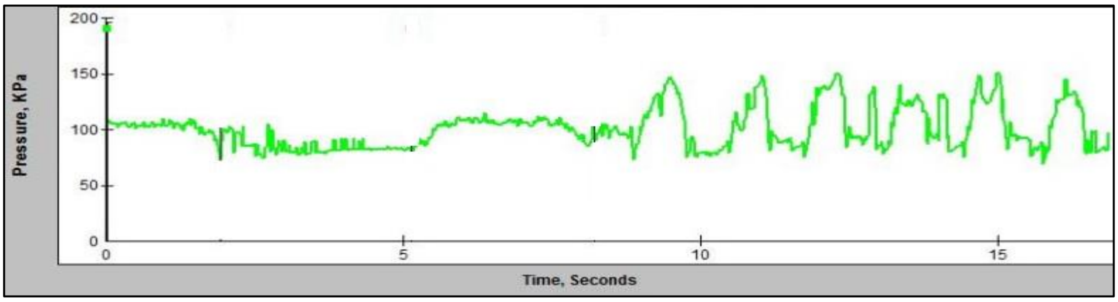


Figure 10 The Interface pressure at **lateral** region of the socket vs.

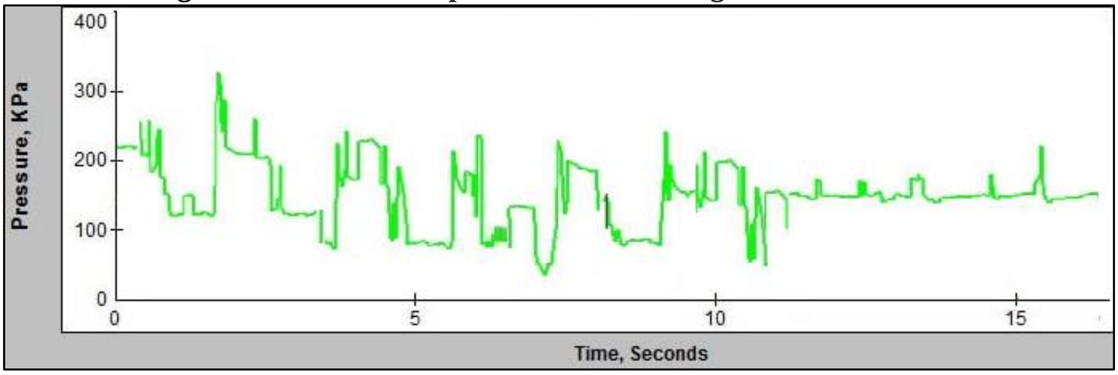
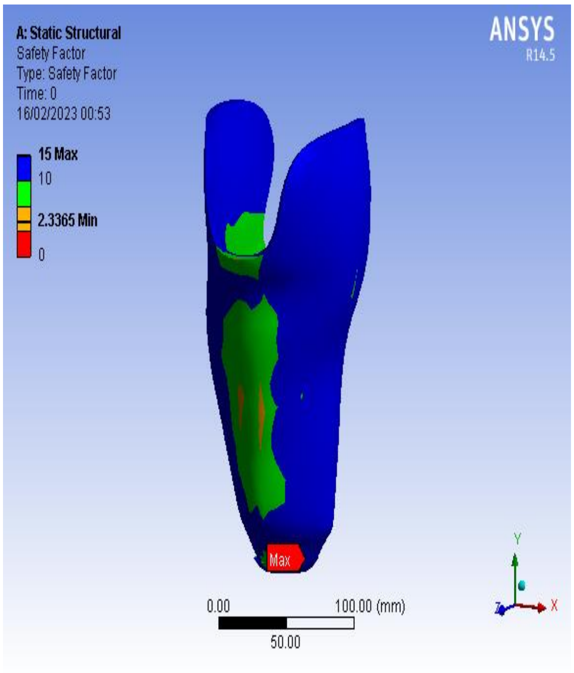


Figure 11 The Interface pressure at **posterior** region of the socket vs.

3.4. Numerical Results



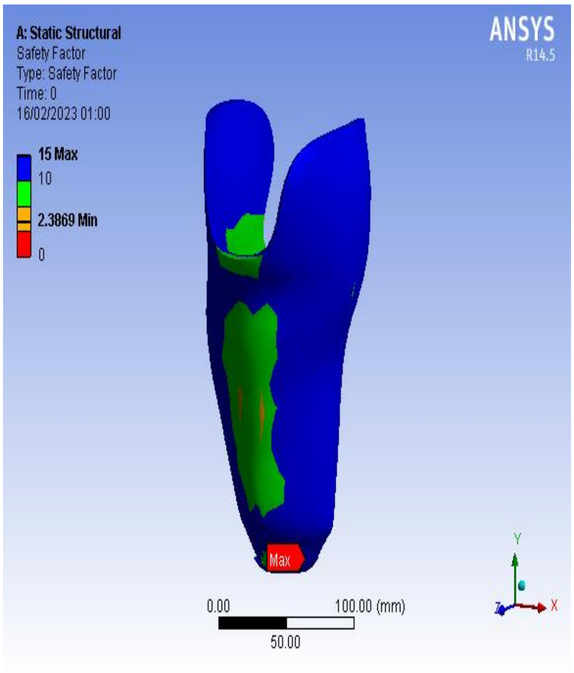


Figure12. The safety factor for fatigue Group W Figure 13. The safety factor for fatigue GroupB

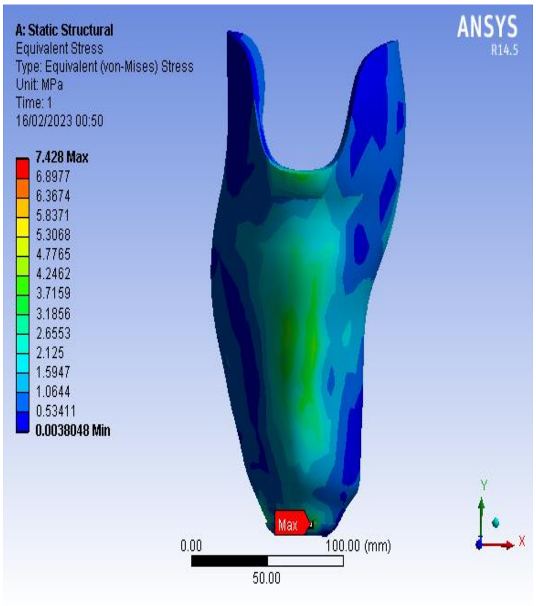


Figure 14. Von-Mises stress for Group W

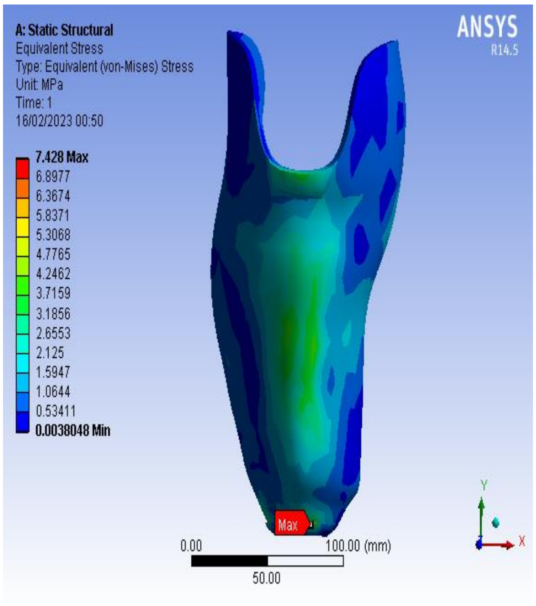


Figure 15. Von-Mises stress for Group B

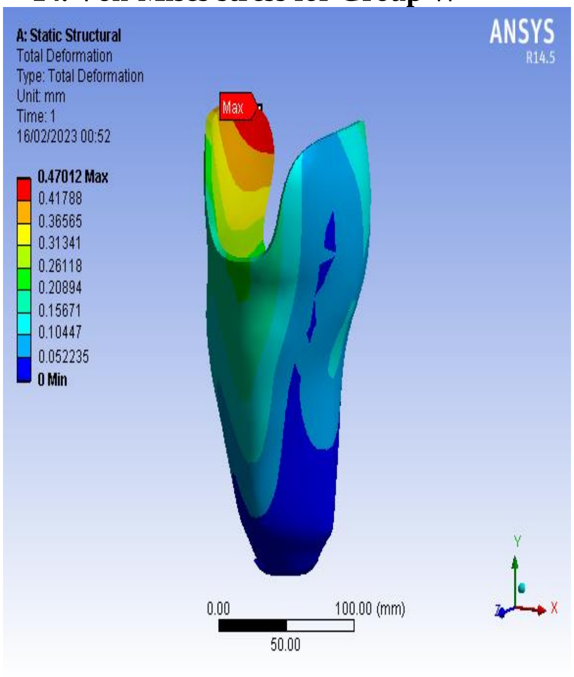


Figure 16 Total deformation Group **W**.

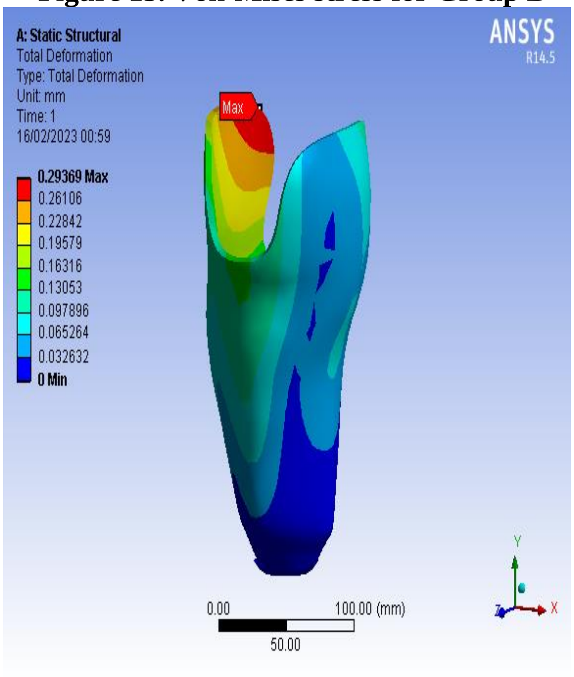


Figure 17 Total deformation Group **B**

4. CONCLUSIONS

The values of yield stress, modulus of elasticity, and ultimate tensile strength of the mechanical properties improved by about 28.67%, 363%, and 17.4%, respectively, when using a layer of carbon fiber with four layers of burlap on both sides in the W group compared to the PP group. However, group B, the group used in the Rehabilitation Center for the Disabled and Prosthetic Limbs in Kut City, showed an improvement in the values of yield stress, modulus of elasticity, and ultimate tensile strength of the mechanical properties of 20.34%, 641%, and 20.9%, respectively, when using a single layer of carbon fiber in the middle with four layers of perlon on both sides. It is clear that group (w) has a higher endurance limit stress value. Therefore, the patient's socket will last longer, and therefore burlap can be considered a successful alternative to perlon in group (B) because of the natural properties of burlap, as it is more comfortable, less expensive, and available in local markets. Since the medial and posterior muscles are more active when the patient moves, the higher interface pressure at the medial area of the socket is 350 kPa and the posterior region is 330 kPa, preventing pressure at the tibia's anterior and lateral regions. The fatigue safety factor for group B in the below-knee composite material socket model was 2.39, and group W was 2.34, which is regarded as safe by design.

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