Computer simulation of horse shoes made of polymeric composite subjected to external loading

Bustami Syam¹, Maraghi Muttaqin¹, REK Siregar¹ and Fakhrur Rozy²

¹Impact and Fracture Research Center, Department of Mechanical Engineering, Faculty of Engineering, Universitas Sumatera Utara
²Mechanical Engineering, Universitas Sumatera Utara

*Email: bstsyam@gmail.com

Abstract. A horse shoe is designed to protect a horse's hoof from wear. Like the human shoes, the horse shoes should also meet the ergonomic design, i.e. strong enough to withstand external loadings, comfort, and safe. Conventional horseshoes made of iron, for example, have good mechanical properties, but they are not comfort enough for horses due to its higher weight to size ratio. The internal stresses due to the external loading of the shoes to the soil surface, rocks, asphalt or hard surface will transfer the force of the horse's foot pounding against the horse's foot, so that it can hurt the horse's foot if used for a long time. Therefore, a new research on polymeric foam alternative materials is the main concern to reduce existing problems. The purpose of this study was to conduct a static loading simulation of horse shoes made of polymeric foam reinforced with glass fiber using ANSYS software. In the simulation specimens are modelled with SolidWorks. The aims are to determine the stress distribution of to two horse shoes models. It was found that the stresses on z-direction for both commercial and polymeric composite horse shoes material were not significantly difference in values. Stress in z-direction constitutes the bending stresses due to external loadings. The stress contours on both modes are also similar. The stress concentration occurs around the vicinity of the shoe connectors. The maximum normal stresses in z-direction at those locations for steel and polymeric composite are 7.819 MPa and 7.850 MPa, respectively. Comparing those stresses with the static tensile strength of both materials we may conclude that both horseshoe structures are acceptable to be used. However, in terms of the applicability the one made of polymeric composite are more easily to be used.

1. Introduction

Horse shoes are designed to protect a horse's hoof from wear. Currently, horse riding sports are popular because not only for sports or hobbies but also has entertainment value. Therefore, it can be said that horse riding is an entertainment sport that can be enjoyed by anyone. Generally, horseshoes are made of steel and aluminum. Conventional horseshoes made of metals, have good mechanical properties, e.g. tough and other structural stability qualities; however, they are not comfort enough for horses. The nature of the impact on the soil surface, rocks, asphalt or hard surface will transfer the force of the horse's hoof during the installation of the shoes. They may also hurt the horse’s foot if they are used for a long time [1]. Another problem is that the wear rate of the steel material is high enough so that it may shorten the its wear life. Wear occurs due to the friction contact between two objects which causes the movement of material. Besides, as described earlier the heavy steel horseshoe may
limit the flexibility of the horse's hoof. Engineering horse shoes from alternative materials such as polymeric foam materials is a major concern to reduce existing problems. In our laboratory, we have used so-called polymeric foam for some lightweight structural products, such as helmets, traffic cones, parking bumpers and car bumpers [2-4]. In this paper, the research objectives are to determine the stresses experienced by horse shoes that occur due to static compressive loads using simulations for both materials made of steel and polymeric composite foam.

2. Research method

2.1. Material
As shown in Figure 1, horse shoes are designed to be able to accept external loads in such a way as to meet technical and manufacturing requirements. For this, we chose a newly developed material at our research center that is lightweight and strong enough to withstand external loadings.

![Figure 1. Horse shoes.](image)

There are several classes of polymeric foam materials [5]. In this study, we choose type C where the physical and mechanical properties of the material are shown in Table 1.

| Specimen | $S_{uc}$ (MPa) | $S_{ut}$, (MPa) | Poisson ratio | $E$ (MPa) |
|----------|----------------|----------------|---------------|-----------|
| C        | 19.1           | 19.3           | 0.3           | 221.8     |

2.2. Geometry of horse shoes
This study uses a U-shaped horse shoe model, which is the most common model in the field. The following figure shows a sketch of a horse shoe in 2 and 3 dimensional models.
3. Result and discussion

3.1. Load model

The load applied to the horse shoe contact area is shown in Figure 4. The numerical calculation is focused on the stress distribution using commercial FEM software, with 3-D elements. For both models we also calculated stresses in x, y and z direction. We are also providing result of equivalent stress, Let's examine the stress contours of the model one by one.

**Figure 2.** 2 dimensional horse shoe model.

**Figure 3.** Horse shoes model (a) commercial horseshoes made of steel (b) model made of polymeric foam.

| B: Perforated Static Pressure | A: Static Pressure |
|------------------------------|-------------------|
| Pressure                     | Pressure          |
| Time: 1, s                   | Time: 1, s        |
| 2009/09/2019 16.25           | 2009/09/2019 16.24|
3.2. Stress contour

Figure 5-8 shows the stress distribution in the x, y, z directions. The equivalent stresses were also calculated and the results were shown in figure 8. Table 2 shows the results of numerical calculation for both models. It is shown that the stresses on z-direction for both commercial and polymeric composite horseshoes material were not significantly difference in values. Stress in z-direction constitutes the bending stresses due to external loadings. The external loadings are load applied to the upper surface of horseshoe models, as shown in figure 4. The stress contours on both modes are alike (Figure 8). The stress concentration occurs around the vicinity of the shoe connectors. The maximum normal stresses in z-direction at those locations for steel and polymeric composite are 7.819 MPa and 7.850 MPa, respectively. Comparing those stresses with the static tensile strength of both materials we may conclude that both horseshoe structures are acceptable to be used. However, in terms of the applicability the one made of polymeric composite are more easily to be used. Because we may provide the horseshoe cover. The horseshoe plate is inserted into the cover, as shown in Figure 9.

| Horseshoe                  | Weight (kg) | Equivalent Stress (MPa) | Stress x Axis (MPa) | Stress y Axis (MPa) | Stress z Axis (MPa) |
|----------------------------|-------------|-------------------------|---------------------|--------------------|--------------------|
| Steel                      | 0.753       | 7.076                   | 3.167               | 2.964              | 7.819              |
| Polymeric foam composite   | 0.0719      | 7.034                   | 3.315               | 3.274              | 7.850              |
Figure 5. Normal stress x axis for horse shoes (a) made of steel (b) made of polymeric foam.

Figure 6. Normal stress y axis for horse shoes (a) made of steel (b) made of polymeric foam.

Figure 7. Normal stress z axis for horse shoes (a) made of steel (b) made of polymeric foam.
4. Conclusions
It was found that the stresses on z-direction for both commercial and polymeric composite horseshoes material were not significantly different in values. Stress in z-direction constitutes the bending stresses due to external loadings. The stress contours on both modes are also similar. The stress concentration occurs around the vicinity of the shoe connectors. The maximum normal stresses in z-direction at those locations for steel and polymeric composite are 7.819 MPa and 7.850 MPa, respectively. Comparing those stresses with the static tensile strength of both materials we may conclude that both horseshoe structures are acceptable to be used. However, in terms of the applicability the one made of polymeric composite are more easily to be used. Because we may provide the horseshoe cover. The horseshoe plate is inserted into the cover, as shown in Figure 9.

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