

A study on the Method of Manufacturing Horseshoe using Polycarbonate and the Analysis of Mechanical Properties of Horseshoe

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Abstract

This study proposes a method of manufacturing horseshoe using Polycarbonate by utilizing certain characters of Polycarbonate as a material. An injection mold for the horseshoe was made first, and it is installed on the molding machine. Thereafter horseshoe is manufactured according to the injection molding conditions. Also, this study acknowledged the valid durability and strength of the horseshoe by applying the values of mechanical properties to analyze the strength using FEM(finite element method).

Key words: polycarbonate horseshoe; injection molding horseshoe; FEM strength analysis;

INTRODUCTION

Horse riding is an activity that moves in the velocity and direction according to the rider's will. There are four methods of horse riding, or horse gait, which are walk, Trot, canter, and gallop. Generally walk and trot is related to the rider position, while canter and gallop is used in actual horse riding game.[1] Walk, which is the most slow horse gait, has 110m/min velocity by landing the horses' feet separately, known as four-beat.[2] Trot is faster than walking with 220m/min velocity and the feet is symmetrically landed in turn, known as two-beat.[3] Canter and gallop both are relatively faster movements of the horse with 340m/min and asymmetrical three-beat movement. The body part which makes contact with ground in all four movements is the hooves of the horse. Horse hooves needs to support both the jockey and its weight as well as the force of impact. Such is the reason that the wall of the hooves gains damage frequently. To solve this issue, a horseshow made of metal is fixed to the hooves with a nail for substantial time. The original design of the horseshoe weighed approximately 450g, and needed a long nail to maintain the heavy weight of the horseshoe. Consequently the sharp end of the nail gave damage to the parts other than the wall of the hooves. Additionally, the metal made horseshoe was, and still is complex problems in creating the product. The reason is that in the past, the horseshow had to be hand-made, and in present, the forging and heat-treatment has to be done parallel in order to keep the

stiffness and hardness of the horseshoe.

This study uses Polycarbonate material to produce the horseshoe to solve these problems of metal made horseshoe. The three mechanical properties, modulus of elasticity, max tensile strength and max compressive strength of Polycarbonate is 6.9 GPa, 117.2 MPa, 117.2 MPa each, and the molding temperature and its density is 135°C, 1.35g/cm³. The mechanical properties are similar to those of metal, but the molding temperature is considerably lower, therefore the molding process becomes simpler along with the light weight of Polycarbonate than metal. The study proposes the use of Polycarbonate to manufacture the horseshoe. Therefore an injection molding for the horseshoe was made first, and the mold is installed to the molding machine. Thereafter horseshoe is manufactured according to the injection molding conditions. Also, this study acknowledged the valid durability and strength of the horseshoe by applying the values of mechanical properties to analyze the strength using FEM(finite element method). As a result the manufacturing process was simpler than original metal-made horseshoe and the weight was 8 times lighter (69g), therefore it has several advantages than the original product.

INJECTION MOLDING MANUFACTURING

Injection molding is a process of creating a form made of plastic fusion material melted by heat and injecting the material to a certain shape of mold. For the study, polycarbonate material was used in injection molding. As a thermoplastic resin, polycarbonate has the following characteristics. First it is light brown and transparent in natural state, and has high value of tensile strength, flexural strength, impact strength. Also it has high resistance to heat (heat distortion temperature of 135°C~140°C), as well as low temperature (up to -100°C). Its characteristics are very similar to that of metal used in horseshoe. Figure 1. (a), (b) shows the design of the mold of front and back horse hooves for Polycarbonate horseshoe injection molding. Here, the material for the mold is heat treated high carbon steel S50C.

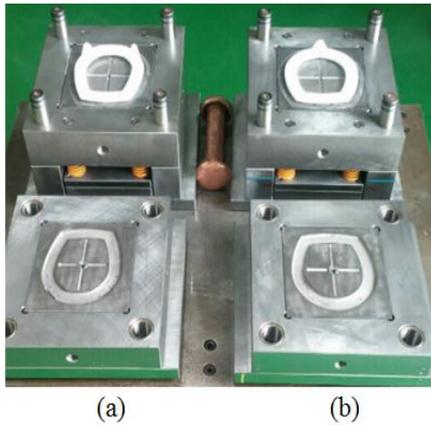


Figure 1: Injection Mold for Polycarbonate Horseshoe

Figure 2 is the Polycarbonate horseshoe made by injection molding. Figure 2. (a), (b) shows the horseshoe for front and back horse hooves. Additionally, the study conducted the molding process under the molding temperature of 50°C and injection molding temperature of 270°C~ 280°C. The mold of manufactured horseshoe is modified and complemented to fit the tolerance of the product design, and the molded form of the horseshoe is met with the molding conditions.



Figure 2: Molded Polycarbonate Horseshoe

Figure 3. (a), (b) shows the fitted polycarbonate horseshoe for front and back horse hooves. Also Figure 3. (d) is the polycarbonate horseshoe fixed to the horse. By observing the walking of the horse, it showed no discomfort in balance or during the walk.

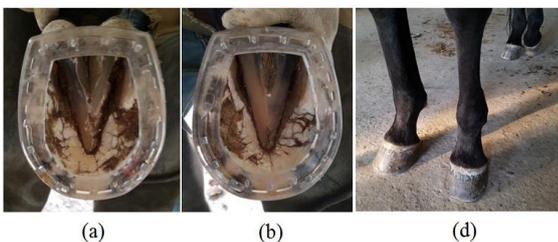


Figure 3: Polycarbonate Horseshoe fit to a Horse

POLYCARBONATE HORSESHOE DESIGN AND MECHANICAL PROPERTY ANALYSIS

Table 1: indicates the mechanical properties of Polycarbonate material.

Table 1: Mechanical properties of Polycarbonate

Properties	Value
Young's modulus	2.3 GPa
Tensile Strength	62.7 MPa
Compressive Strength	62.7 MPa
Heat distortion temperature	135°C
Density	1.35 g/cm ³

Figure 4 shows the design and drawings for the horseshoe injection molding. Width and length is 120mm and 130mm each, with the thickness of 8mm.

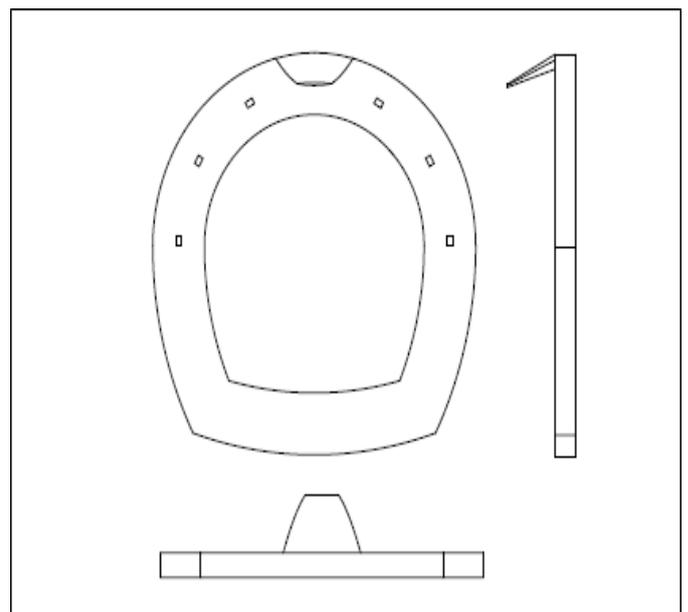


Figure 4: Polycarbonate Horseshoe Drawings

To analyze the mechanical property of Polycarbonate horseshoe, a solid model is required. Figure 5 shows the 3D solid model of the Polycarbonate horseshoe for mechanical property analyses.

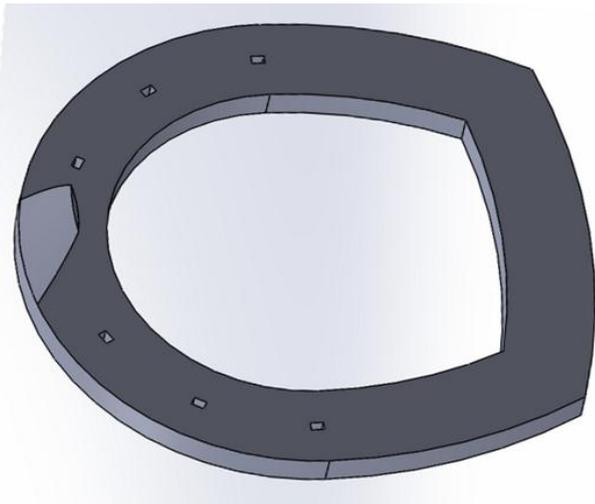


Figure 5: Solid Model of the Polycarbonate Horseshoe

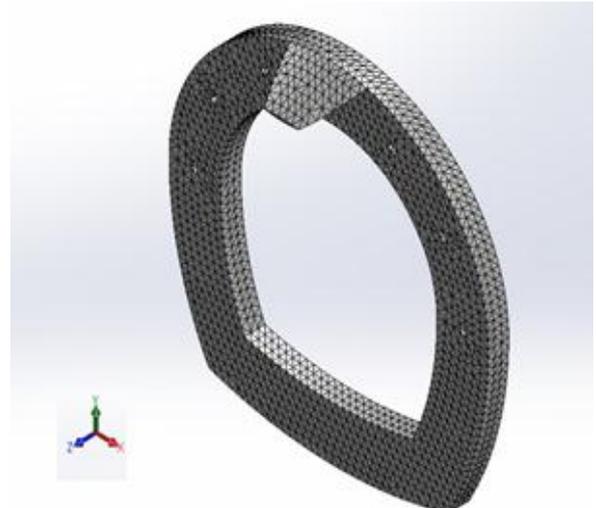


Figure 7: Mesh model for FEM analysis

To appropriately understand the mechanical property of Polycarbonate horseshoe solid model, a boundary condition is set as indicated in Picture 6. Here, the upper part of the horseshoe is closely fixed to the horse hoof, and the lower part is in a free state as it is frequently makes contact with the ground.

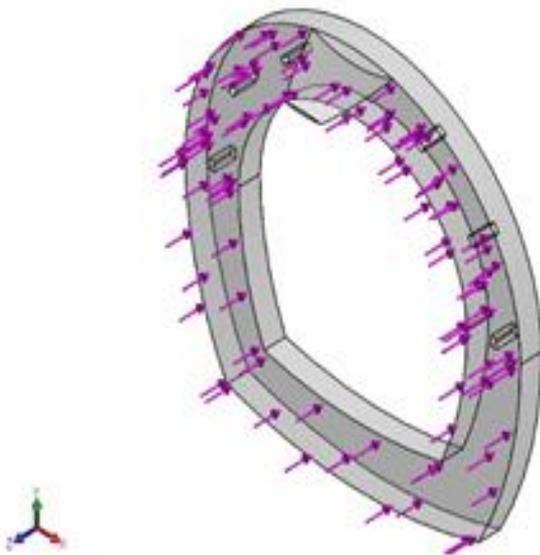


Figure 6: Constraint boundary condition of the model

Figure 7 shows the mesh model to analyze the stress of Polycarbonate horseshoe. Here, the number of the nodes and elements is 31,026 and 18,946 respectively, with the average size of the element 2.8mm.

Generally the maximum force to the ground while trotting is 8,000N.[4][5] Therefore, an experiment to measure the durability of the horseshoe after interpreting the mechanical properties of Polycarbonate horseshoe was accorded by applying distributed load of 8,000N to the upper part of the horseshoe.

Figure 8 shows the stress analysis of the Polycarbonate horseshoe. Here, the minimum stress is 1.02MPa and maximum stress is 2.07Mpa.

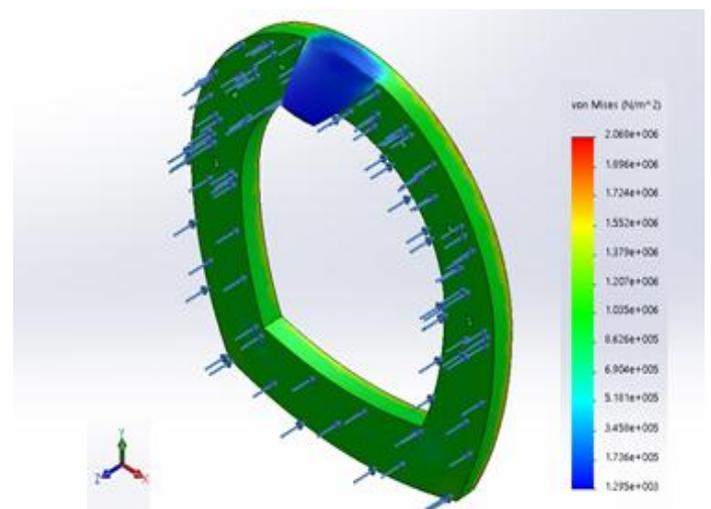


Figure 8: Stress Analysis of the Polycarbonate Horseshoe

Figure 9 indicates the strain analysis of Polycarbonate horseshoe. Here, the minimum and maximum strain while 8,000N distributed load is applied to the upper horseshoe is $1.99e^{-6}$ and $6.86e^{-4}$, each.

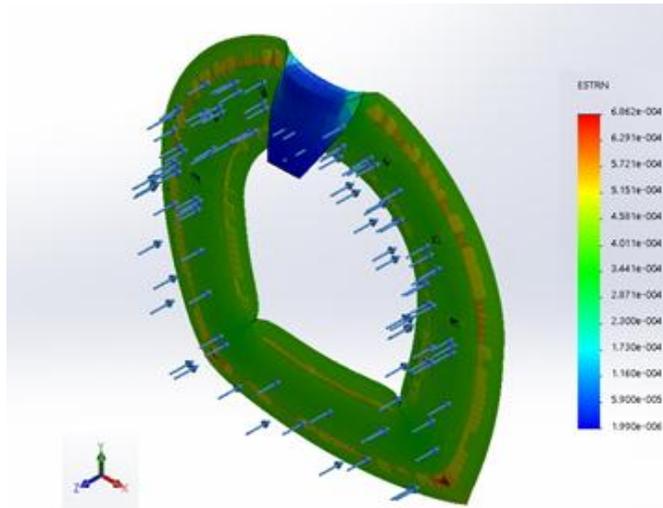


Figure 9: Strain Analysis of the Polycarbonate Horseshoe

The simulation shows the mechanical properties of polycarbonate horseshoe made by injection molding. As a result, the maximum stress by applying 8,000N to the horseshoe is 2.07MPa. Here the maximum allowable stress to the polycarbonate is 62.7MPa as indicated in table 1. In conclusion, because the maximum stress is substantially less than maximum allowable stress, the durability of polycarbonate horseshoe is appropriate. Furthermore, the strain to the horseshoe with 8,000N is minimal and therefore has very low possibility of damage

CONCLUSION

This study designed and developed a polycarbonate horseshoe using injection molding. A FEM was used to test the durability of polycarbonate horseshoe and the result is as follows.

1. Polycarbonate horseshoe is relatively simple and inexpensive compared to the original metal horseshoe and is possible for mass production,
2. Stress analysis shows that the polycarbonate horseshoe has sufficient durability.
3. Strain analysis shows the strain of polycarbonate horseshoe is close to 0.
4. The polycarbonate horseshoe our study developed is approximately 7 times lighter than the original metal horseshoe, and therefore it can be seen that the weight burden is very small while the horse is walking or running

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