Călin-Vasile PRODAN, Iacob-Liviu SCURTU

DESIGN AND EVALUATION OF A HORSE SADDLE USING CAD SOFTWARE

Abstract: *The pressure on a horse's back can affect their performance during the equestrian competition. A better pressure distribution on the surface of the horse's back can be obtained using a custom saddle, considering the rider's weight and back anatomy. The first part of the paper presents a recent study regarding the mathematical and CAD methods used to generate the hyperbolic paraboloid of the saddle surface. The second part of the paper shows the saddle design modelled using CAD software. The horse's back and rider's anatomy stay at the base of the saddle's surface. The saddle surface is divided into several areas for a better and more accurate evaluation. The third part of the paper presents the saddle evaluation using the finite elements method, using two load simulation cases in different rider situations. The improved shape of the saddle and conclusions are shown in the last part of the paper.*

Keywords: *saddle design, CAD design, hyperbolic paraboloid surface*.

1. INTRODUCTION

1.1 General context

A good symbiosis between the horse and the competitor influences success in horse competition. The saddle connects them, designed to distribute the competitor's mass more effectively from the horse's back. In general, saddles of standard sizes for daily activities on a farm are used, which can be a disadvantage in competition. The horse saddle is defined by the shape of a hyperbolic paraboloid, a double-curved surface created by a movable line parallel to a fixed plane that crosses two fixed oblique lines [1]. In horse competitions, it is recommended to use custom-made saddles tailored to the horse's anatomy, which provide better coverage of the rider's mass distribution. The development of the saddle can be traced back to the nomads from the Eurasian steppe, who designed it for long horse trips in the 7th century B.C. [2].

Interaction between saddle-horse backs can have repercussions in the case of sports competitions; these can cause pain to the horse's back, and it no longer manages to perform. Nowadays, saddle pressure reduction on the horse's back is extensively studied, and new materials for the construction of saddles and costumed saddle geometry behind the horse's back are produced. A complete study on pressure reduction by the seat panel is presented by Murray et al., where accurate data is taken from the riding, and graphical diagrams of the distribution of the saddle pressure on the horseback are presented [3].

Thermography, a method that measures the temperature of the back surface and the contact surface of the saddle, can help determine a more balanced distribution of the saddle's pressure in the thoracic region of the horse's back. In current studies, this technology is used to detect a reference grid, a visual representation of the temperature distribution obtained by measuring the temperature from the thoracic surface of the horse's back using a thermal camera [4].

It's crucial to recognize that the geometry of the saddle plays a pivotal role in the biomechanics of both the horse and the rider. This underscores the need for a harmonious rider-saddle-horse interface. As academic researchers and horse competition enthusiasts, it's our responsibility to understand and optimize this interface [5–6].

This study presents the stages of saddle design, which include determining the areas on the horse's back affected by the saddle's geometry and improving the saddle's geometry according to the horse's back geometry to increase horse comfort when using the horse saddle during horse competitions.

1.2 Saddle parts

To better understand the saddle parts in Figure 1, the essential components of an American Polo Saddle, which are in contact with the horse's back surface, are presented [7].

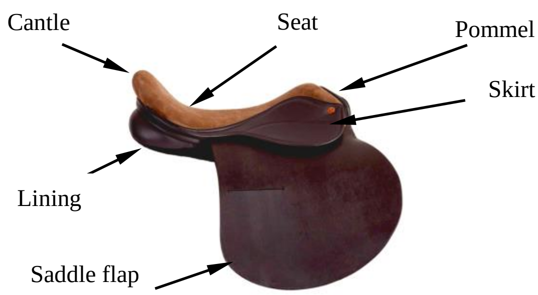


Figure 1 Saddle parts

2. SADDLE CAD DESIGN

The custom saddle design is done by scanning the horse's body and reconstructing its shape using CAD software or by visually approximating the shape of the horse's back. The following presents the method of creating the model of the horse's back and the structure of the customized saddle.

2.1 Horse body design

The first step in our modelling process is designing the horse model, which specifically focuses on the contact portion between the saddle and the horse's back. Figure 2 illustrates this process. This process involves using construction plans, on which the sketches defining the exterior surface of the horse are drawn.

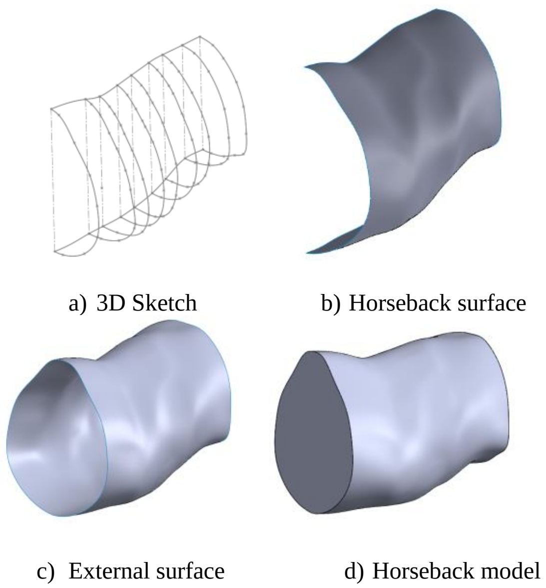


Figure 2 CAD horseback model.

In this study, the dimensions of the horse's anatomical model are measured from the horse and modelled in the CAD environment. For greater accuracy of the horse's back surface, the back of the horse can be scanned, and the surface from the resulting images of the tomograph computer can be reconstructed. Another easier method is to reconstruct the three-dimensional model through the interlude of 3D scanning with a dedicated scanner.

2.2 Saddle design

The geometry of its model is generated starting from the three-dimensional model of the horse's back, as shown in Figure 3. In the first stage of modelling, parallel planes are drawn. These sketches define the shape of the sections, and the surface geometry is given by the guiding curves that unite the sketches on the parallel planes. In the second stage, the lower surface of the saddle, the lower part that is in contact with the back of the horse, is generated.

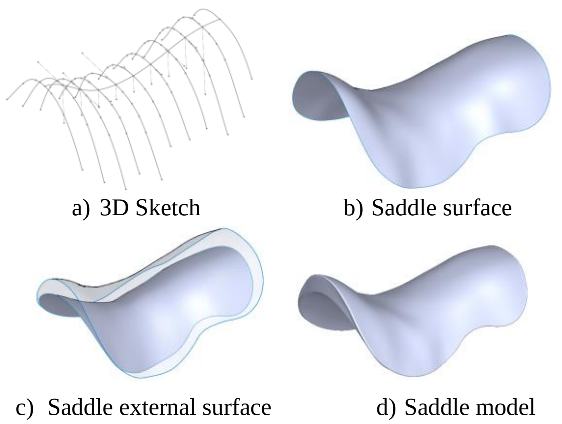


Figure 3 Saddle model generation.

Once the contact surface is established on the horse's back, the modelling of the side saddle, where the rider sits, commences. This process involves following the contours of the already generated surface and approximating the rider's settlement surface. The resulting saddle model, as depicted in Figure 4, is designed to be generically and stirrup-modelled to support the rider's legs.

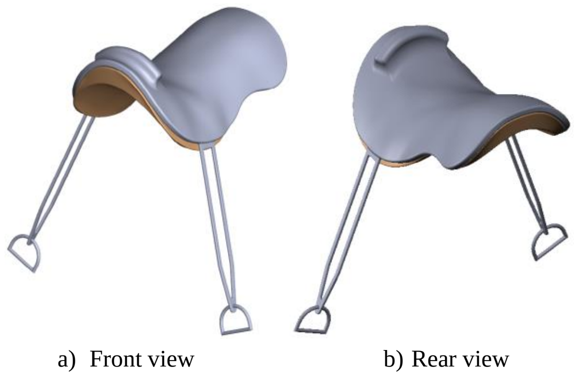


Figure 4 CAD horseback model.

2.3 CAD saddle assembly

The saddle model is assembled on the horse's back model so that it can be visually evaluated according to Figure 5. The triple projection presented in the figure, completed by axonometric projection, provides a clear view of how to lay the saddle on the horse's back.

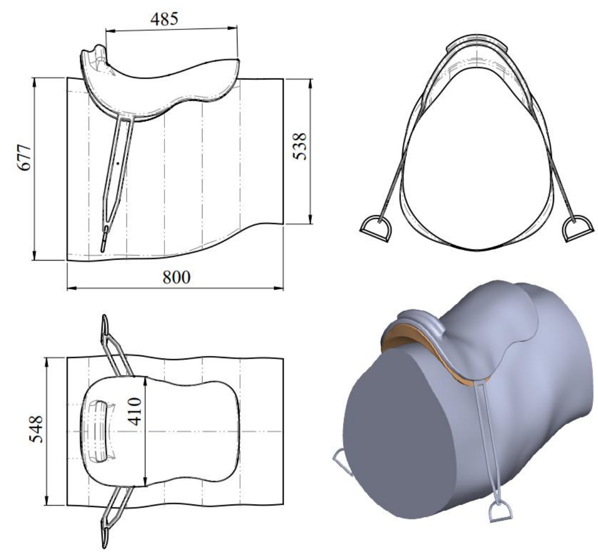


Figure 5 Overall dimension of models.

The next step for validating the proposed model is analyzing the contact between the saddle and the horse's back. Also, care should be taken to ensure the rider's prolonged comfort during riding.

3. SADDLE SHAPE ANALASYS

The analysis of the uniformity of the contact between the saddle's surface and the horse's back is not just a theoretical exercise. It has direct implications for the comfort and performance of both the horse and the rider.

The present paper studied two cases: when the jockey is placed totally on the saddle and when the horse is raised and standing, the charging being only on the stirrup.

3.1 Base saddle geometry analysis

Figure 13 shows how the contact surfaces of the saddle and the horse's back are divided into eight zones to determine the pressure zones exerted on it.

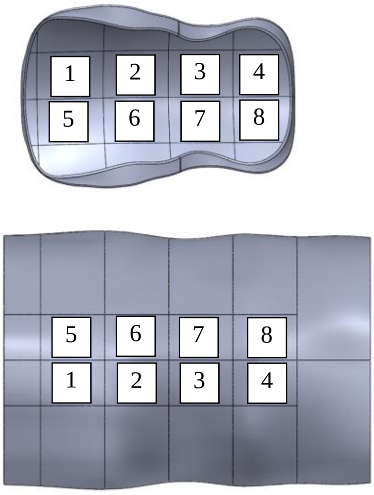


Figure 6 Divided surfaces of horse back and saddle.

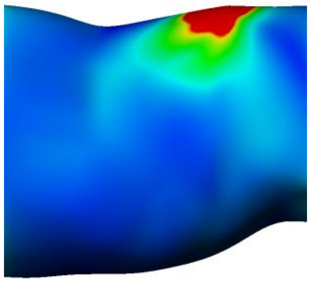
The finite element method is employed to establish the uniformity of pressure with utmost precision, which requires meticulously establishing the boundary conditions and incorporating materials that faithfully mimic the horse body and the components of the saddle. For the lower element of the saddle that comes into contact with the horse's back, a rubber-based material is chosen, and for the element on which the rider is placed, a plastic material was chosen. For the horse's body, a more elastic rubber-based material is chosen. In the first case of simulation to evaluate the pressure distribution, the rider is considered to be placed on a portion of the surface of the saddle, as can be seen in Figure 7. In the second case, the loading is done only on stirrup because it is considered that the rider does not sit on the surface of the saddle.

Figure 7 Pressure action on saddle surface.

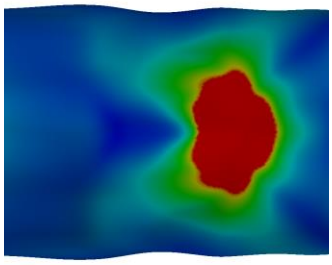
For a better comparison between reality, in which the mass load is dynamic, and simulation, in which the load is static, the rider's weight is considered to be 120 kg.

3.2 Base saddle results

In the first case where the rider's mass is distributed on the defined surface of the saddle, on the back surface of the horse, the more pronounced pressure area is in the back of the saddle, in areas 3, 4, 7 and 8. Figure 8 presents the side and top view of the horseback pressure distribution according to the first simulation case.



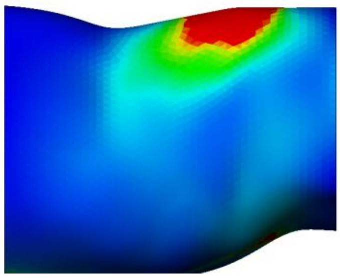
a) Side view



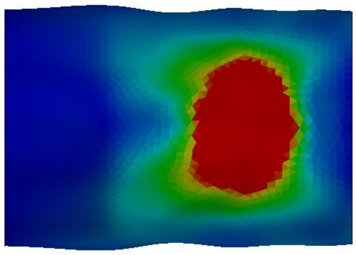
b) Top view

Figure 8 Case 1 - Pressure distribution on the horse back surface.

The back of the saddle affects the back side of the horse, so the pressure is not evenly distributed on the back of the horse. Figure 9 presents the pressure distribution for the second case, when the mass acts on the saddle stirrup, lifting the rider from the horse back on the stirrup.



a) Side view



b) Top view

Figure 9 Case 2 - Pressure distribution on the horse back surface.

3.3 Improved the saddle geometry

After analysing the results, a proposed saddle geometry is modified to reduce the pressure in the vertebral area. The lining shape of the saddle is changed to relieve the pressure on the spine. Figure 10 presents the modified part of the saddle.

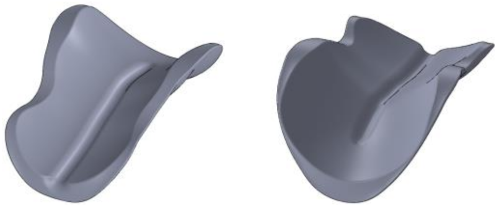
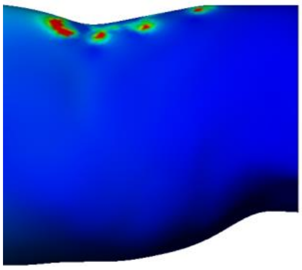
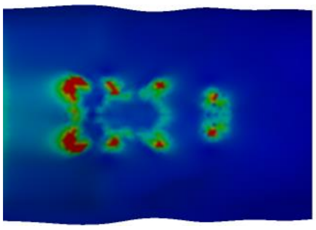


Figure 10 Improved geometry of saddle surface.

The study is run under the same boundary conditions as the first case. Figure 11 shows the results obtained from the first case. It can be observed that the pressure is distributed on the horseback area better than in the base model.



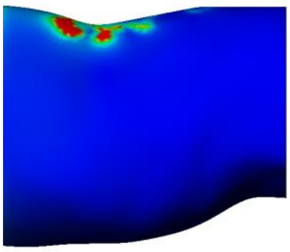
a) Side view



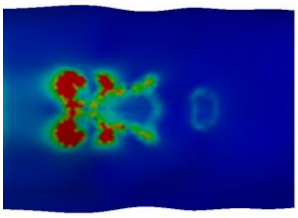
b) Top view

Figure 11 Case 1 - Pressure distribution on the horse back surface (improved geometry).

Figure 12 presents the results of the second case, which shows the pressure distribution of the rider's weight on the horseback.



a) Side view



b) Top view

Figure 12 Case 2 - Pressure distribution on the horse back surface (improved geometry).

4. CONCLUSIONS

This paper studied the modelling of a saddle used in horse competitions. The use of the CAD modelling environment and the software's capabilities to create the model assemblies are strong points, increasing the accuracy of the results. The analysis of the pressure area on the surface of the horse's back is carried out using the finite element analysis method. The materials used in the study are approximately similar, and the values of stress or displacements are not considered, following strictly the distribution of pressure caused by the rider mass on horseback.

REFERENCES

[1] Melaragno, M. (2012). *An introduction to shell structures: The art and science of vaulting*. Springer Science & Business Media.

[2] Tekiner, H., & Kelestimur, F. (2015). *A cultural history of the Turkish saddle*. Journal of Turkish Studies, 10, 319-328.

[3] Murray, R., Guire, R., Fisher, M., & Fairfax, V. (2017). *Reducing peak pressures under the saddle panel at the level of the 10th to 13th thoracic vertebrae may be associated with improved gait features, even when saddles are fitted to published guidelines.* Journal of Equine Veterinary Science, 54, 60-69.

[4] MacKechnie-Guire, R., Fisher, M., Mathie, H., Kuczynska, K., Fairfax, V., Fisher, D., & Pfau, T. (2021). *A systematic approach to comparing thermal activity of the thoracic region and saddle pressure distribution beneath the saddle in a group of non-lame sports horses.* Animals, 11(4), 1105.

[5] Murray, R., Fisher, M., Fairfax, V., & MacKechnie-Guire, R. (2023). *Saddle thigh block design can influence rider and horse biomechanics.* Animals, 13(13), 2127.

[6] Roost, L., Ellis, A. D., Morris, C., Bondi, A., Gandy, E. A., Harris, P., & Dyson, S. (2020). The effects of rider size and saddle fit for horse and rider on forces and pressure distribution under saddles: A pilot study. *Equine Veterinary Education*, *32*, 151-161.

[7] Site: *https://www.thesaddlecompany.co.uk/images/ Saddle-Co-Brochure.pdf*, *Accessed*: 30.03.2024.

Authors:

Lecturer PhD. Eng. Călin-Vasile PRODAN, Technical University of Cluj-Napoca, Faculty of Automotive, Mechatronics and Mechanical Engineering, Department of Automotive Engineering and Transports, E-mail: vasile.prodan@auto.utcluj.ro

Lecturer PhD. Eng. Iacob-Liviu SCURTU, Technical University of Cluj-Napoca, Faculty of Automotive, Mechatronics and Mechanical Engineering, Department of Automotive Engineering and Transports, Corresponding author, E-mail:liviu.scurtu@auto.utcluj.ro