SHAPING THE FOOT OF A HORSE

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Introduction:

Three different forms or states of support of a horse are recognized when it is in motion, these are: the walk, the trot and the gallop, each of them is differentiated by the number of extremities that are in contact with the ground. and the time of suspension of these in the air, for example the step, always at least one of the extremities is supported and therefore there is no time of suspension in the air; the trot, on the other hand, is composed of two support times on the ground, in such a way that a hand and a leg are supported diagonally alternately, separated by a suspension in the air, finally the gallop is characterized by the fact that in one of his times is completely up in the air. This basic observation, in which a limb is in contact with the ground, is what has given rise to a mathematical model that aims to quantify the effect that a horseshoe causes on the complex movement system of a horse. The model presented only has mechanical factors involved such as weight, impact force, position, speed, acceleration, etc., which means that factors such as race, specialty, age, etc. have not been considered. The whole problem has been condensed into the interaction of kinematically related bodies that somehow represent the horse as a whole.

Objective:

This study aims to comparatively quantify the structural effect produced by the use of a horseshoe based on an iron alloy and another based on a copper alloy, the structural effect is based on knowing the forces that are generated in both horseshoes under a same movement condition, in this way it will be possible to determine the comparative behavior, this modality has been developed since the behavior of a horseshoe based on iron is widely known and therefore its comparison will be direct. To achieve the objective, the following specific objectives have been developed.

- Physical model
- Mathematical model
- Simulation

The results of this model will make it possible to define which of the two horseshoes has a better performance from a purely structural point of view. The term best performance is based on the following conditions:

- The forces transmitted should be as low as possible
- The transmitted energy should be as low as possible

If these criteria are met, it will be possible to determine whether one shoe is better than the other.

Methodology:

The model developed is presented in this section, to develop this model the following considerations have been taken:

- In any of the three states of support of a moving horse, in some of its stages a limb is supported, therefore only one support will be studied.
- In any of the three states of support of a horse in motion, in some of its stages a limb contacts the ground at a certain speed, which will be of greater value if it goes from walk, trot and gallop.
- It is considered that the components most strongly involved are the horseshoe, the hoof up to its first joint and the rest representing the horse.

As results of the hypotheses raised, the following model has been developed that can be seen in Figure 1, note that there is a strong condensation when studying the area near the horseshoe, transforming the entire system into a model of only 3 degrees of Liberty.

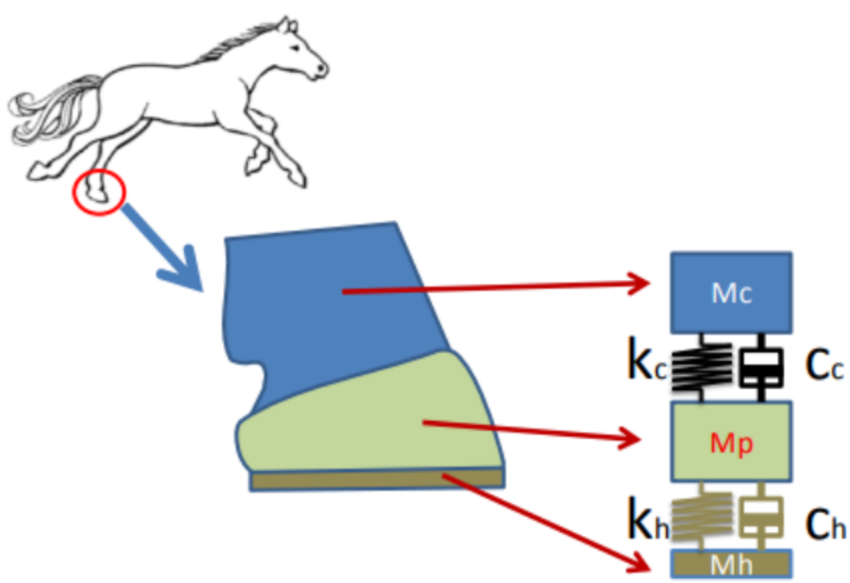


Figure 1.- Model of the horse's footprint

Where:

Mc Mass of the Horse

Mp Mass of the Pesuña until first joint

M_h Mass of the Horseshoe

k_c Stiffness associated with the horse

C_c Damping associated with the horse

k_h Stiffness associated with the horseshoe

C_h Damping associated with the horseshoe

The values of each of the constants used have been determined from experimental measurements of the elastic modulus and coefficient of restitution, which have been modified according to their geometry.

Of this model, two versions are made, where each of them differs only from the material of the horseshoe, keeping all the other values unchanged, in this way we can obtain comparative values objectively.

Given the characteristics of the model and the comparison between them, it has been considered that the best test corresponds to a fall of the bodies on a floor that is considered totally rigid; The bodies being joined by springs and shock absorbers transmit forces from one element to the other, these will be quantified and therefore the comparative behavior is determined, the results are dimensioned in order to generalize them.

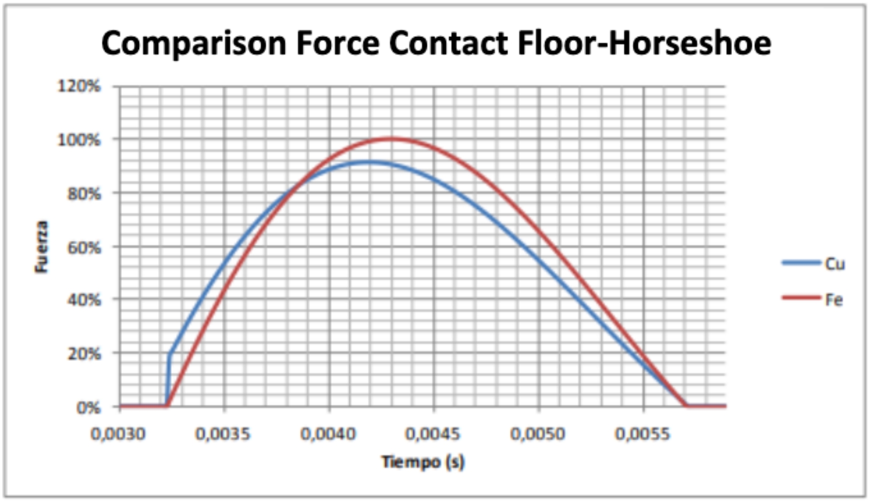
The equations that are solved correspond to a system of second order differential equations, whose forcing function is generated when impacting with a platform considered completely rigid.

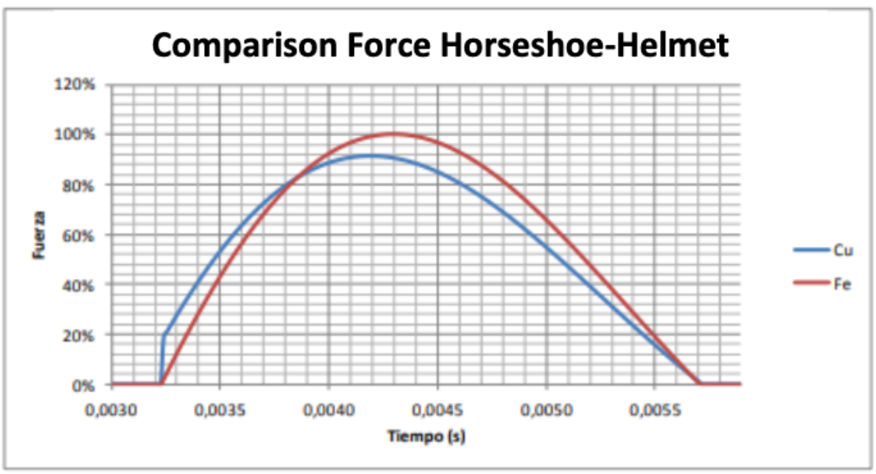
$$\begin{bmatrix} M_c & 0 & 0 \\ 0 & M_p & 0 \\ 0 & 0 & M_h \end{bmatrix} \begin{Bmatrix} \ddot{x}_c \\ \ddot{x}_p \\ \ddot{x}_h \end{Bmatrix} + \begin{bmatrix} C_c & -C_c & 0 \\ -C_c & C_c + C_h & -C_h \\ 0 & -C_h & C_h \end{bmatrix} \begin{Bmatrix} \dot{x}_c \\ \dot{x}_p \\ \dot{x}_h \end{Bmatrix} + \begin{bmatrix} k_c & -k_c & 0 \\ -k_c & k_c + k_h & -k_h \\ 0 & -k_h & k_h \end{bmatrix} \begin{Bmatrix} x_c \\ x_p \\ x_h \end{Bmatrix} = \begin{Bmatrix} 0 \\ 0 \\ \delta(t) \end{Bmatrix}$$

Presentation of Results:

The results obtained correspond to the forces that are generated in each of the bodies, in the first place the forces between the ground and the horseshoe are presented in the second between the horseshoe

Y el casco y en tercer lugar el casco con el resto del caballo. Se vuelve a indicar que los modelos son aplicables a ambos tipos de herraduras, considerando todas las condiciones iniciales y de borde similar, exceptuando las propiedades mecánicas de cada herradura.





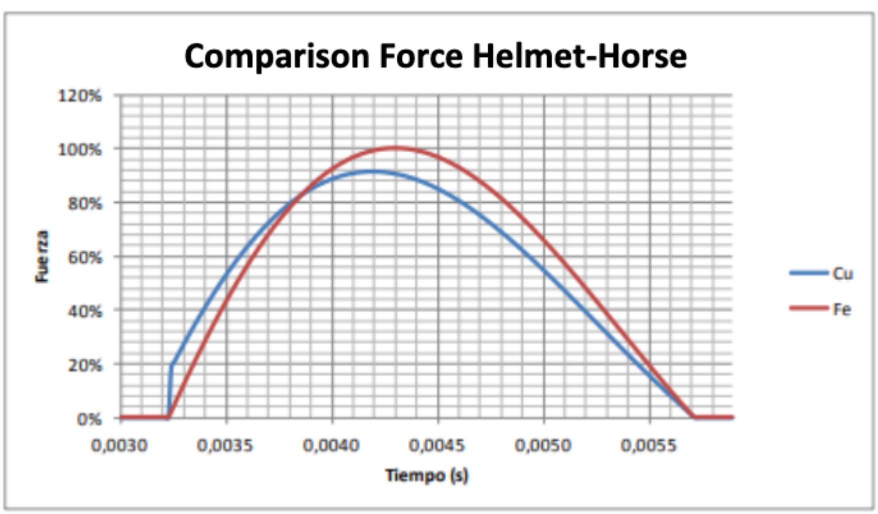


Figure 2.- Percentage variation of the forces in the interaction of the bodies

Table 1 shows the maximum values obtained in each of the body interactions.

	Floor-Horseshoe	Horseshoe-Helmet	Helmet-Rest of horse mass
Maximum force Cu	91.44	91.46	91.47
Maximum force Fe	100	100	100
% Difference Maximum Force	**8.56%**	**8.54%**	**8.53%**

Conclusions:

From the results obtained it is possible to obtain the following conclusions:

1. The copper horseshoe produces a transmission of force to the model components of lesser magnitude than the iron horseshoe. This condition is maintained as the elements are joined.
2. A slight attenuation of the magnitude of the force is observed as the elements join.
3. The value of 8.56% attenuation of the peak of force is significant because the process to be modeled corresponds to a cyclical sequence that can last a significant time.
4. The interpretation of this result means that when using a copper-based horseshoe, as it has a lower magnitude of action and reaction force in these components and since this force must be exerted by the horse, this magnitude of force is being saved.
5. From an energy point of view, if two horses run at the same speed and have similar characteristics, it is obtained that the horse that uses copper-based horseshoes will use less energy.
6. Based on the previous conclusion and from a purely biomechanical point of view, as the horse uses less energy, it will have physical reserves that it can use to increase its performance.
7. It should be noted that this simplified model already makes it possible to infer the biomechanical benefits of using the copper-based horseshoe.