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P3_4 Knights In Shining Armour: The Joust

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Abstract

The aim of this paper was to determine the power of a lance strike from a heavily armoured knight on horseback. The lance can deliver a blow with an energy of 53.0kJ and transfers 1030Ns of momentum. These values are likely inflated, highlighting the difficulty of analysing this complex collision without considering effects that are beyond the scope of this paper to analyse.

Introduction

The lance was a knightly weapon for much of the middle ages. Wielded from horseback it is capable of dealing life threatening injuries to an opponent even in highly protective plate armour.

We will be considering a lance couched under the arm and supported by a lance arrêt that locks the lance in place with the armour of the user and a jousting saddle, eliminating all movement in the rider to allow momentum to be conserved.

We will be considering the situation in which a lance impacts an opponent.

Methodology

The knight will be modelled as a particle undergoing and inelastic collision. Using Eq.(1) we can determine the momentum of our system.

$$p_{knight} = m_{total} v_{gallop} \tag{1}$$

where

$$m_{total} = m_{horse} + m_{knight} + m_{armour} + m_{lance}$$

By using Eq.(1) we can evaluate if the lance itself has the strength to withstand this force.

$$F_{impact} = \frac{dp}{dt} \tag{2}$$

This force is transferred to our knights opponent through the lance, hence the lance has to be able to transfer this amount of force. If F_{impact} exceeds F_{max}, calculated using Eq.(3), then the lance is broken and no more force than F_{max} can be imparted through the lance.

$$F_{max} = \frac{dp}{dt} = A\sigma_{UTS} \tag{3}$$

Where σ_{UTS} is the Ultimate tensile stress of the lance, p is momentum, t is time, and $($A) is the cross sectional area of the lance. F_{max} is the maximum force that the lance can take without breaking.

We are assuming that the collision is inelastic with the implication that the broken end of the lance is stuck into the opposing knight.

By considering the force applied and the transfer of momentum we can calculate the energy transferred in the collision using Eq.(4).

$$KE = m_{impactor} \left(\frac{dp}{m_{impactor}} \right)^2 \frac{1}{2} = \frac{(dp^2)}{2m_{impactor}} \tag{4}$$

Where KE is the kinetic energy transferred in the blow and $m_{impactor}$ is the mass of the impacting body. If the lance breaks then this will be assumed to be the mass of the lance. If the lance remains intact then the mass will be the total mass.

Assumptions

It is difficult to ascertain the exact dimensions of a lance however it must be held in the hand so we have assumed round with a diameter of 10cm and a cross sectional area of 0.00785m^2.

Cavalry lances were commonly made from European Ash and has a mass of between 8kg and 12kg[2]. We have chosen to use a lance of 10.0kg weight to come down in the middle of this range. The UTS of European Ash varies but a value of 13100kPa (1900PSI)[3] has been found.

The knight is riding a destrier, a type of highly desirable warhorse, measuring 15 hands (1.54m). An average destrier was capable of reaching a gallop of 13.4ms^{-1} (30mph)[1] and has a mass of around 450kg.

We are assuming that the knight weighs 80kg on the basis that they were fitter than average. One of the surviving tournament amours of King Henry VIII was used for armours weight at 29.3kg[4].

An impact time of 0.01s has been estimated as a reasonable period for the force to be applied through, though no formal data could be found. This value may differ in experimentation which is beyond the scope of this paper. We are also assuming that due to the lance arrêt as well as the saddle that all the momentum from the strike can be imparted on the opposing knight through the lance.

Results

Using the assumed values we can determine using Eq.(1) that $p_{knight} = 7700$Ns.

This momentum is imparted over a period of 0.01s and using Eq.(2) we determine the max force applied to be 153kN. Using Eq.(3) we can determine that the maximum force the lance can endure is 103kN, well less than F_{max} so the lance is assumed to be broken on impact.

This 103kN force is applied to the opponent. Using a rearranged form of Eq.(2) we can determine that the momentum transferred, dp, is 1030Ns. Using this result and Eq.(4) it is determined that the impact transfers 53kJ of energy with the mass used being the mass of a lance due to $F_{max} < F_{impact}$.

Conclusion

The Impact of the lance delivers an energy of 53kJ and transfers 1030Ns of momentum. These numbers are likely highly inflated due to the σ_{UTS} value used being the shear stress parallel to the grain. As such it is difficult to determine the energistics of this collision without first calculating σ_{UTS} perpendicular to the grain as well as calculating the flex of the lance. This would require a 3D analysis of the impact forces on the target through the lance which is well beyond the scope of this paper It is highly likely that flex in the lance, or a shear down one grain line of the lance, is responsible for the destruction of the lance.

References

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