Project: **helmet**

Title of Project: Advanced helmet protection

Direct and rotational impact

Abstract:

In real life a race car driver, motorcyclist, hockey player, football player in fact any sports a player can suffer two types of impacts-direct (linear) and rotational. The helmet was the first solution and does a decent level of protection. However, in today's game the helmet is too stiff and can not dissipate the impact energy. To improve dissipation of the impact energy and reduce brain injuries we developed a material that is more flexible and has the capability to absorb the energy resulting from impacts. This product is a dilatant fluid and its commercial name is HITT-PG. (High Impact Transfer Technology). To evaluate the amount of energy absorbed, we used the latest computer software. Finite Element Analysis (FEA) is a computerized method for predicting how a product reacts to real-world forces, vibrations, heat, fluid flow, and other physical effects. Finite element analysis shows whether a product will break, wear out, or work in the way it was designed. It is called analysis, but in the product development process, it is used to predict what is going to happen when the product is used. The tests showed excellent dissipation of the impact energy. Our material is capable of dissipating at least 85% of the energy/force created by both linear and rotational impact.

Version:	*Divulgation Date:*	*Presented by:*	*Approval date*	*Approved by:*
1	12/03/2015	Nelson Oliveira (PhD)	13/03/2015	

Area:	Helmet protection	**Level of protection:**	**confidential**

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Direct impact

Introduction

In this report we present the simulations that were made to evaluate the dissipation of the impact/force energy. The protection is our own patented dilatant fluid. The simulations were made using Finite Element Software. The impact simulations were made according the European Standard EN 1078:2008 guidelines for safety (similar to the US NOCSAE test specifications). According with the standard guidelines, it is mandatory to use an anvil with a diameter of 130 mm and a velocity of impact of 5.32 m/s. In these tests we made two comparable simulations, one without the protection and another with our HITT-Pg protection. Between the protection and the anvil was a friction coefficient of .02. The test procedure is presented in the following figure.

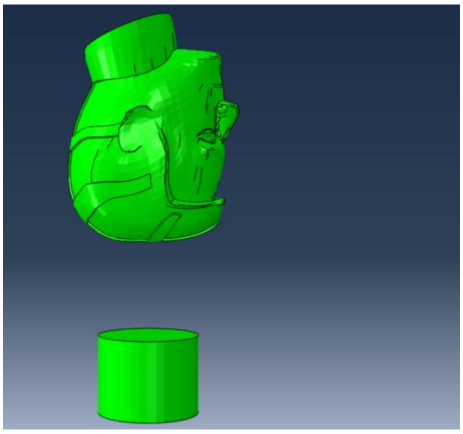

Figure 1 impact simulation

In this study we analyzed the dilatants material. It shows the reduction of energy from an impact. The exo-protection (HITT-PG Head Gear) used is this study is presented in the following figure.

Figure 2 protection with a dilatant fluid

Materials

In the simulations we used three materials, steel in the anvil, bone in the dummy and dilatant fluid material.

The steel properties used in the simulation are presented in the following table.

Table 1 material properties of the steel

Density	7850	Kg/m3
Elastic properties		
Young's Modulus	140000	MPa
Plastic properties		
yield strength	776	MPa
Stress at Break	922	MPa
Strain at break	40	%
Break energy	500	J

The bone properties used in the simulation are presented in the following table.

Table 2 material properties of the bone

Density	1440	Kg/m3
Elastic properties		
Young's Modulus	19300	MPa
Plastic properties		
yield strength	139	MPa
Stress at Break	140	MPa
Stress at Break	0.719	%

The fluid properties used in the simulation are presented in the following table.

Table 3 dilatant fluid properties

Density	1300	Kg/m3
Viscosity	300	Pa.s

Results

The initial results obtained in the simulation were made without any protection. The results in the beginning of the impact are as follows.

Figure 3 results after impact

The simulation showed stresses near the 4.05 MPa. This stress is due to the distribution of the impact between the head and the steel disc.

In the following figure is presented the variation of the stresses along the head, in the half of the time that the head was in contact with the anvil.

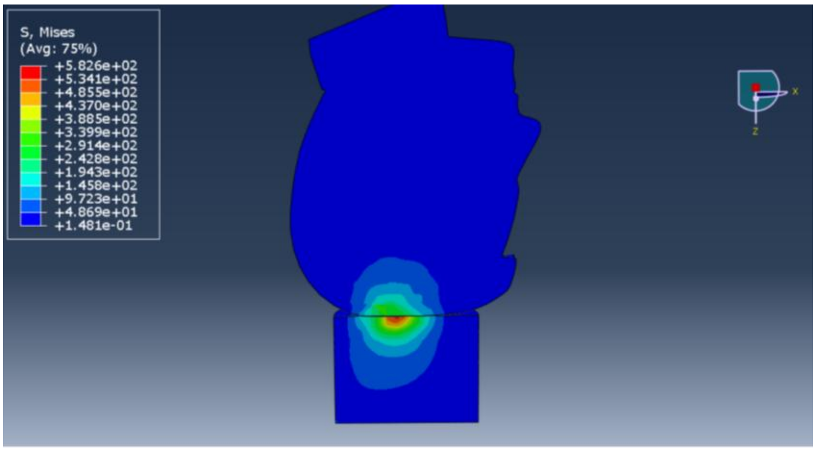

Figure 4 higher stresses obtained in the impact

The higher stresses were measured on the top of the head. In the simulation we measured stresses in the head of 390 MPa.

In the following image is showed the remaining stresses that were maintain in head after the impact.

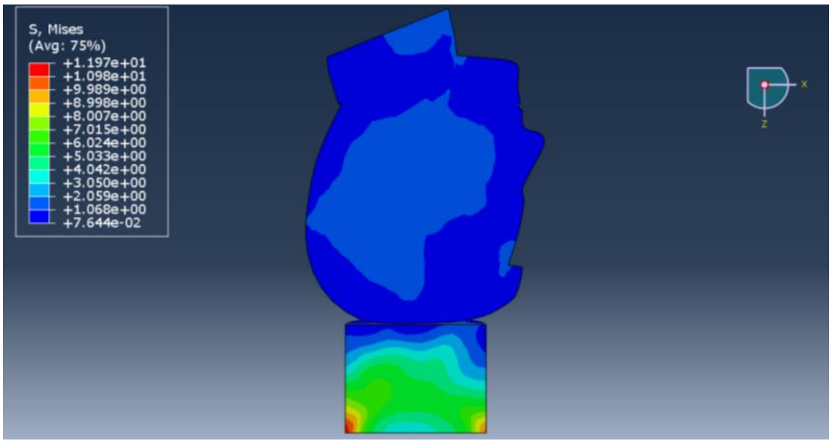

Figure 5 after the impact

It was measured stresses of 3 MPa around the area of the brain, in the neck and in the area of the eyes.

In the following paragraphs will show the results obtained with the use of the our protection. The following image is related to the first moment, when the dummy crashed against the steel disc.

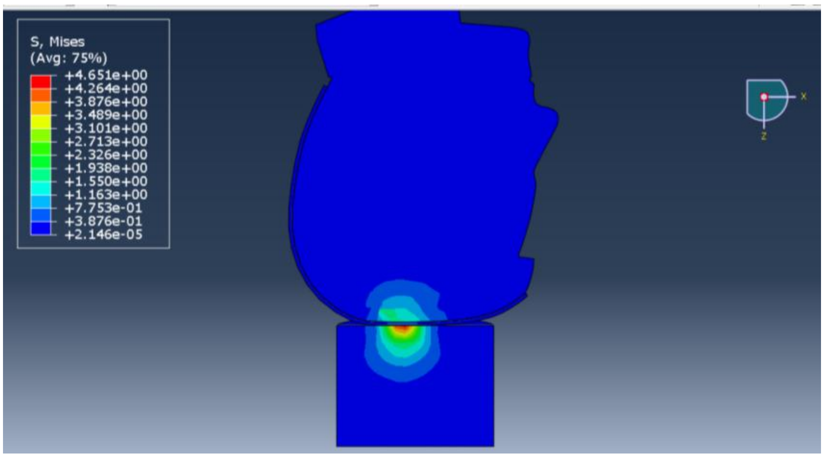

Figure 6 first moment of the accident

During the simulation we measured higher stresses on the disc than at the head. When the dummy crashed into the disc, we measured a stress of 4.5 MPa. In the head the higher stress measured was 2.71 MPa. With our HITT-PG protection it is possible to reduce the stress to 1.79 MPa.

In following picture we will present the stresses measured in the middle of the impact.

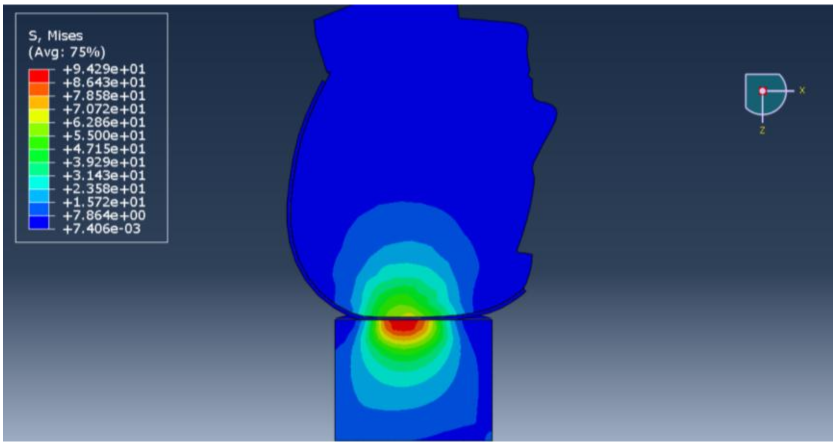

Figure 7 stress measure at the middle of the crash

The stresses measured in the steel disc were higher when compared to the stress measured in the head. During the impact we measured the head stress level of 61 MPa.

In the following figure it shows the stresses that remained in the head after the end of the impact.

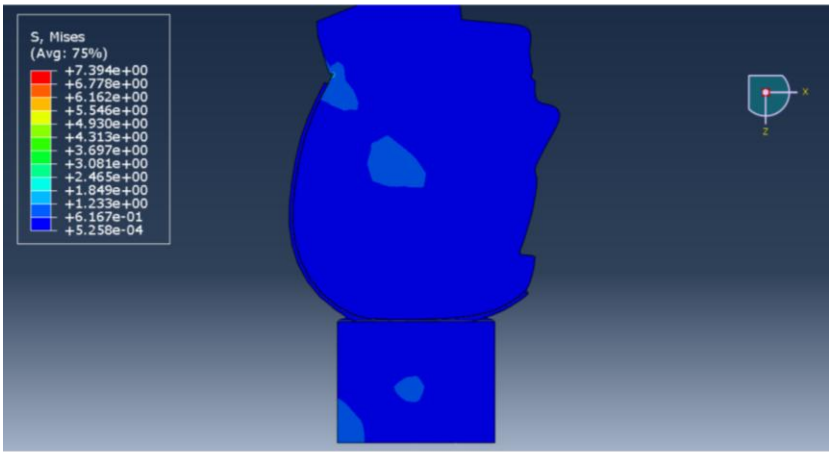

Figure 8 Stresses measured after the impact

After the impact the stresses measured in the head were localized. In this case on the center of the head and the neck. In the neck after the crash we measured stresses near 2.6 MPa

Following will be presented an image with the stresses obtained in the helmet.

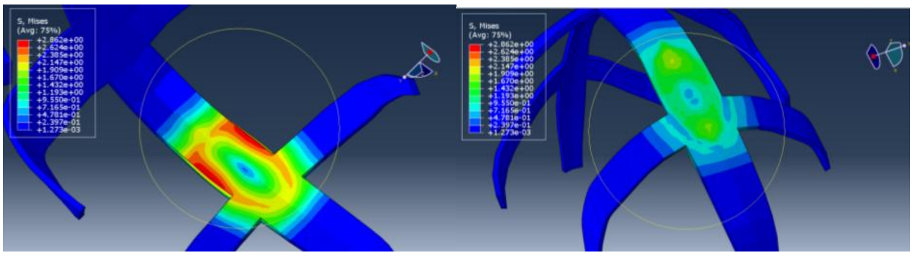

Figure 9 helmet

At the middle of the crash zone was seen a uniform distribution of the stresses, along the protection. This means that the load that will arrive to the head will be less when compared to the head without protection.

Conclusion

It is possible to conclude that:

The stresses obtained in the simulation without the helmet were lower compared to the simulation with the helmet, because the load was divided between the head and the steel disc. In the simulation of the dummy with our protection the loads were higher in the steel disc because the load didn't pass to the dummy's head.

After the impact, the load distribution was higher in the dummy without protection than the dummy with our protection.

The HITT-PG presented a good load distribution. This means that when the dummy receives the impact, the load will be distributed to a larger area which will d=reduce the stress concentration.

Rotational impact

Introduction

In the previous section we analyzed the direct (linear) impact of a dummy's head into an anvil. Due to requirements of the market, the rotational impact was also analyzed. To evaluate the rotational impact we used the scientific paper "Head impact biomechanics in ski related accident", from Svein Kleiven, Peter Halldin [1]. This was published in the British Journal of Sports Medicine. According to them, the rotational impact anvil has a slope of 20º and it is necessary to use an impact velocity of 5.4 m/s. In these new tests we made two simulations, one without the protection and another with our protection. Between the dummy and the anvil we used a friction coefficient of 0.2.

The size of the anvil used in these tests was equal to the previous study. The test procedure used is presented in the following figure 10.

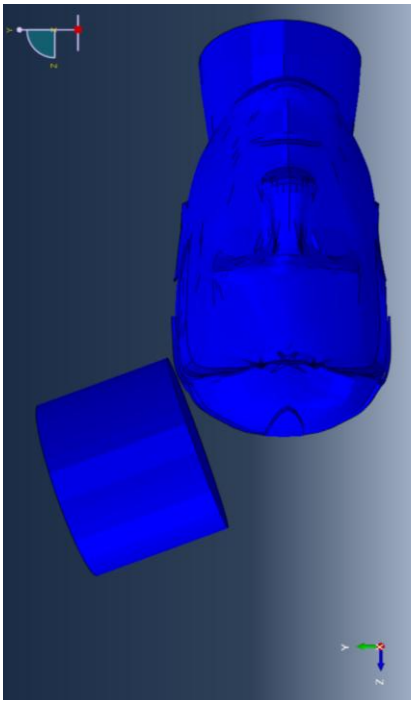

Figure 10 rotational impact

The materials properties used in these simulations were the same used in the direct impact.

Results

The exo-protection (HITT-PG) presented above was evaluated, according to the parameters of the rotational impact that are present in the document “Head impact biomechanics in ski related accident”. Following will be presented the results from rotational impact to a head that has our protection and in a head without protection.

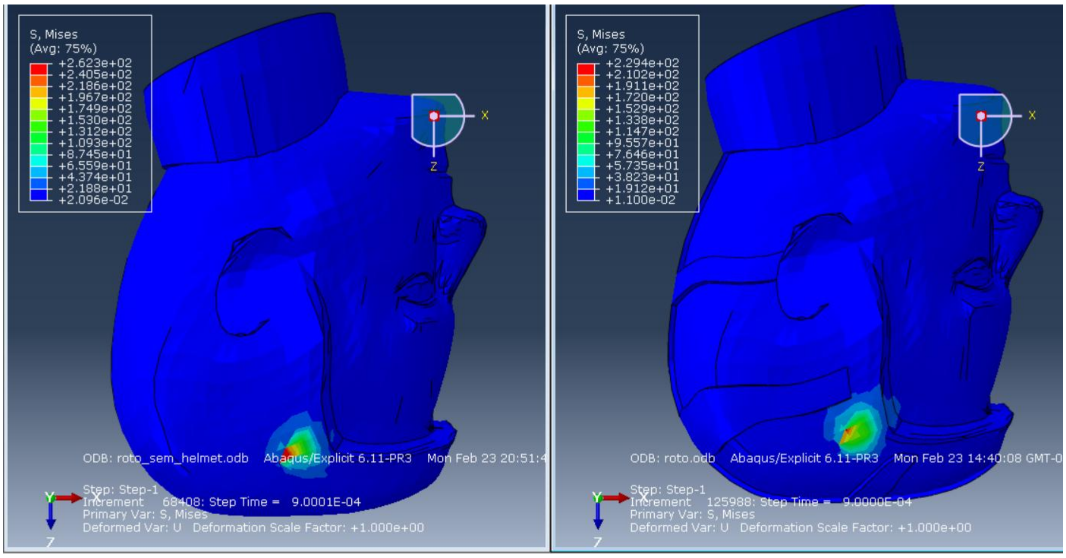

Figure 11 impact with and without the helmet

The simulation showed equal stresses to the dummy's head that have the protection and in the head that doesn't have the protection. Were observed stress level high enough to fracture or break bones. Which is 140 MPa.

Due to this we needed to re-design the exo-protection (HITT-PG Head Strap). In this case, we designed an exo-protection capable to absorb rotational impacts. In the following figure is presented the new exo-protection (HITT-PG Head Strap).

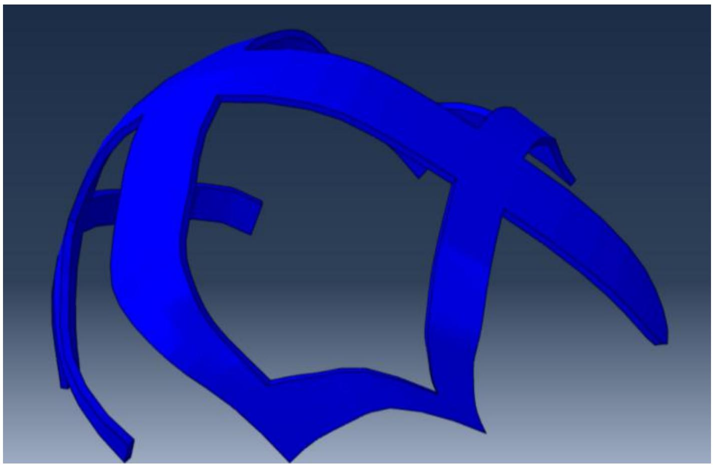

Figure 12 new HITT-PG Head Strap

In this new exo-protection we added more material in the lateral zone so it can absorb the energy from lateral impacts.

In the following image we show the stress levels measured at the beginning of the impact.

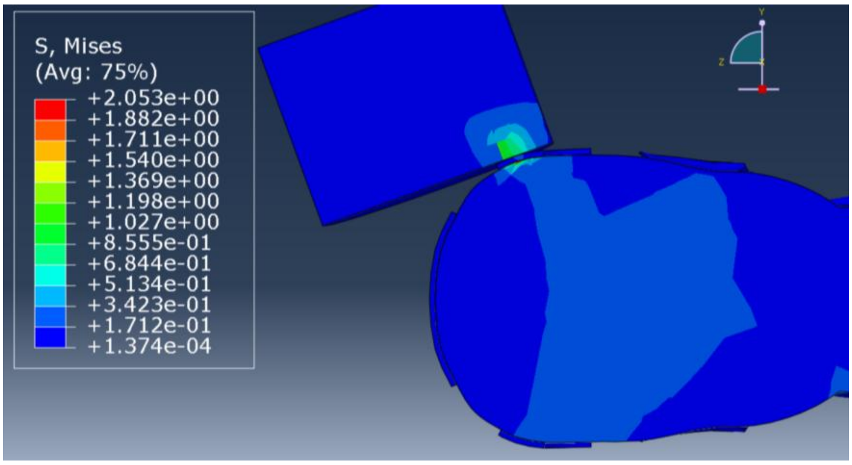

Figure 13 begining of the impact

When the head touches the anvil we measured stresses of 2.0 MPa at the zone of the impact.

In the following image is shown the higher stress measure in the impact.

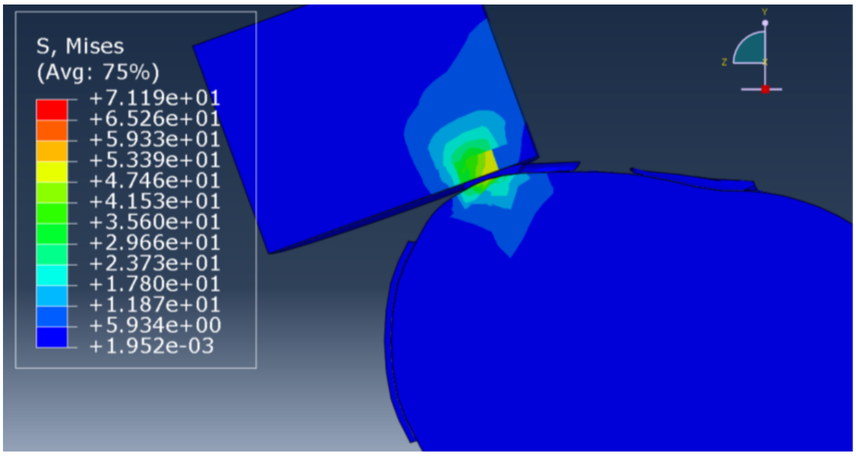

Figure 14 higher stress measure in the impact

During the impact, the higher stress measured was 71 MPA which is half of the stress of breaking bone. The stress to break the bone is 140 MPA.

In the following image is shown the same impact without the helmet.

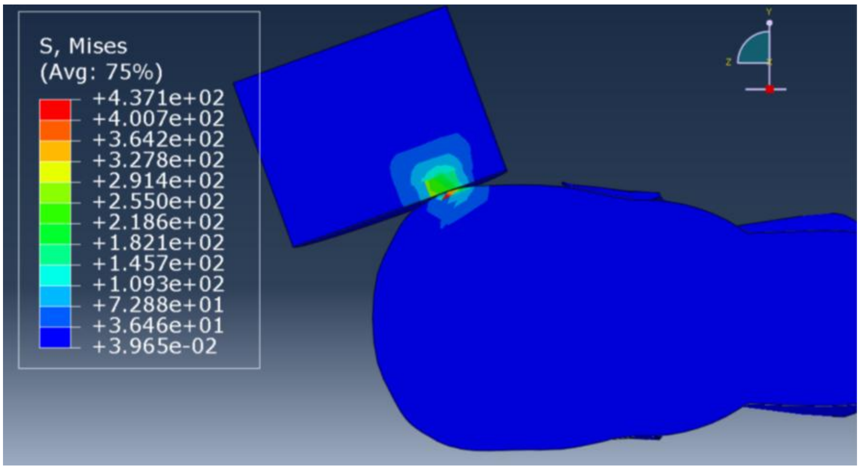

Figure 15 stresses measured during impact

Without the helmet were measured stresses near 4 times higher than the stress to break bone.

In the following figure is shown the stresses measured of the exo-protection.

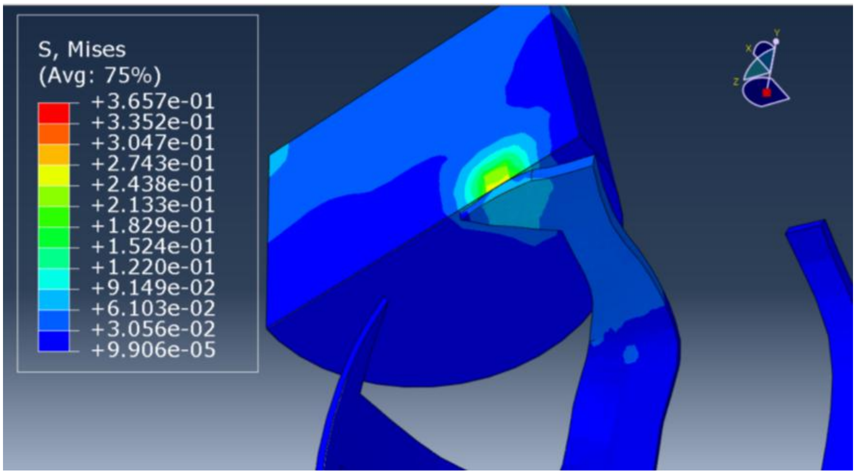

Figure 16 stresses measured in the anvil and in the protection

At the same time we measured stresses of 71 MPa to the head. In our protection we measured stresses smaller than 0.2 MPA.

Conclusion

With these result it's possible to conclude that:

With the protection, the person will not fracture the skull and will not suffer a serious injury. The stress levels measured during the impact are half of the stress to break bones.

Without our HITT-PG protection the person will suffer serious injuries. We measured stresses four times higher of stress levels that bones break.

The HITT-PG material is capable to dissipate at least 85% of the energy of the impact. In the case of rotational impact the stress measured was 50% lower;

Bibliography

[1] – Kleiven, Svein; Halldin, Peter. “Head impact biomechanics in ski related accident”. Br J Sports Med, 2013,47.