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Simulation of Airbag Impact on the Eye Using Finite Element Analysis

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Abstract

This paper focuses on the eye injuries related to airbags during frontal crashes of motor vehicles. This investigation will address the deformation of the eye part during the impact. The objectives of this work are to observe the behaviour of the eye during the impact, and also try to analysis the simulated stresses and strains to clinically observed injuries. All programming was written and conducted in ANSYS Parametric Design Language (APDL). Two eye models were generated by using Finite Element (FE) modelling software (ANSYS v9.0) with identical geometry. Airbag geometry is added to both models and transient dynamic analysis was performed on both the models to simulate impact with the eye. Initial velocity was assigned to the eye models to move towards the airbag and analysis of the eye deformation during the impact at various locations was conducted and the results will be observed. The maximum stress and strain values at the joints of the both the models are calculated.

Keywords

Ansys, ADPL, Finite element analysis

1. Introduction

The motivation of this study- now a day's airbags are quite common in all automobiles and it is one of the major safety equipment during traffic accidents. Airbag protects from major head injuries and even from death during accidents. Although airbags are designed to reduce the injuries, but they itself causes some less severity injuries like upper extremity fractures, skin abrasions and eye injuries. Among those most severe injuries associated in the ocular region- although the injuries are rare, and a possibility of visual impairment or permanent damage to the region. But the airbags were saved many lives after the introduced, as per report in 2007 by 'The National Highway Traffic Safety Administration' (US government) [1] estimates that 176 millio n airbags equipped in passenger vehicles including 164 million with dual airbags were on the road. In between 1987 to 2007 a total of 25,282 lives, and 2,788 lives in 2007 were saved by using the airbags.

This paper focused on the eye injuries related to airbags during frontal crashes of motor vehicles. This investigation will address the deformation of the eye part during the impact. The objectives of this work are to observe the behaviour of the eye during the impact, and also try to analysis the simulated stresses and strains to clinically observed injuries.

The model was created using ANSYS finite element commercial software. The modelling approach was to construct the geometry from the bottom up using primitives, i.e., key points, lines, line arcs in FEM software (ANSYS), by using appropriate commands. Two eye models were generated by using Finite Element (FE) modelling software (ANSYS v9.0) with identical geometry. The first model geometry consists of the cornea, ciliary body, sclera, lens, aqueous, vitreous and socket with bony part, here facial bone and optic nerve is omitted. In the second geometry facial bone is added to the first model to analyse whether it can protect the eye from a large blunt object.

2. Literature Review

Allen Breed invented a "sensor and safety system" in 1968, the world's first electromechanical automotive airbag system. Crash sensing technology gave birth to the airbag industry. Work was done previously on the eye injuries due airbags by using finite element modelling software. In the paper by Power et al [13], the eye model consists of cornea, sclera, ciliary body, fatty tissue, vitreous, aqueous, lens, goggles and six muscles.

In a paper by Eilichi Uchio et al the human eyball was developed based on the information obtained from cadaver eyes, using 3-dimensional FEA program of PAM-CRASH (Nihon ESI, Co., Ltd.). In this eye model cornea, sclera, lens, ciliary body, aqueous humor and vitreous humor are used to create a model.

In the paper by Eiichi et al the eye model was designed based on the information from cadaver eyes using 3-dimensional FEA program of PAM-CRASH version 1998 (Nihon ESI, Co., Ltd.). The

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model included cornea, sclera, ocular tissues, aqueous humor and vitreous humor, but the lens was replaced by transsclerally fixated poly PC IOL.

Matthew Birchmore developed an axisymmetric eye model to analyse injuries caused by paintball impact. The modelling approach was to construct the geometry from the bottom up using primitives, i.e., key points, lines, line arcs in FEM software (ANSYS), by using appropriate commands.

3. Methodology

The geometric values of the eye model were taken from Birchmore [5], who investigated paintball impact injuries on the eye, which is an axis symmetric model. Now try to work on the plane strain model. Two eye models were generated by using Finite Element (FE) modelling software (ANSYS v9.0) with identical geometry. The first model geometry consists of the cornea, ciliary body, sclera, lens, aqueous, vitreous and socket with bony part, here facial bone and optic nerve is omitted. In the second geometry facial bone is added to the first model to analyse whether it can protect the eye from a large blunt object.

Software code was written to create the geometry of the model descriptions; all programming was written and conducted in ANSYS Parametric Design Language (APDL. Two modelling techniques exist in ANSYS, the first to specify geographical landmarks (key points) then joining these landmarks by using lines and line arc, then forming areas from those lines, line arc and volumes if required. This modelling is known as 'bottom-up approach'.

The ANSYS has the ability to assemble a model using geometric primitives, by using fully lines, areas and volumes known as 'top-down approach'. When the primitive are created, the software program will automatically create the total 'lower entities' associated with primitive. The first modelling strategy was selected, which is bottom-up method a simple method of creating the geometrical structure. Its advantage is that it provides a great control over the model when compared with the top-down method when the primitives are predefined. Geometric values for the eye model like, corneal bulge and cornea-sclera thickness was taken from Matthew Birchmore. Two models were designed, one with facial bone and other without facial bone.

Four straight lines were plotted up to here on the model, two to define the end of the sclera and cornea on the axis, and the other two to separate the sclera and cornea. Although the sclera and cornea do not abruptly end in real human eyes there is no mechanism in ANSYS to merge the properties of the two correctly at the join, theoretically for this to be done one should know the rate at which the sclera's properties merged into the cornea's properties in a real system.

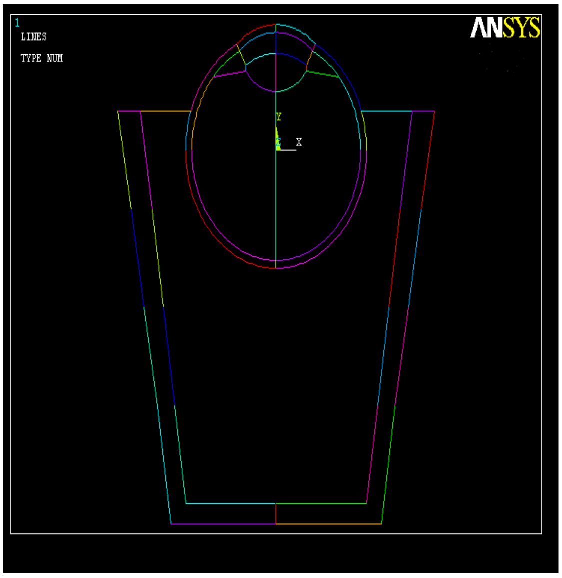


Figure 1: Final geometry of a model without facial bone

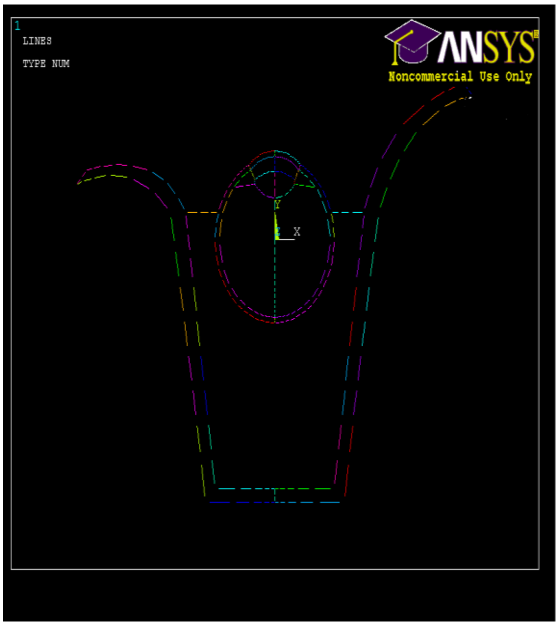
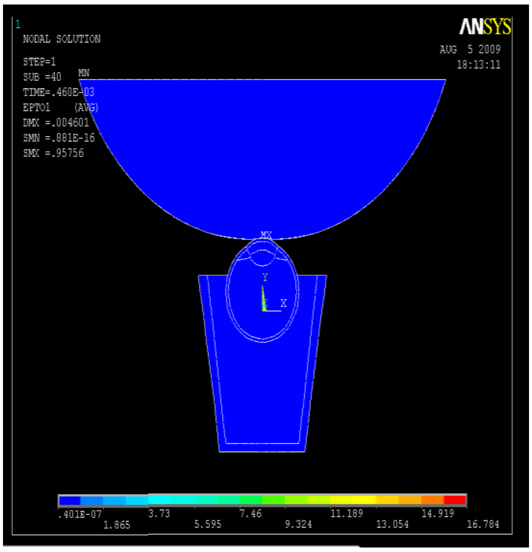
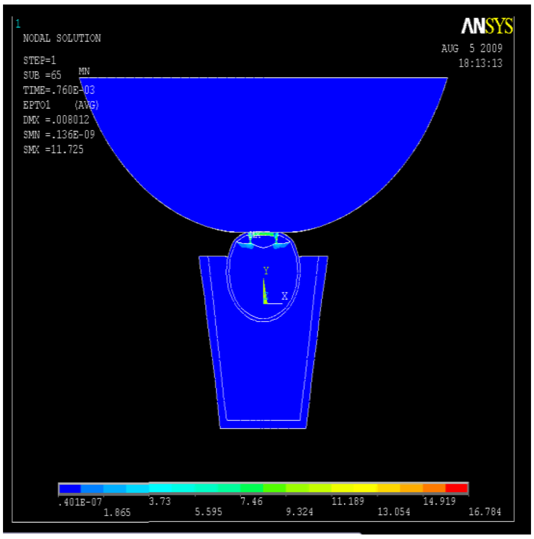


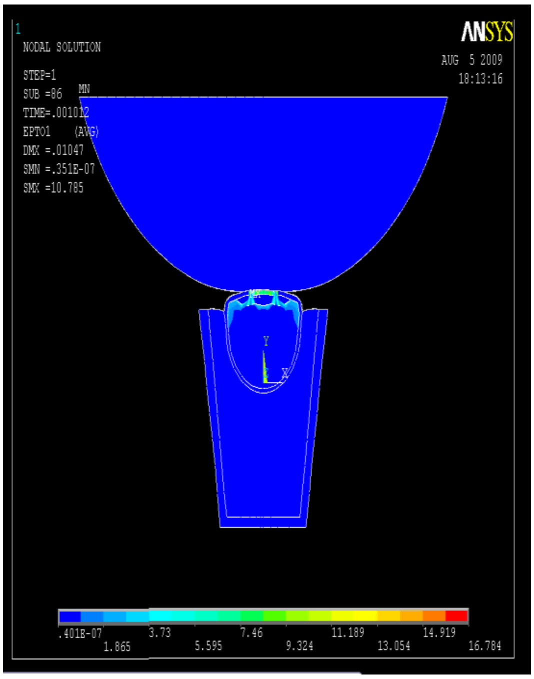
Figure 2: Final geometry of a model with facial bone

4. Results

The deformation shape of the eye without facial bone is shown in the below figure 1 in four consecutive frame images. The eye model was moved towards the airbag with an initial velocity of 10m/s with a time of impact 0.012 seconds.







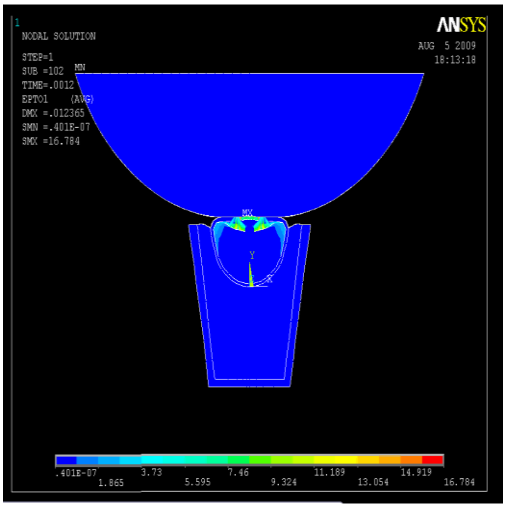
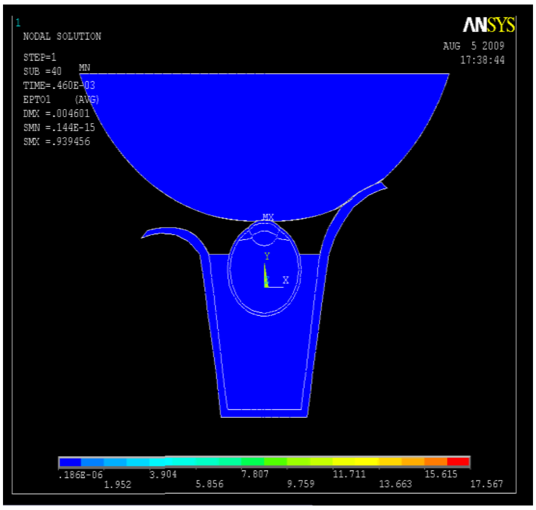
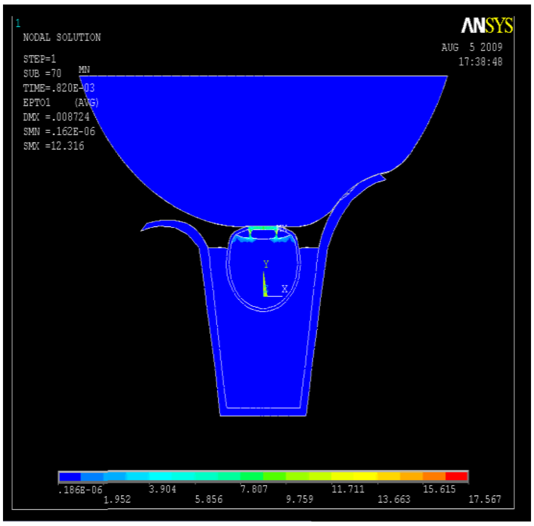
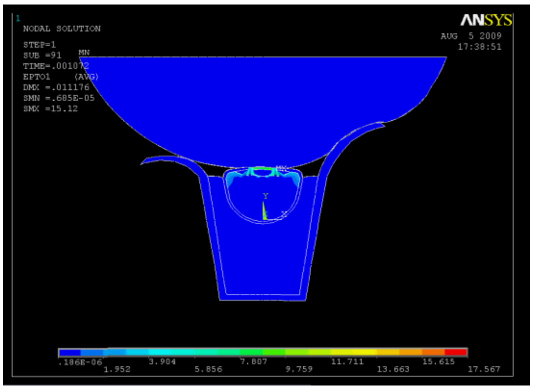


Figure 3: Deformed shape of the eye model without facial bone (1 to 4 images)

The deformation shape is shown in the figure-2 for the model with the facial bone and the same initial velocity and duration







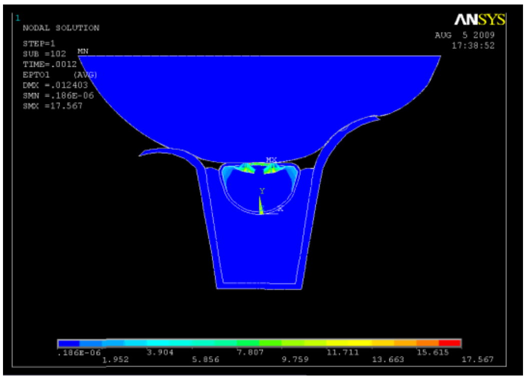


Figure 4: Deformed shape of the eye model with facial bone (1 to 4 images)

By observing the deformed shape of both the models, it can be seen that there is no much difference in the deformed shape. This is because of the airbag is sinking from the facial bone and hitting the eyeball.

Table 1: The maximum stress and strain values at the joints of the both the models are shown in table 1

Model	Strain	Stress [Pa]
With facial bone	0.96204	0.283E+7
Without facial bone	0.795047	0.266E+7

5. Conclusions

This study suggests from the transient analysis, we can determine that ANSYS is able to perform the high speed impact analysis which includes the contact elements. However, due to the low stiffness of the airbag and complexity of the analysis was limited to initial velocity of 10m/s or below to get the deformation of the eye.

The analyses suggest that the less severity of injuries may be possible at low speed impact as 10m/s. However, this is just an assumption due to extremely limited amount of mechanical data available in the existing conditions for the analysis.

Future work

The future work is needed to improve the model. First, the airbag mechanical data should be accurate in such a way that it should be nearly same to the airbag properties and the stiffness and height of the more realistic modelling of the facial bone should also be considered in improving the model efficiency. Second, to make the eye model more complete, optic nerve should be added to the model. This is the recommended future work to improve the model and to analysis accurate locations of eye injuries during traffic accidents.

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