Helmeted-Head impacts of Motorcyclist having High-Speed An Application of Finite Element Method

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Abstract

Motorcycle is one of the very common and cheapest means of personal transport in Karachi [1]. The two-wheeler auto vehicle driver is at a high risk of hitting and impactingthe ground with the collision of headfirst at the road surface having a diverse range of travelling speeds, from the urban road's average speed limit of 50 km/h to the race tracks' maximum speeds of 120–150 km/h and above.Motorcycle helmets, on the other hand, are tested at a lower impact speed of about 26 km per hour compared to the average speed of bike accidents in the real world, as per draft Pakistan Standard Specifications Protective helmets for motorcycle riders i.e. The unit, which is made up of the head form and helmet, must fall on the test anvil at a speed equivalent to 7-0.15+0.0 m/s for the anvils defined in C-2.1.2.1 and 6-0.15+0.0 m/s for the anvils stated in C-2.1.2.2, immediately before impact. [2].

To simulate headfirstimpact at travelling speeds (or tangential impacting components) of 50 km per hour and above, a head model having finite element attributes will be integrated with a motorcycle helmet model in this study. The effects of different falling helmet sides (front, side, and top) and varying ground-to-outer-helmet friction coefficients (0.4 & 0.68) will be investigated.

In general, this study will highlight the importance of testing helmets in relatively high speed as compared to testing speed of helmet impact in laboratories along with the consideration of helmet-to-ground interaction with different co-efficient of friction.

Keyword: Finite Element Method & Model, Head-first high Speed impact, Motorcycle, Helmet, Traumatic Brain Injury (TBI), Road Traffic accidents.

1. Introduction

Two-wheeler auto vehicle accidents are the leading cause of morbidity and mortality among drivers and passengers in traffic accidents worldwide [3] & [4]. Road traffic accidents (RTAs) are the second biggest source of serious injuries and disabilities in Pakistan, and the fifth leading cause of healthy life loss. Particularly with respect to our city Karachi, Motorcycle riders are considered to be more susceptible to traffic accidents, suffering severe injuries or even passing away as a result. [5]. Motorcycle riders most commonly get death and serious injuries from traumatic brain injury (TBI) [6]. By using significant protective helmet, we can reduce the head injury severity. The safety standards and helmet design will be improved by taking into account helmeted head impacts under real-world collision scenarios.

It is found that the oblique impact occurs more often than the linear one in motorbike accidents [7]. The presence of oblique impact is because of two forces i.e., the normal or perpendicular force and tangential force which can lead to translational and revolving head motion. The oblique impact in single vehicle collisions, when the rider is ejected from his bike after colliding with another vehicle, or due to any other potential collision, may consist of two velocity components. The motorcycle's speed at the time of impact created the horizontal (or tangential) velocity component, while the fall from height caused the vertical (or normal) velocity component. [8].

In different oblique testing methodologies, the investigators have tested the helmets at range of speeds between 5.5–7.5 meter per second (19.8 – 27 kilometer per hour) and at impacting angles ranging between 30º to 60º. Therefore, the speeds used in the present applied laboratory testing methodologies are slower than those in actual accident situations.[9]. The objective of this research is to improve our knowledge of helmeted head collisions at low to high speeds to improve helmet testing methods that could potentially be used.Taking high speed as in consideration like real world bike crashes which can't be taken in laboratory due to design limitations of testing machine.

2. ANSYS Simulation Software

ANSYS software is generally used to simulate 3D model structures, or analyzing strength, toughness, elasticity, temperature distribution, deformation, fluid flow, and other impacts on 3D model. We also use ANSYS for the simulation to analyze deformation and normal stress on the full head helmet impacting on road surface at high speed i.e. of 54 Km/h. Figure 2.1 shows an example of general graphical user interface of ANSYS software which is also known as the workbench.

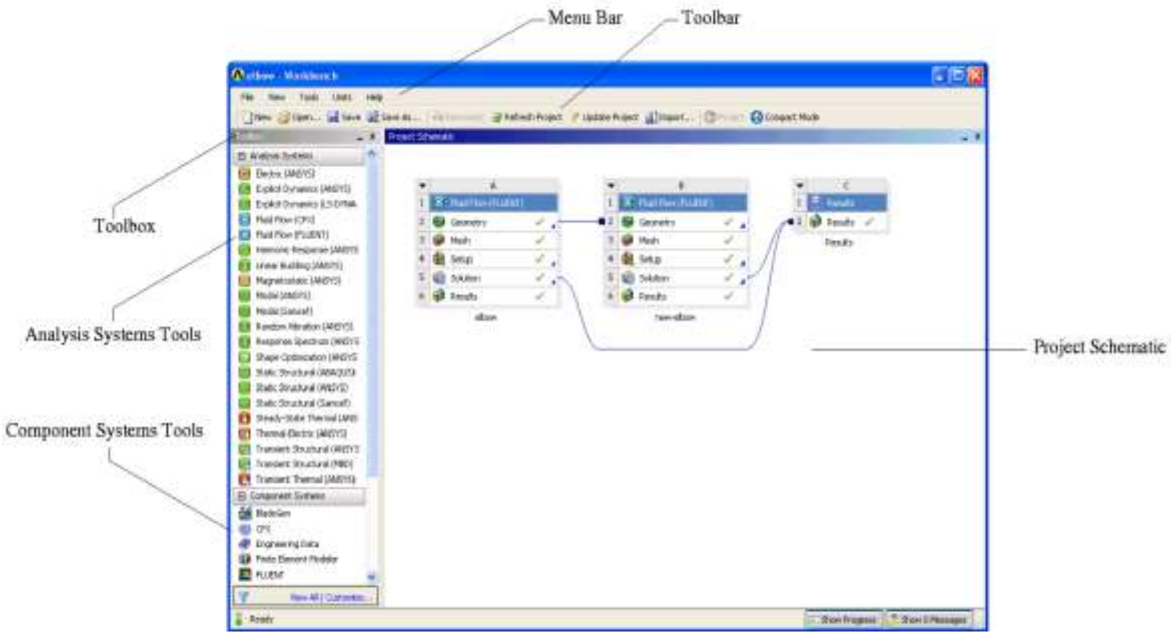

Fig 2.1 Theworkbench graphical user interface of ANSYS

3. 3D model, Geometry & Material Specifications

3.1 <u>Full Head Helmet</u>

Full face helmet along with head form is used in this study. Figure 3.1 shows the helmet dimensions.

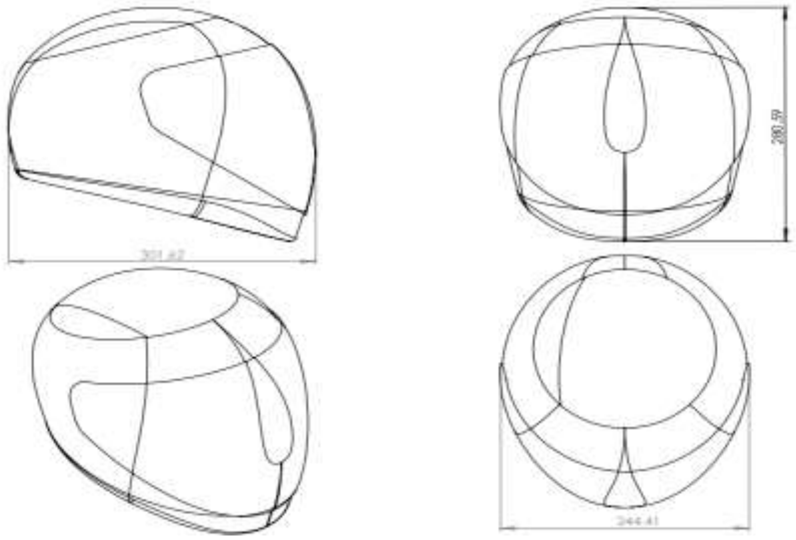

Fig 3.1 Dimensions of the Full head helmet

3.2 Geometry of the Full Face helmeted model and Road Surface in ANSYS

The 3D models of the full head helmet along with head form and the Road Surface along with its geometry that are used in this study are shown in figure 3.1.

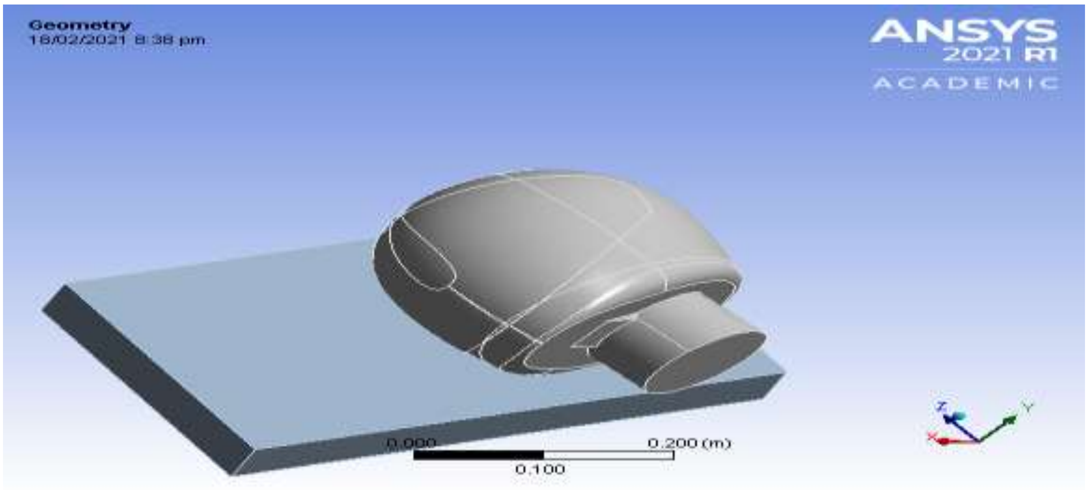

Fig. 3.2 Geometry of Helmeted Head form with side impact on Concrete Road Surface

3.3 Structural Parameters/Material type of Full Face helmeted model and Road Surface in ANSYS

In our study, we used ABS (Acrylonitrile Butadiene Styrene) as material type of full face helmet and Concrete as material type of Road Surface. Table 3.3 shows the material type and its related specifications used in this study

S.No	Geometry	Material Type	Density (kg/m³)	Young's Modulus (Pa)	Tensile yield strength (Pa)	Tensile ultimate strength (Pa)

1	For Helmet with Head form	Plastic, ABS (high-impact) Acrylonitrile Butadiene Styrene	1030	1.628e + 09	2.744e + 07	3.626e + 07
2	For Road Surface	Concrete (Cement)	2392	1.936e + 10	1.095e + 06	1.196e + 06

Table 3.3 Material types and its related specifications of Helmet & Road Surface

3.4 Why I use ABS (Acrylonitrile Butadiene Styrene)

- Acrylonitrile Butadiene Styrene (ABS) is a combination of three separate substances. Acrylonitrile (a pungent, toxic liquid, used in making polymers), Butadiene (is the organic compound with the formula $(CH_2=CH)_2$, and Styrene (Styrene is an organic compound having chemical formula as $C_6H_5CH=CH_2$). This is the derivative of benzene.
- ABS is a common thermoplastic polymer.
- ABS plastic is also much more affordable than the more expensive polycarbonate
- ABS has a higher impact strength (ability to withstand a suddenly applied load) than any of the other common engineering plastics.

4. Methodology

4.1 Full Face Helmeted Head Impact Configurations

In order to determine the impact between the helmeted head with road surface, I used Finite Element Method Explicit dynamic analysis for THREE different Impact configuration with a friction co-efficient of 0.68 (dry roads) & 0.4 (wet roads).

a. Face Head First
b. Top Head First
c. Side First

4.2 Finite Element Method

- The finite element method (FEM) is a numerical approach for doing finite element analysis (FEA) of any specific physical phenomenon.
- Numerical method to solve engineering problems using mathematical techniques via computational tools.
- Looking of FEM as breaking a major problem into a number of smaller ones ("Finite Elements") is a straightforward way to comprehend it. Investigating the issue as a whole is made simpler by this.

4.3 Explicit Dynamic Analysis

- High speed interactions or complex contact is often used explicit dynamics.
- It is computationally effective for the study of big models with somewhat quick dynamic response periods as well as for the analysis of incredibly discontinuous occurrences or processes.

4.4 Mesh Geometry of Helmeted Head & Road Surface

As meshing is the important part of Finite Element Analysis, We meshed (divide the entire geometry in small equal elements) helmeted head and concrete road surface with an element size (mesh size) of 0.05m over the entire surfaces. Then I performed analysis in which I observed total deformation and normal stress as an impact of helmeted head.

Figure 4.4 shows helmeted Head with side impact on Concrete Surface after meshing of 0.05 m below:

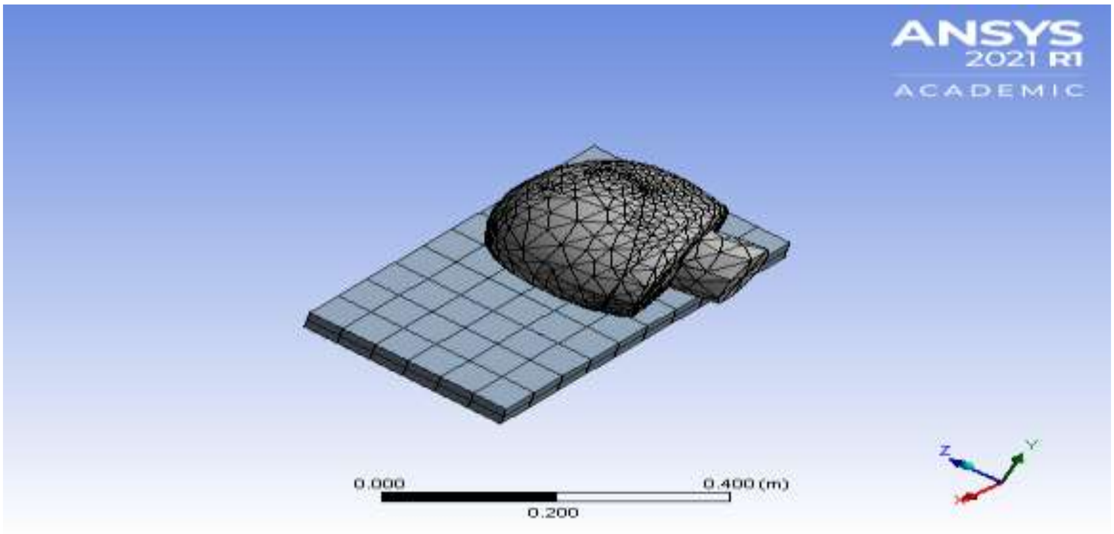

Fig. 4.4 Helmeted Head with side impact on Concrete Surface after meshing of 0.05 m

5. Impact Analysis Outcomes in Face, Top & Side first Impact

5.1 <u>Face first Impact Analysis</u>

Fig 5.1 (a) & (b) shows impact of total deformation & normal stress on helmeted when Face side of helmet interacts first with road surface having coefficient of friction of 0.68 between helmet & Road Surface

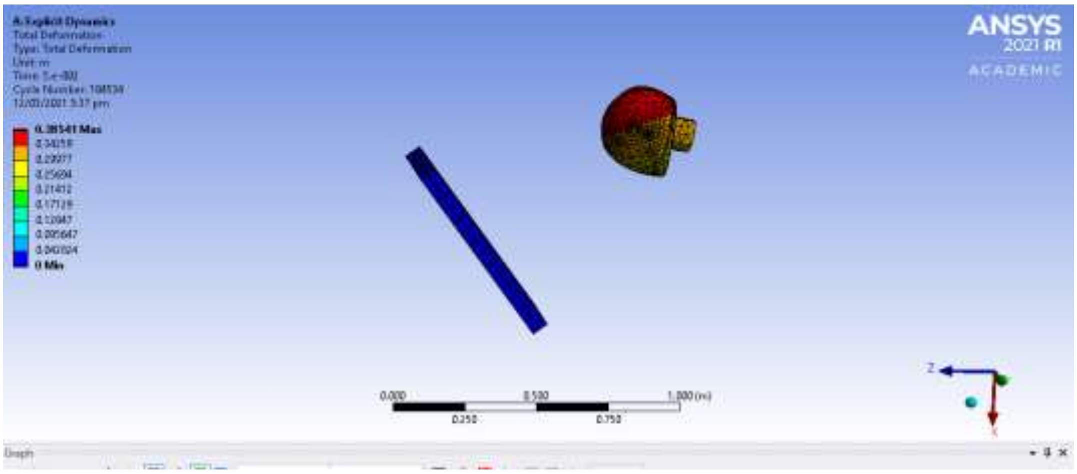

Fig 5.1 (a) Total Deformation when face first impact at 0.68 coefficient of friction

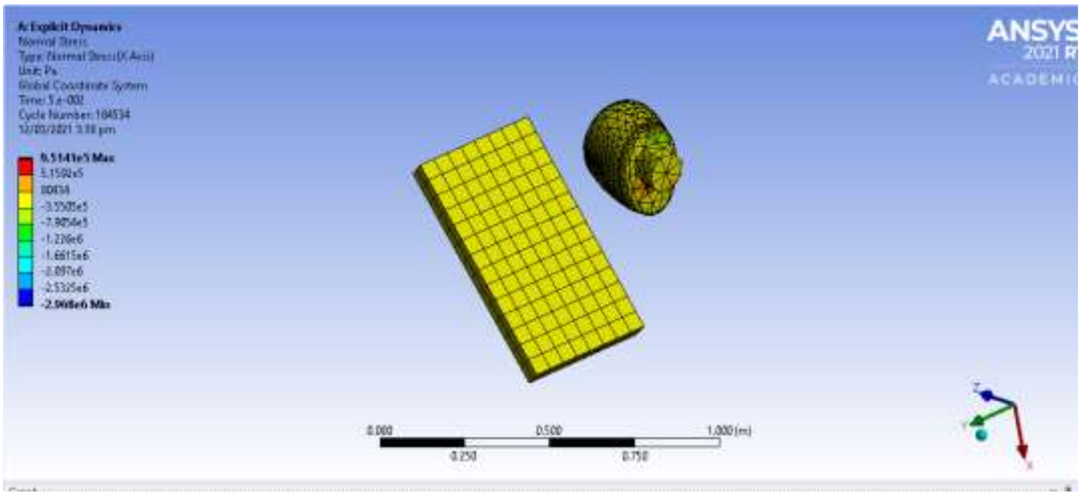

Fig 5.1 (b) Normal Stress when face first impact at 0.68 coefficient of friction

Fig 5.1 (c) & (d) shows impact of total deformation & normal stress on helmeted when Face side of helmet interacts first with road surface having coefficient of friction of 0.4 between helmet & Road Surface.

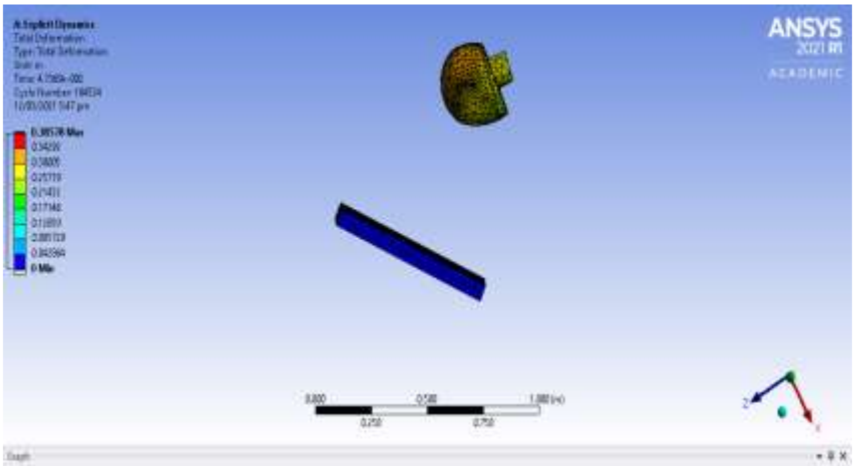

Fig 5.1 (c) Total Deformation when face first impact at 0.4 coefficient of friction

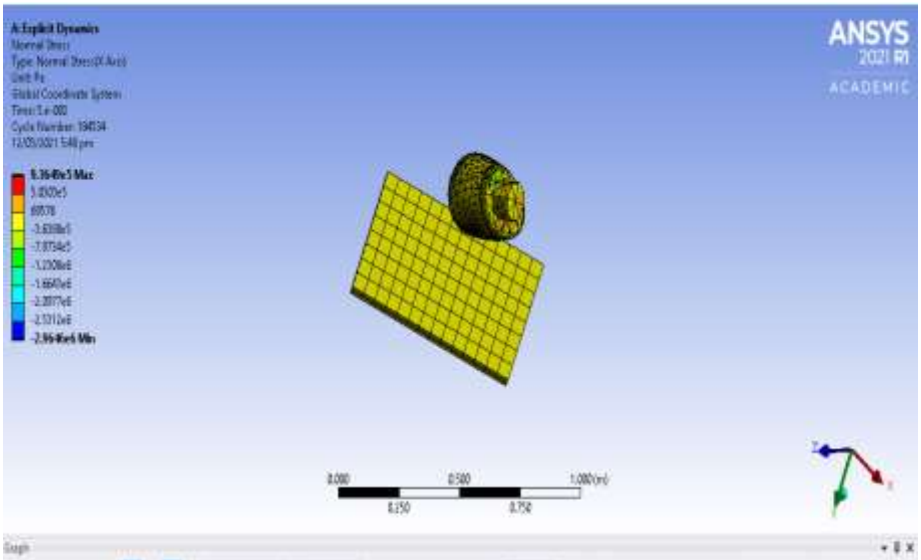

Fig 5.1 (d) Normal Stress when face first impact at 0.4 coefficient of friction

5.2 <u>Top of helmet first Impact Analysis</u>

Fig 5.2 (a) & (b) shows impact of total deformation & normal stress on helmeted when top of helmet interacts first with road surface having coefficient of friction of 0.68 between helmet & Road Surface.

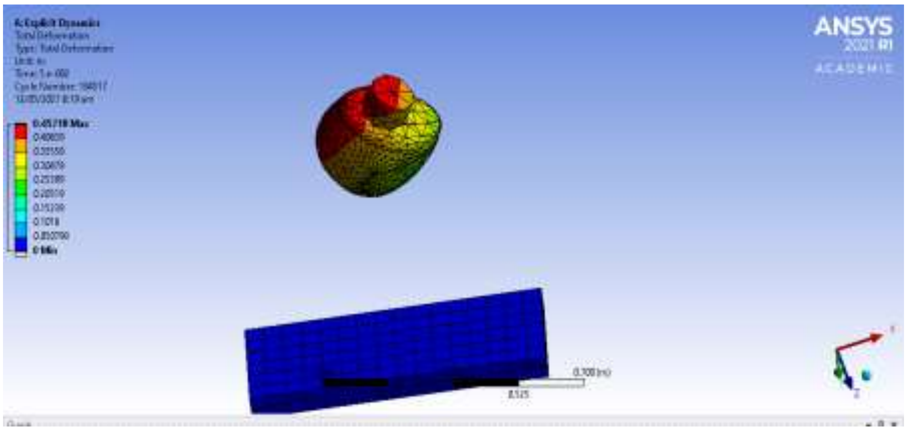

Fig5.2 (a) Total Deformation when top of helmet impact at 0.68 coefficient of friction

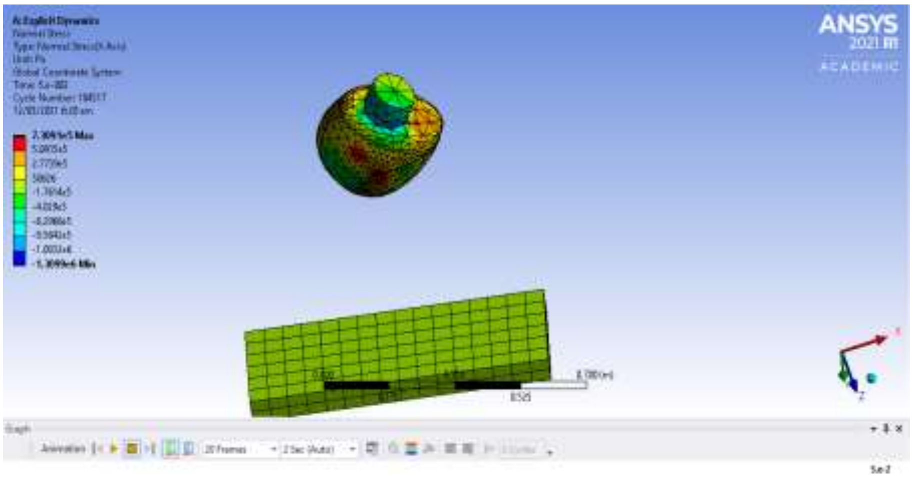

Fig 5.2 (b) Normal Stress when top of helmet impact at 0.68 coefficient of friction

Fig 5.2 (c) & (d) shows impact of total deformation & normal stress on helmeted when Face side of helmet interacts first with road surface having coefficient of friction of 0.4 between helmet & Road Surface.

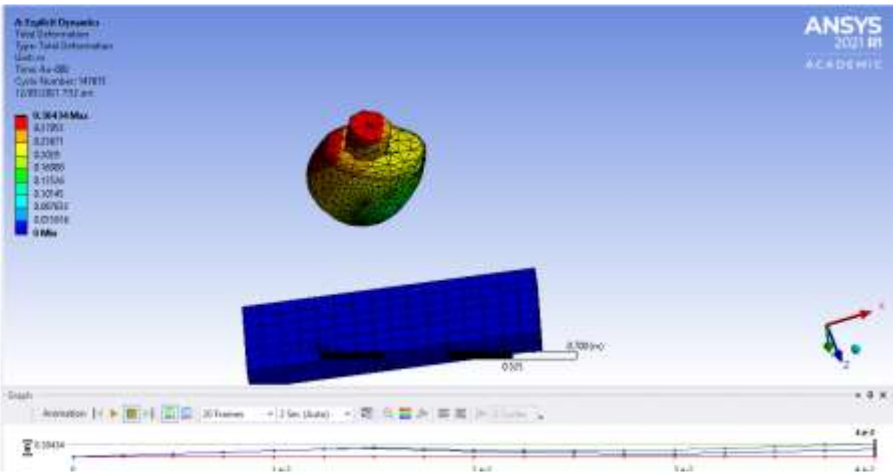

Fig 5.2 (c) Total Deformation when top of helmet impact at 0.4 coefficient of friction

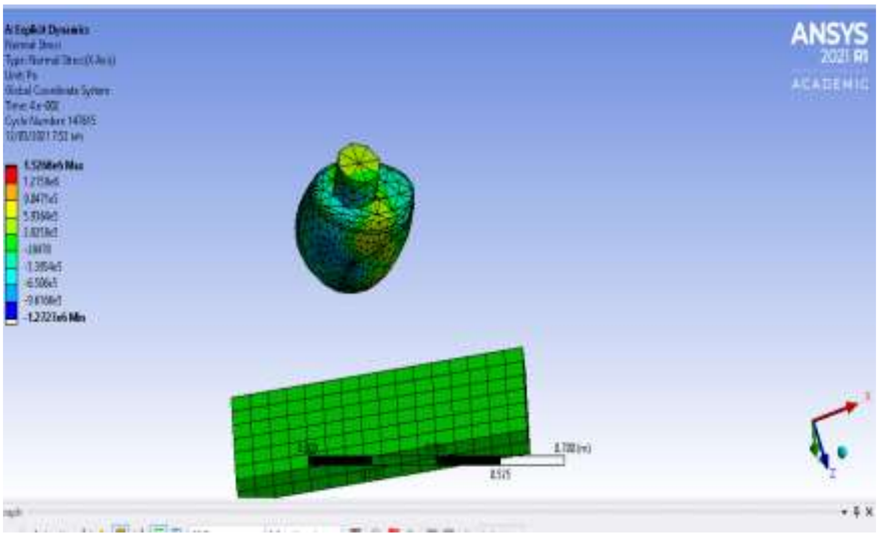

Fig 5.2 (d) Normal Stress when top of helmet impact at 0.4 coefficient of friction

5.3 Side of helmet first Impact Analysis

Fig 5.3 (a) & (b) shows impact of total deformation & normal stress on helmeted when side of helmet interacts first with road surface having coefficient of friction of 0.68 between helmet & Road Surface.

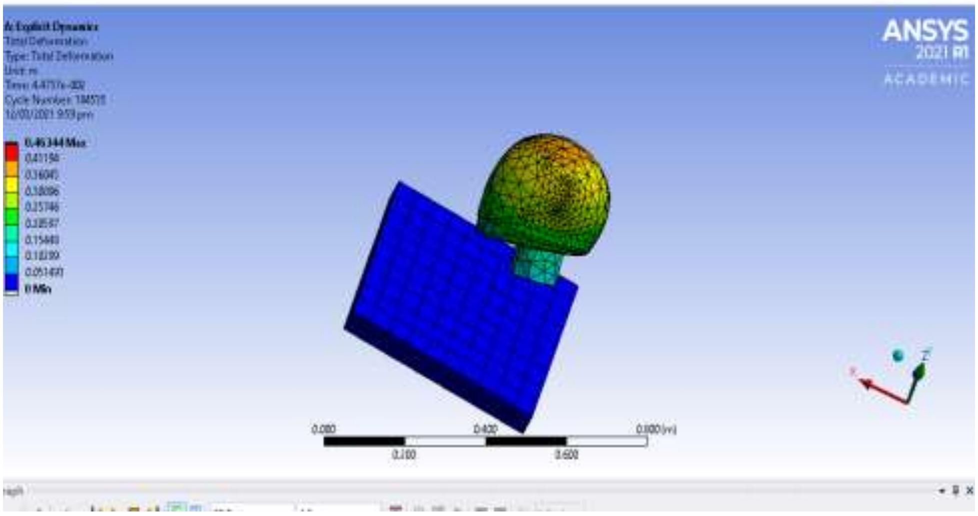

Fig 5.3 (a) Total Deformation when side impact first at 0.68 coefficient of friction

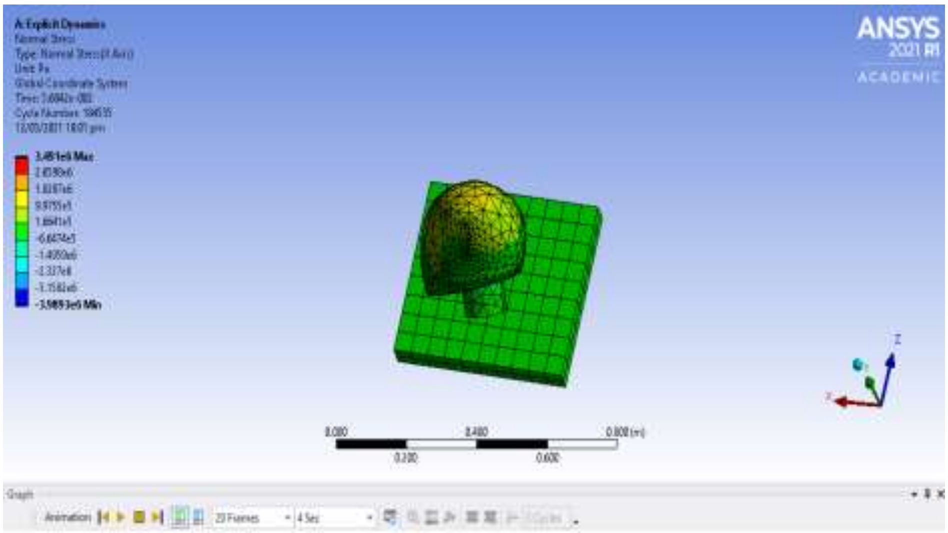

Fig 5.3 (b) Normal Stress when side impact first at 0.68 coefficient of friction

Fig 5.3 (c) & (d) shows impact of total deformation & normal stress on helmeted when side of helmet interacts first with road surface having coefficient of friction of 0.4 between helmet & Road Surface.

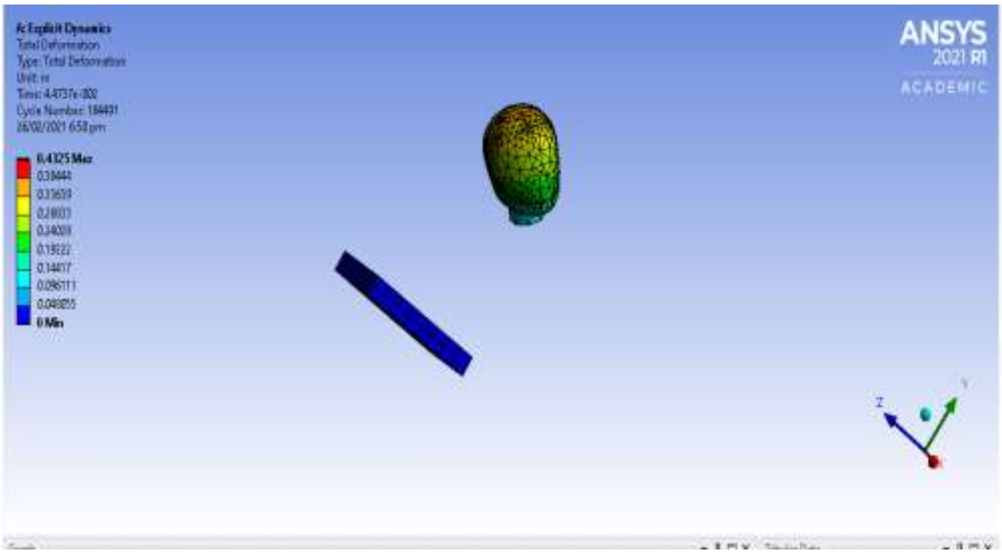

Fig 5.3 (c) Total Deformation when side impact first at 0.4 coefficient of friction

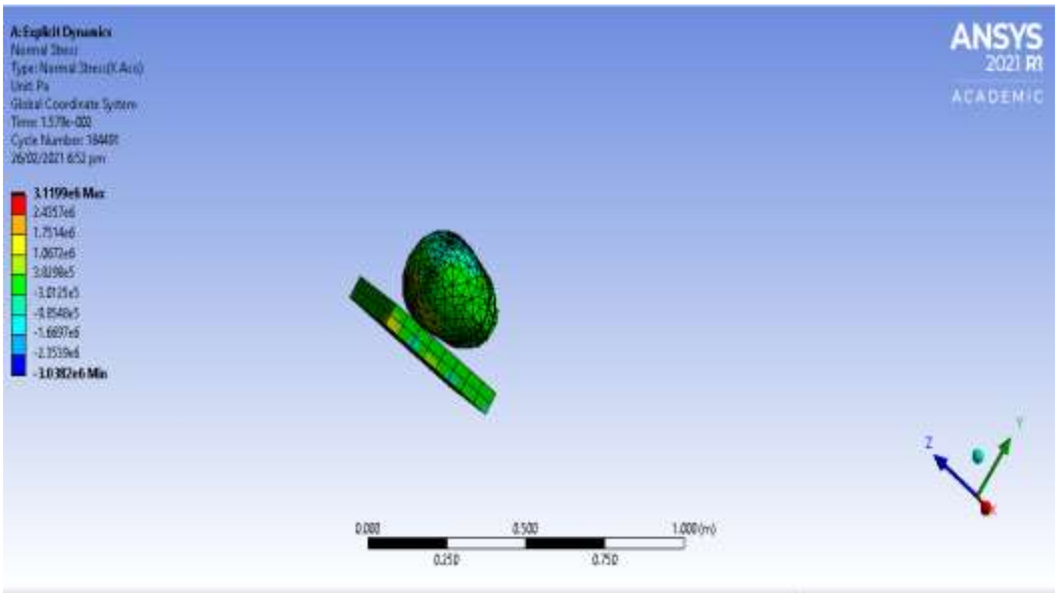

Fig 5.3 (d) Normal Stress when side impact first at 0.4 coefficient of friction

5.4 Analysis Summary

Position of Helmet	Analysis	0.4 Co-efficient of Friction (Wet Road)	0.68 Co-efficient of Friction (Dry Road)
Face Head First Impact	Total Deformation (m)	0.38578	0.38541
	Normal Stress (Pa)	9.3649e + 05	9.514e + 05
Top Head Impact	Total Deformation (m)	0.30434	0.4571
	Normal Stress (Pa)	1.5268e + 06	7.3091e + 05
Side Head Impact	Total Deformation (m)	0.4325	0.46344
	Normal Stress (Pa)	3.119e + 06	3.491e + 06

6. Conclusion

At the end of this research project work:

- Explicit dynamic analysis of a Helmeted Head Impact is conducted for total deformation and normal stress based on the standard helmet design using ABS material in this research work.
- Taking 15m/s Helmet Impacting speed (i.e., 54 km/h)
- According to above data, there is highest total deformation (i.e.,0.46344 m) during side impact, which shows that the geometry (design) of helmet along with internal head form should be plan such that there will be no major injury during side impact with high speed.
- The above findings also showed that the normal stress value is maximum (i.e.3.491e + 06 Pa) during side impact where we observed high deformation but this stress value is under **tensile yield strength** (i.e. 2.744e + 07 Pa).

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