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Model Development of Lithium-ion Battery and It's Deformation Analysis Due to Road Obstacle

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Abstract- Lithium-ion batteries are the most commonly used battery now-a-days in the electric vehicles. The reasons for Lithium-ion batteries used in electric vehicles are, it charges faster, lasts longer and have high energy density compared to all traditional batteries and it also has high power to weight ratio, higher energy efficiency. But due to presence of higher energy in the less volume of battery can be dangerous. As the battery of the electric vehicle is fitted flat below the passenger cabin just below car passenger compartment. Due to less ground clearance in the electric car, there are chances of accidents on worst road conditions due to penetration of road obstacles into battery of the car. To show this a Li-ion battery is modelled in the CREO-PARAMETRIC 5.0 version modeling software and directional deformation analysis was done in the Ansys Workbench 18.0.

Keywords- Lithium-ion battery, battery cell, cylindrical cell, battery pack, deformation

Introduction- Lithium ion (Li-ion) battery is an advanced battery that uses lithium ion as a key component of its electrochemistry. During the discharge cycle, the lithium atoms in the anode are ionized and separated from their electrons. Lithium ions move from the anode and through the electrolyte to the cathode, where they recombine with electrons and are electrically neutralized. The lithium ions are small enough to pass through the micro permeable separator between the anode and the cathode. Partly due to lithium's small size (second only to hydrogen and helium), lithium-ion batteries can have very high voltage and charge storage per unit mass and unit volume. Li-ion batteries can use many different materials as electrodes. The most common combination is lithium cobalt oxide (cathode) and graphite (anode), most commonly found in portable electronic devices such as mobile phones and laptop computers. Other cathode materials include lithium manganate (used in electric and hybrid vehicles) and lithium iron phosphate. Lithium-ion batteries usually use ether (a type of organic compound) as an electrolyte. [1] The idea to work upon the safety of the electric battery and their deformations due to natural and man-made causes like road accidents, came from going through the papers at reference number [3] and [4].

Types of lithium-ion cells-

Cylindrical Cell- Cylindrical cells can be used in design of small as well as large capacity battery packs. It comes in different width, length and capacities. The advantages associated with cylindrical cells are, it is easy to manufacture and have good mechanical stability. Cylindrical cells can withstand high internal pressure without deforming. Only disadvantage of this cell is that it is heavy and have less packaging factor up to 75% [1]

Fig.1 Cylindrical Cell [2]

Prismatic cell – Prismatic cells makes optimal use of space by using a layered approach. This type of cells are used in mobiles, laptop batteries. This type of cell has the best space utilization as compared to cylindrical cells but it can be more expensive and less efficient in thermal management, have shorter life than cylindrical cells [1]

Fig.2 Prismatic Cell [2]

Pouch cells - Pouch cells are lightweight and flexible. But while designing a battery pack it is important to keep allowances for swelling of the cells. It is most efficient to use and it utilize around 85-95% of space, it is highest among all. Pouch types of cells needs extra support in the battery pack [1]

Fig.3 Pouch Cell [2]

MODELING OF THE BATTERY PACK IN THE CREO PARAMETRIC 5.0-

All of the parts were modeled in the modeling software Creo parametric 5.0. Then all the parts such as cells, cell support, battery pack lower case and upper case were assembled.

Modeling of cell- Selected cell is the cylindrical lithium-ion cell for the battery pack design.

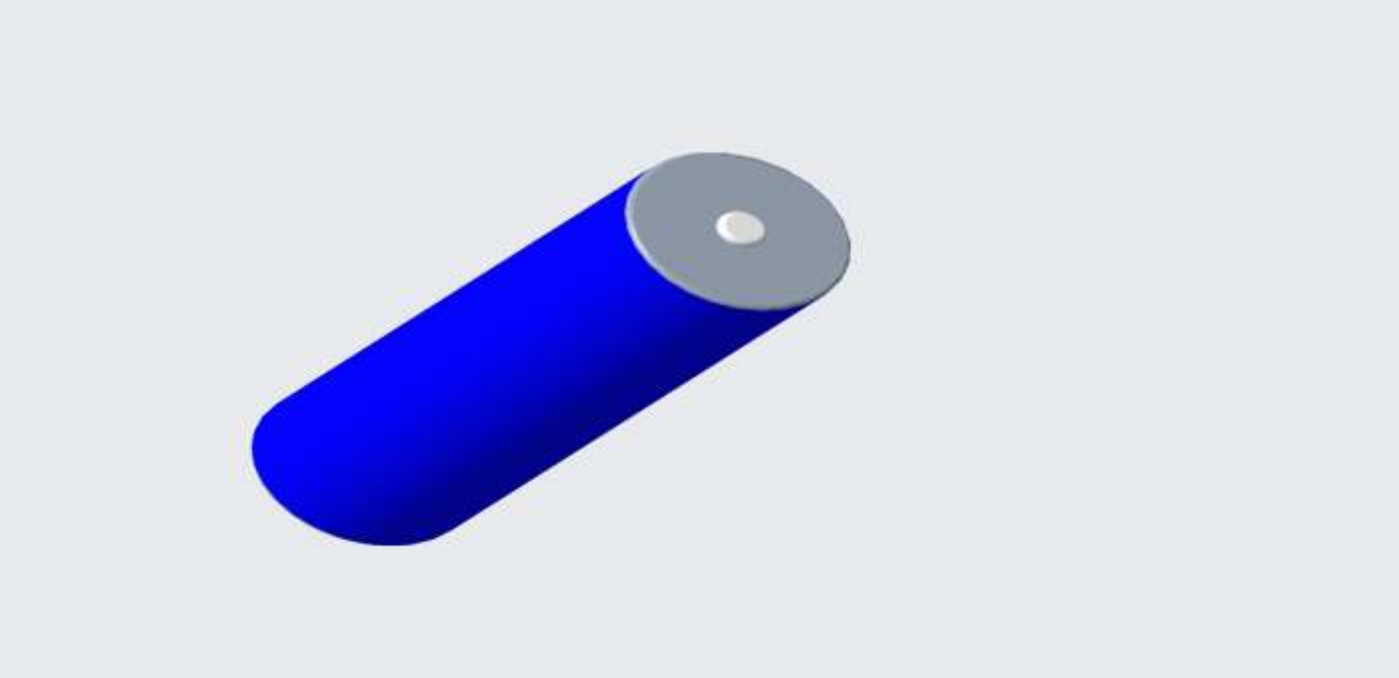


Fig.4 Assembly of cylindrical cell.

Assembly of Module-

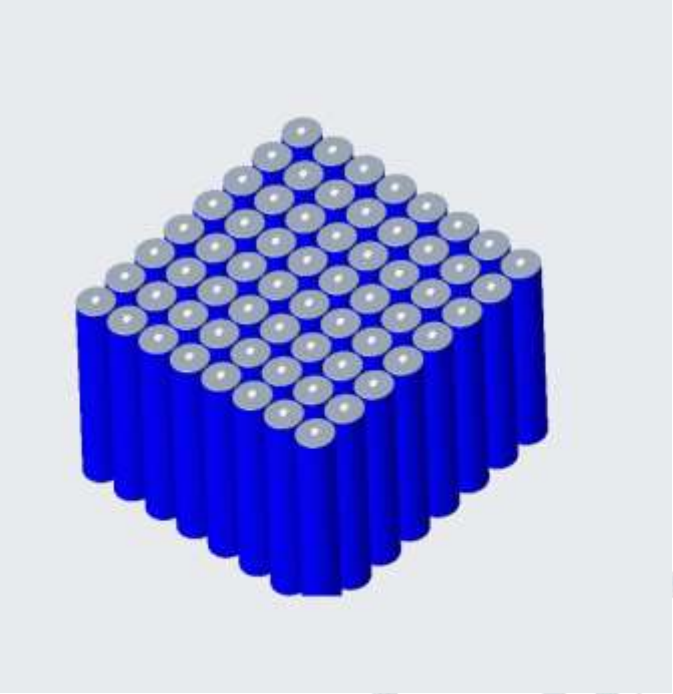


Fig 5. Cells of module without support

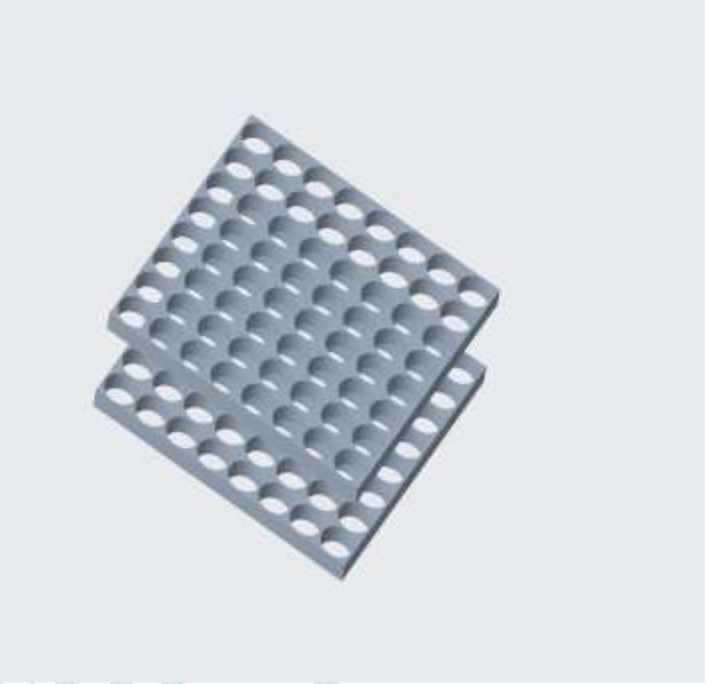


Fig 6. Cell Supports (8×8)

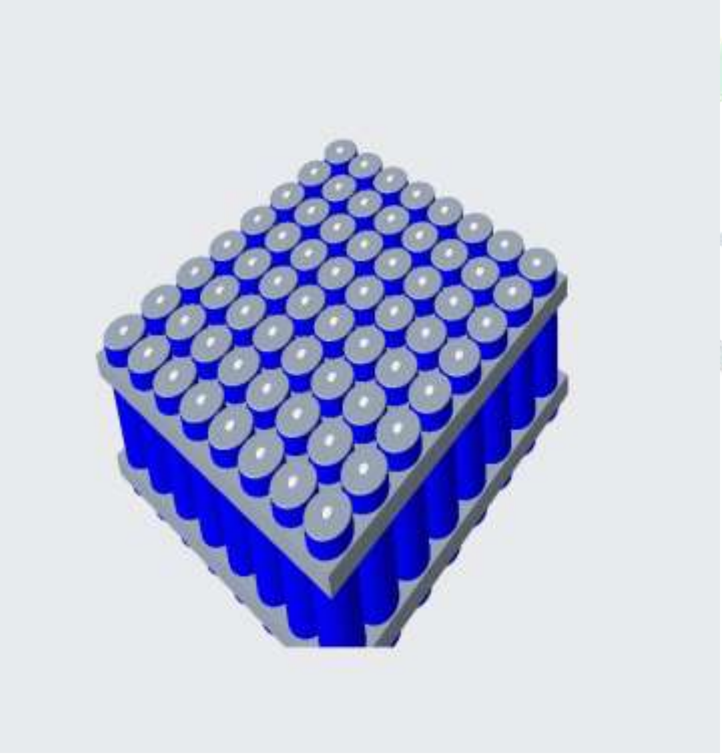


Fig.7 8×8 Module with cell support

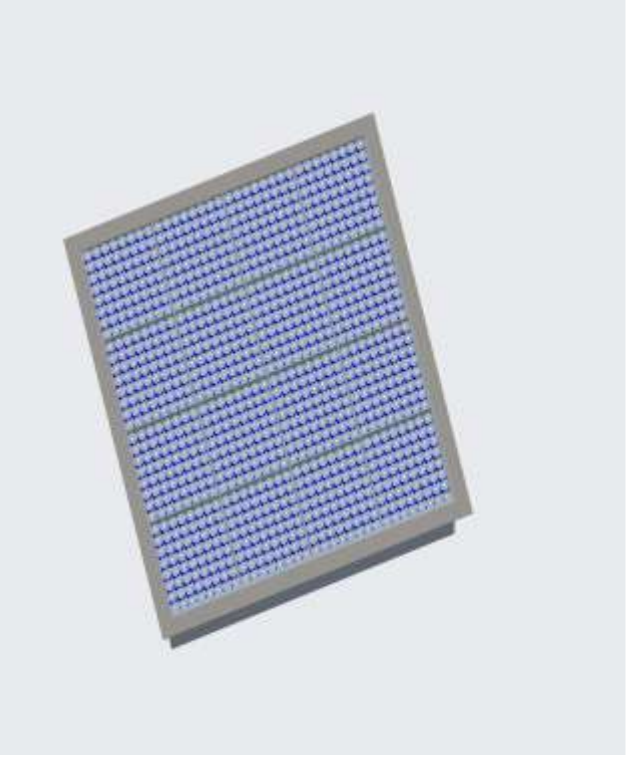


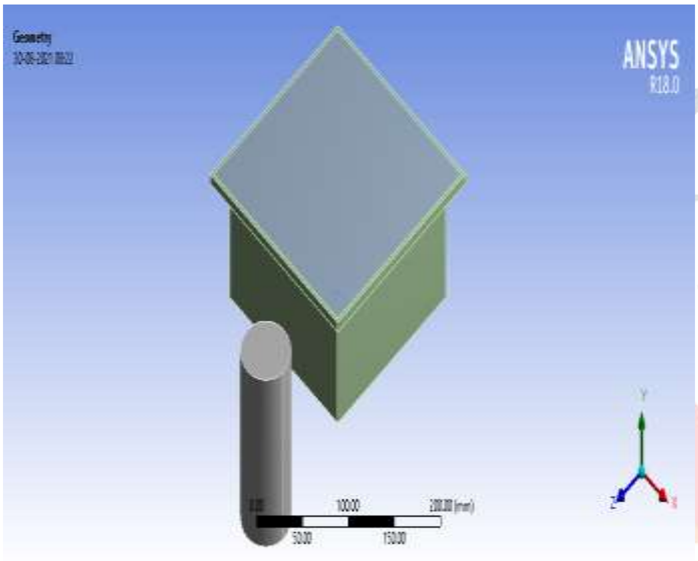
Fig.8 Battery pack

DEFORMATION ANALYSIS IN ANSYS 18.0- The above assembly was converted into the STEP (Standard for the Exchange of Product Data, 3-D CAD file format) and the geometry was imported to the Ansys Workbench 18.0 for the deformation analysis. For this the concrete pole is taken as the road obstacle to the battery pack.

Materials	Al AA2024	Lithium	Rubber
Density	2780 kg/m^3	534 Kg/m^3	1000 kg/m^3
Tensile strength	425 MPa	1.5 MPa	
Poisson's Ratio	0.3	0.355	
Yield strength	325 MPa		
Elongation	19 %		

Table.1 Material Properties

Al AA2024 is used for battery pack housing and cylindrical cell cover, lithium is filled as solid material into the cell cover and the rubber is used for the cell support.



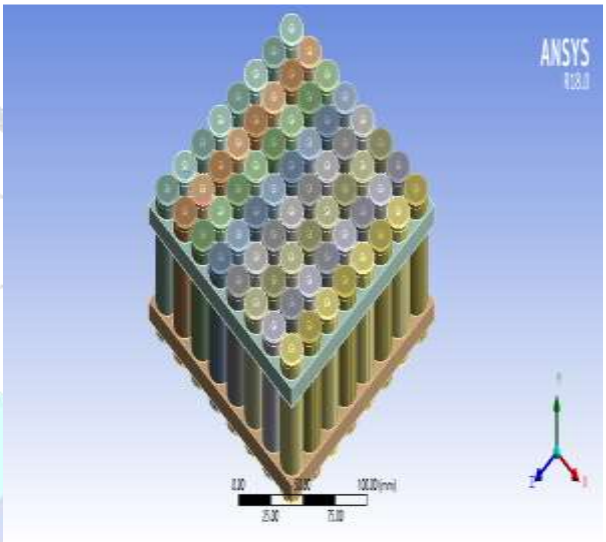


Fig.9 Geometry imported to Ansys Workbench

Fig.10 Internal parts of the battery pack

Discretization- After selecting the materials and its properties for all the components, the model was meshed. The whole battery-pack model was meshed in the smooth grain to achieve correct results. The meshed battery pack can be seen in the figure 11. Finally, the completed model contained 2,78,203 nodes and 5,16,489 elements. Nodes are the selected finite points at which basic unknowns (displacements in elasticity problems) are to be determined in the finite element analysis. The basic unknowns at any point inside the element are determined by using approximating/interpolation/shape functions in terms of the nodal values of the element.

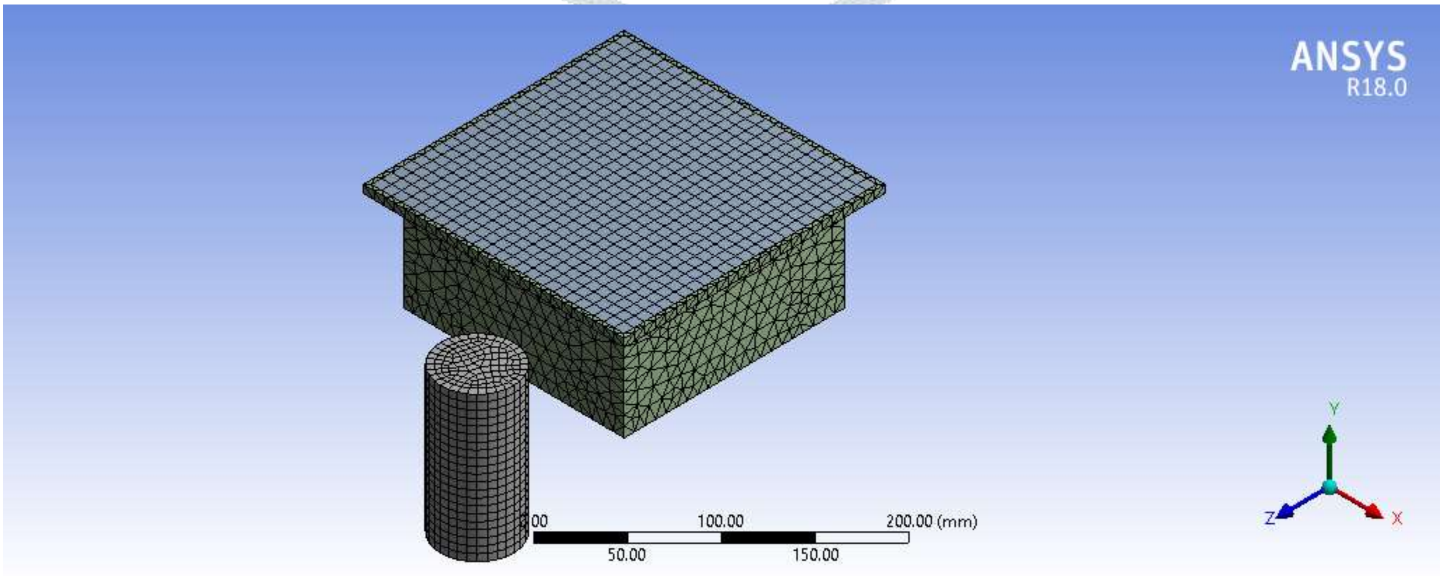


Fig. 11 Meshed battery pack

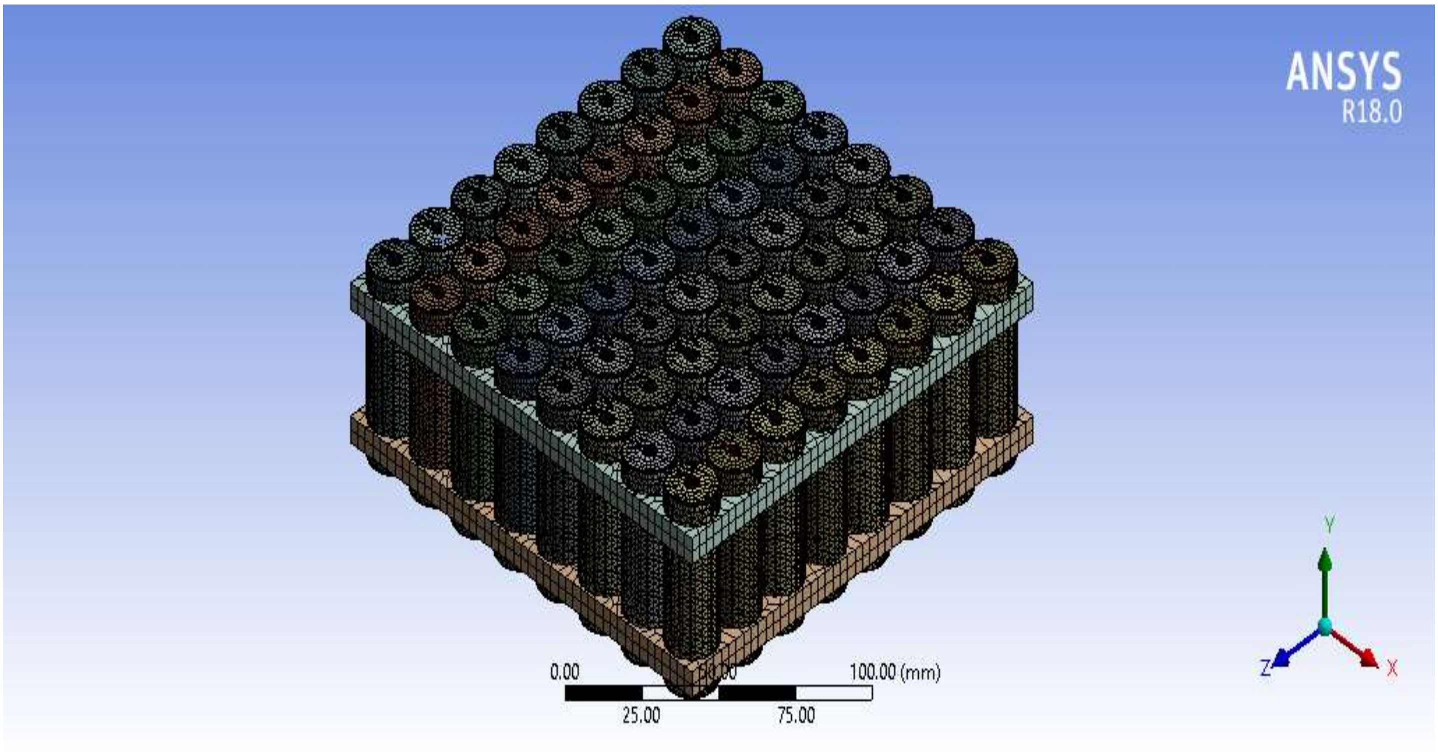


Fig.12 Meshed battery internal parts

Time and Velocity- The velocity was given to the whole battery pack body in the z-axis, as beam was situated in that direction. The velocity is given as (0,0,90) km/hr. and the time set for the analysis is 0.007 seconds, as the concrete beam is placed at distance of only 5 mm from battery-pack.

Force of Impact-

Mass of the Obstacle	Impact Velocity	Impact Duration	Collision Distance	Impact Force on the battery pack
15 Kg	90 km/hr	0.007 sec	1 mm	4687.5 N

Result- As shown in the figure 13, the maximum directional deformation was obtained as 15.339 mm in the z-direction and the total deformation was 17.268 mm. as shown in figure no 15

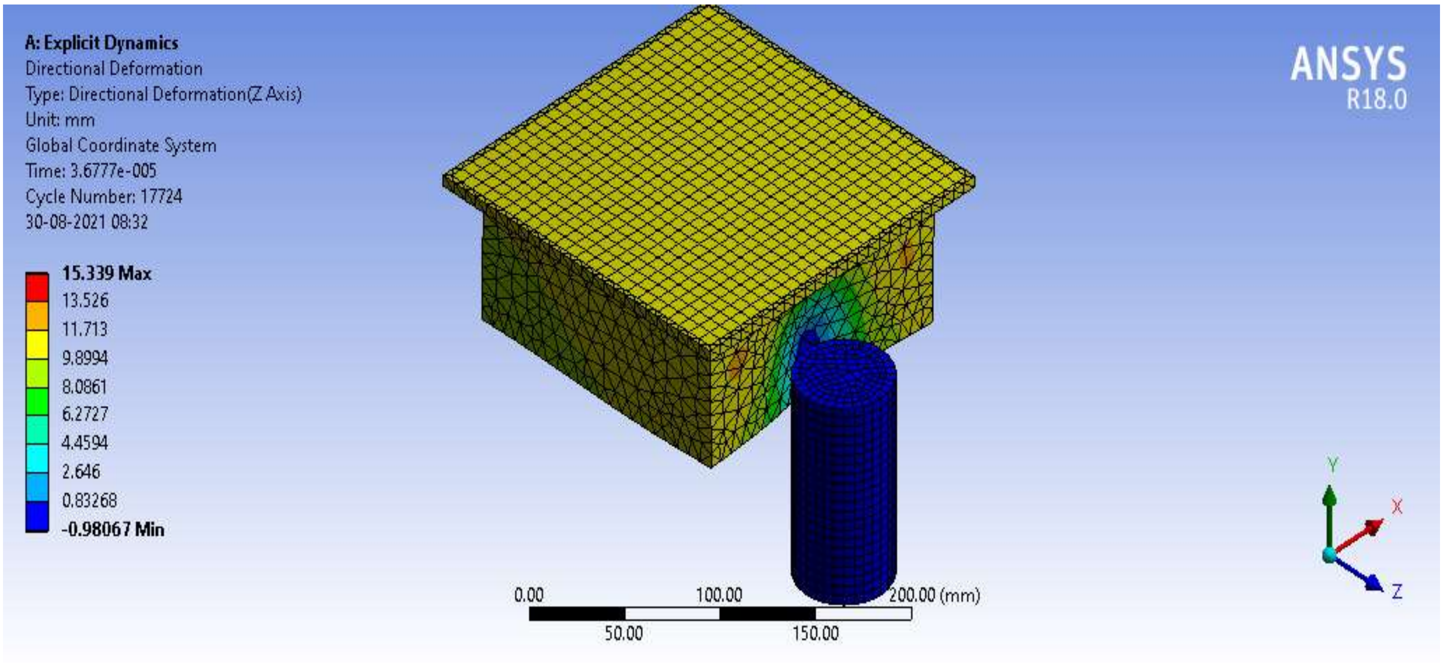


Fig. 13 Directional Deformation of the battery pack in the Z-direction

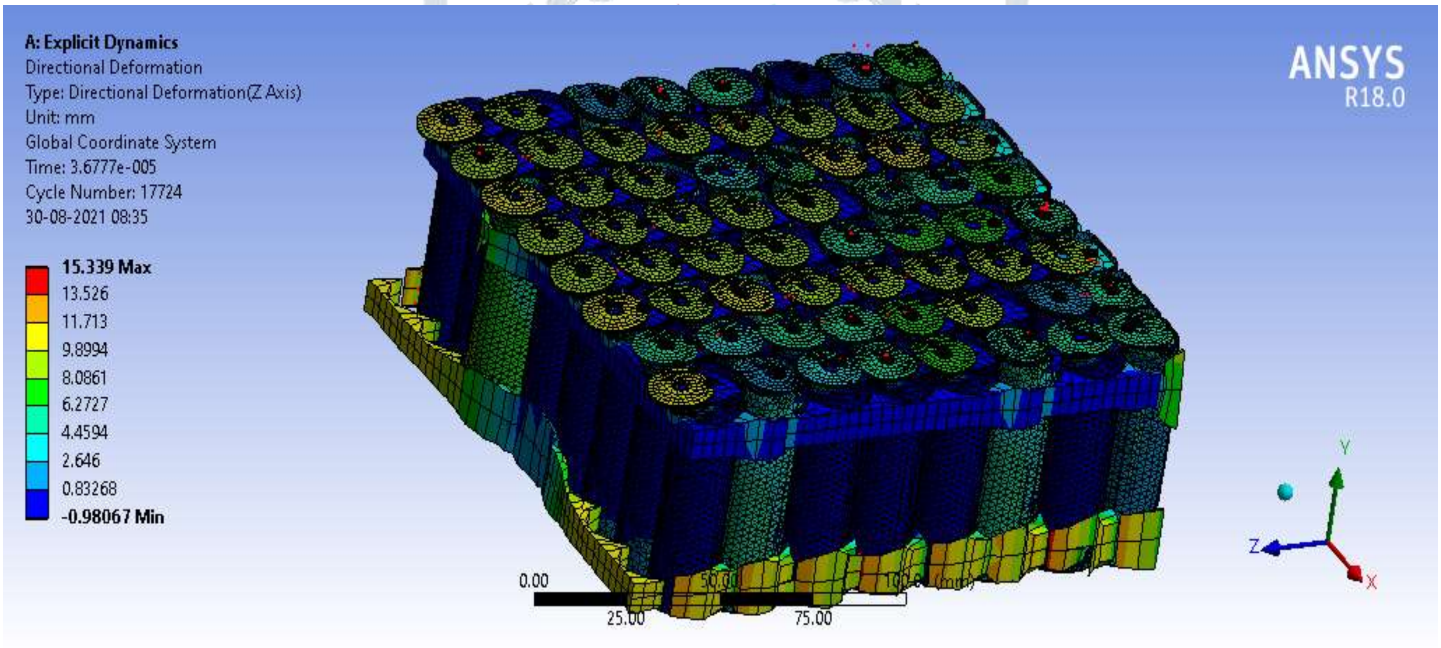


Fig.14 Directional deformation of the battery cell internally

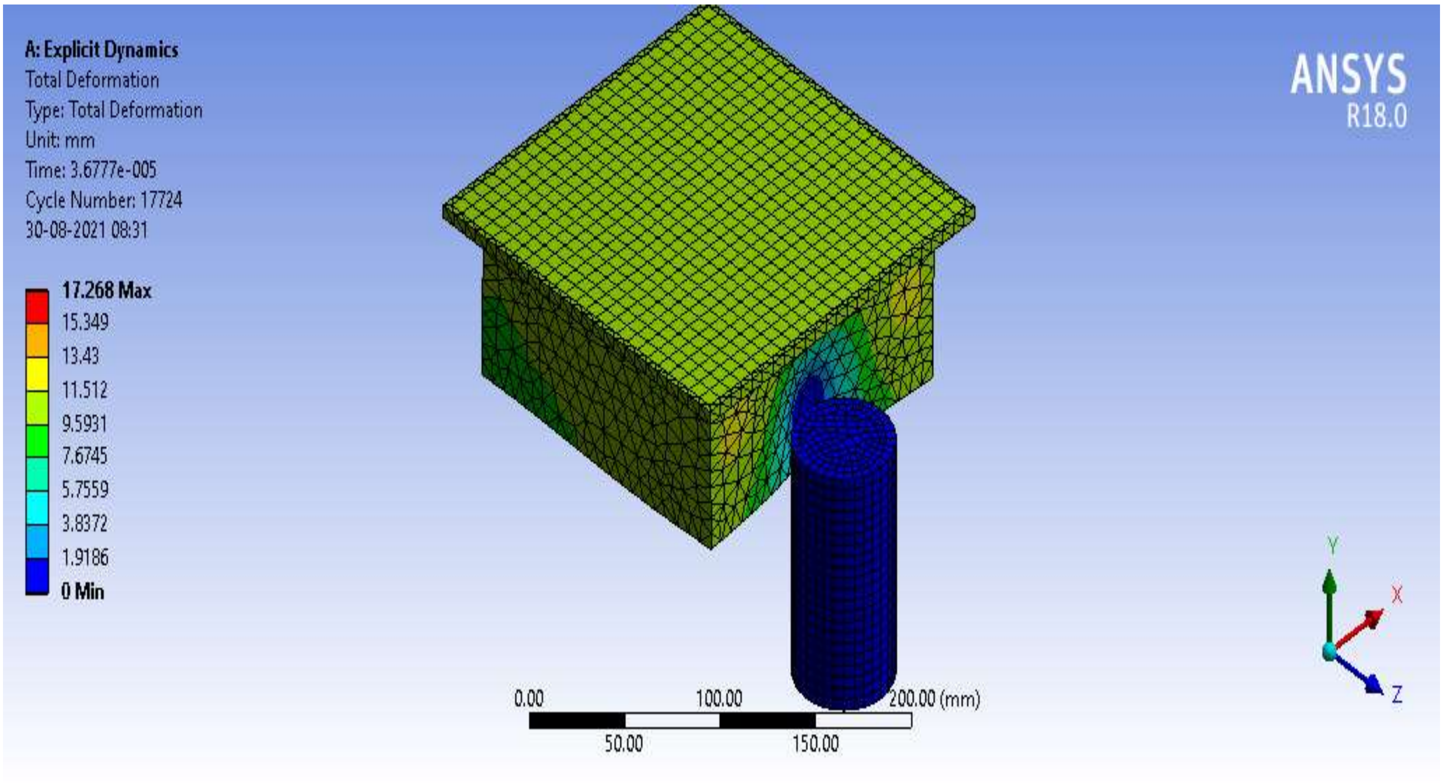


Fig.15 Total deformation of the battery pack in X,Y,Z direction

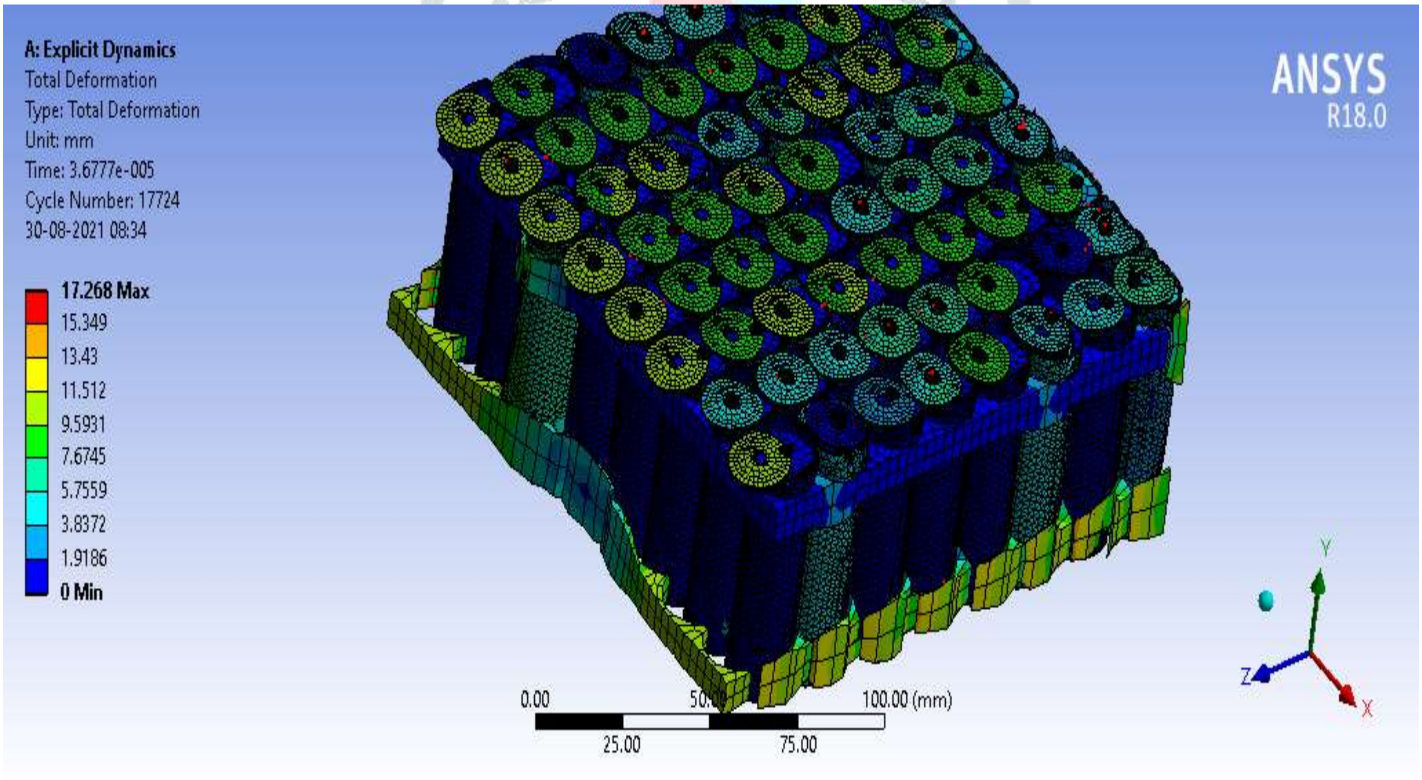


Fig.16 Total deformation of the battery cells

Conclusion- From the above analysis it can be concluded that

1. The directional deformation in the Z-direction in the battery pack at velocity 90 km/hr with the impact force of 4687.5 N by the road obstacle was 15.399 mm and total deformation in the battery pack was 17.268 mm in (X, Y, Z) directions.
2. Due to impact of the road obstacle to the battery pack, the first two rows of the cylindrical cell in the battery pack gets mostly damaged. The positive cap of the cylindrical cells was separated from the cell body and translated in Z- direction. Due to this these cells were disconnected with the circuit.
3. The cells in the other rows were less damage as compare to front two rows but all the connections between the cells were loose and somewhere disconnected. Due to this there are chances of excessive temperature generation on the terminals on the battery cell.
4. The lithium-ion batteries are more sensitive than all other batteries and due to presence of high energy density material, there are chances of electric short circuit and of explosion. This is because every small cell consist two active materials called anode and cathode which are opposite in nature with each other and there is very thin layer separating them to avoid direct contact between them. If such a collision happened, there are chances of direct contact between anode and cathode due to the deformation, this will tend to short circuit in the battery pack. This will be more dangerous in terms of the passenger's safety. For that extra lower protection can be provided to the battery pack that can be able to bear external force and not transfer it to the battery pack.

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