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ANALYTICAL INVESTIGATION ON SPHERICAL SHELL SUBJECTED TO BLAST LOADING

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Abstract

Blast is defined as release of air due to the explosion of bombs and dynamites caused by ignition. Explosives are used in various applications such as mining, demolishing of buildings, gunpowder which is use to propel bullets. Another area where explosions likely occur is in nuclear power plants, here even inhaling or slightest exposure to the radioactive gas can seriously damage the human body, however health precautions have been implemented. The main problem has been isolating the explosives and dynamites when they are not in use. Earlier in the 1600 to 1900, mining factories used to keep it in small wooden or steel sheds which was unsafe as even a small blast would destroy the surrounding structures and lead to death of many workman near it. Our main goal is to design a containment vessel which is able to withstand maximum internal load before complete failure. The prototype of the chamber is modelled with different boundary condition, the time step and the pressure values are evaluated. For different loads of blast loading, which vary due to distance and strength of explosive, they will be considered in this analysis. Modelling is done in program like ABAQUS v6.14 is used for this investigation.

Keywords: Blast loading, Dynamic analysis, Pressure time-history analysis, Displacement time-history analysis, Steel, Spherical vessel.

Introduction

Since the industrial age, we have witness many development in structural work, such as, construction of roadways, buildings and development of nuclear power plants. But for any development we need to make through the old, for this purpose many explosives have been used, like, demolishing of old buildings, clear path in mountains for roads. Now, since we are using explosives, safety of the workmen is our priority. As we don't need explosives on a daily basis, storing them is our primary objective. Earlier days, we used to store explosives in wooden sheds which is obviously not safe, but it was the only way due to limited resources. Nowadays, we have steel sheds that are stable, provide more protection than wooden shed, but still it is unsuitable and main problem is transporting large quantity of bombs. For this, we have introduced a vessel which not only provides a better protection but also, we can transport it to any type of terrain.

An overview of what is blast loading, the effects of blast loading and the structural response from the blast load is explained. Prediction of blast pressure has been calculated using the relationships introduced by Brode [1] (1955) and estimating the maximum blast overpressure in bars due to explosion by Newmark [1] and Hansen [1] (1961). Structural response has been done by elastic single degree of freedom of system. The failure modes of structure both local as well as global due to blast loading, various structural components have been taken into account such as columns, walls. Many programs have been implemented but LS-DYNA has largely been used.

It is concluded the recommendations for guidelines on unnatural load cases and provisions on continuous failure prevention should be included in Building design regulations and standards. [2] Documents the development of a high-performance filament wound composite firing vessel which is radiographically transparent, the main purpose is to house a limited number of explosives in radioactive facilities. In this a two-meter diameter vessel was constructed to hold up to 35kg of TNT without leakage. There have been other applications such as transportation of explosives in small quantities. The Lawrence Livermore National Laboratory [2] (LLNL) collaborated with Los Alamos National Laboratory [2] (LANL), for the development of the vessel, the primary goal was to prevent public and worker exposure to the toxic materials of bombs. Priority was to provide defense without affecting the radiographic transparency of inside composite vessel.

Basically, the paper covers the development of the composite vessel, explosives experiments which are done on prototype vessels, monitoring analysis for leakage, welding the pressure liner and low noise sensors for structural analysis. The design consists of thinnest wall section of aluminum at the equator because this is where stress will be the most. To prevent rupture, engineers have fused the area with the structural design. The loading was done by using CALE2D code and DYNA3D was used for the time-history analysis. Conclusion was made that filament wrapped containment could be used which is light in weight and thin for radiographic image, port seals were used to prevent exposure to the environment. This design can be used for other vessels and to provide shield against blasts.

[3] Studies the design of concrete vessel which is to resist both internal and external explosions. Partial prestressing has been applied at areas where stresses have been focused mainly on the transition zones and near the openings. Various design modifications have been done including integration with structure, the benefits are: - Avoiding stiff corners, saving supporting structures which will be needed to transfer dead load and impact loads, providing resistance of the combined structural system.

It was concluded that the containment design having integral system is capable to withstand the various loading conditions, non-metallic is more beneficial than steel liners and finally partial prestressing might be beneficial. [4] Describes the use of containment vessel when the explosive charges are kept at the center, it consists of using HE (High Explosive) materials and products for detonation experiments. They are used to analyze extreme pressure from shock behavior of materials accomplished by HE charges which when detonated drives the metals with high-pressure, extreme-temperature regime and increase-strain rate while the dynamic analysis is done through radioactive images.

The main goal of this paper is to provide design considerations for the blast loading in vessels using 13.5kg(30lb) HE charges inside a HSLA-100(High Strength Low Alloy) steel vessel with inner diameter of 6ft. Loading developed due to the explosion is estimated by using empirical and numerical methods. The results were that when analyzing the overall impulse of system, blast and fragment loading should be taken together, ductile and non-ductile failure analysis is completed with simplified methods and finally the vessel design met all requirements of current code cases.

[5] Assess the ductile and brittle failure of containment vessels subjected to internal blasts, various codes and standards have been followed for the design of vessel. Various analysis such as elastic or elastic-plastic response and calculation of damage mechanism of explosive containment vessel have been performed.

The experimental procedure consists of two cylindrical vessels; TNT charges are placed in the middle with the help of a hollow cardboard tube. A rate- dependent criterion has been used for ASB (Adiabatic Shear Band) analysis while LS-DYNA is used for finite element analysis of pressure of the containment vessel, various charge sizes was placed and dynamic response measurements was performed. Three pressure rod gauges were used to find the overpressure at various points and electric resistance gauge was used to estimate hoop and axial strain in the experiment. It was noted that the peak overpressure decreases with an increase in longitudinal distance.

[6] Is almost similar to [5] with few dissimilarity, such as, open-ended mild steel cylinder has been use. 10-trials were performed on explosive loaded vessel using PE4 bombs (Plastic Explosive no.4). The main objective of these trials was to determine maximum strain of vessel and how much amount of explosion can the vessel endure. reaction of the cylinder with progressive charge size goes from high plastic deformation to failure by propagation of vertical cracks in the particular region of wall, the experiment provides detail failure process of the structure under the influence of internal explosion. Prediction of wall response under dynamic load was done. High modal vibration was experience due local thin wall and various analysis was done to confirm it.

Efforts were done to measure the strain-history by using gauges that were attached to the wall of cylinder at detonation of charge, but failed, due to excess energy the gauges got detached and because of this incorrect data was produced. Final cylinder gave appropriate measurement which was needed for the analysis.

Failure mechanism of cylinder was performed well under blast loading due to explosive placed at centre. Once the energy level was high, the containment became unstable in the middle around the circumference. [7] Elaborates elastic response of a multi-layered cylindrical shell which is subjected to uniformly distributed pressure. Mainly two problems were to be solved-(a)Quasi-static which was fulfilling inhomogeneous stress boundary conditions and (b)Dynamic response which is in co-ordination with homogeneous stress boundary.

Assumptions were: -Shearing stresses due to friction were neglected for ribbon layers, ribbons were accurately contacted with each other, they were wound in the same direction and angle, cross-section of shell remained plane during change.

Finally, hoop stress in the inner surface increased with increased of winding angle. [8] Discuss the effects of internal blast loading which is provided within spherical vessel for testing the efficiency and determining the damage caused by the explosives provided at the centre of test chamber, it can also be used to determine whether the explosive is dynamic or static. It is tested in a prototype stainless steel cylinder that is efficient in cost also, we can use the vessel for various applications such as military, for storing ammunition and explosives, transportation which include moving of semtex explosive and TNT. It is fix at all sides and blast loading is propagated throughout the surface of the wall. W.L. Ko [9], H.G. Pennick [9] and W.E. Baker [9] gave a brief description about response of a multi-layered spherical vessel due to internal blast load. In this, a multi-layered spherical vessel was subjected to gradual internal blast and analysis was performed to determine the movement of elasto-plastic vessel due to internal loading. The vessel consisted of N number of concentric shells of same material, providing gaps of equal thickness. Five cycles of vibration were performed and the results were found for each gap.

It was noted that the inner layer of the shell suffered the most deformation and showed various vessel responses. The worst case was when the inner- layer gap was at 1mm when inter-laminar impact is elasto-plastic. Under loading condition, all the effected layers went plastic deformations.

[10] Shows dimensionless number for analysis of dynamic response of a box-shaped structures influenced by internal blast loading. Under the influence of dimensionless number, the analysis was performed which illustrated the response of the vessel for induced blast load and to determine the structural integrity with internal explosion. After this, the data was analysed and an expression was obtained which can be used for the understanding of various rectangular boxes under the influence of internal blast loading. It also explains the efficiency and uses of dimensionless number.

The results were compared with conclusion of other experiments conducted by various scholars and the final expression was obtained with the help of dimensionless number.

The main objectives are:

- To design vessel so as to isolate blast propagation due to explosive charges.
- To analyze the dynamic response and investigate blast wave propagation so as to estimate blast intensity.
- To prevent destruction caused due to blast load and calculate maximum capacity of vessel before failure.

Conceptual Framework

The entire research work is divided into various process and stages which is shown in fig 1. Progress is being done as per the various stages.

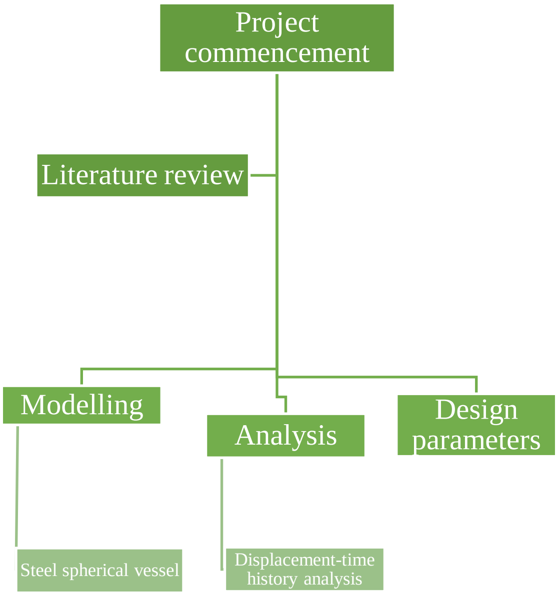

Fig. 1: Conceptual Framework

A. Data

Different data have been implemented for design, material property, dimension of spherical vessel and loading which are described in table 1, 2, 3.

1. **Material property:** The properties of 1020 steel are described in table 1.

Table 1
Material properties

Variable	Value
Mass density	7850kg/m3
Young's modulus	210GPa
Poisson's ratio	0.3

2. **Member dimension:** Dimension of vessel is illustrated below in table 2.

Table 2
Member properties

Variable	Value
Diameter	200mm
Radius	100mm
Thickness	50mm

3. **Loads:** The blast load is taken as per IS: 4991-1968 and is shown in table 3.

Table 3
Load

Load description	Value
Blast load	The magnitude of blast load is 1.

B. Displacement-Time history analysis:

The displacement-time history produced due to blast load is analyzed by using ABAQUS v6.14. It is shown in figure 2, The explosives were placed at the center of the vessel.

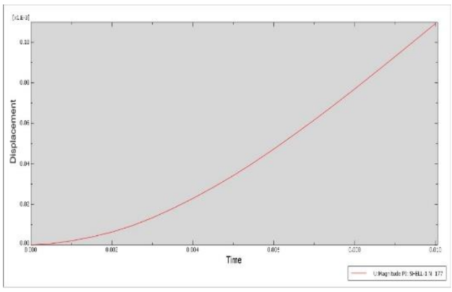

Fig. 2: Displacement-time history analysis

C. Model

The model is depicted in figure 3 with an opening provided at the top for inserting explosives in the spherical vessel. Figure 4 shows meshing of the vessel before applying the loads.

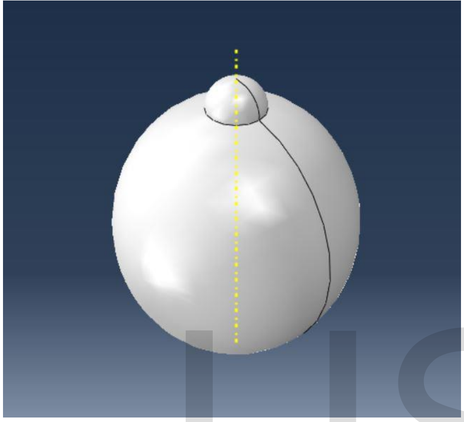

Fig. 3: Designed vessel

Results and discussion

The analysis is carried out on steel spherical vessel. The meshing is formed independently as shown in fig 4. It can be seen from fig 5 that the blast loading effect is observed at the center before it effects the whole vessel because of explosive placed at the center of shell.

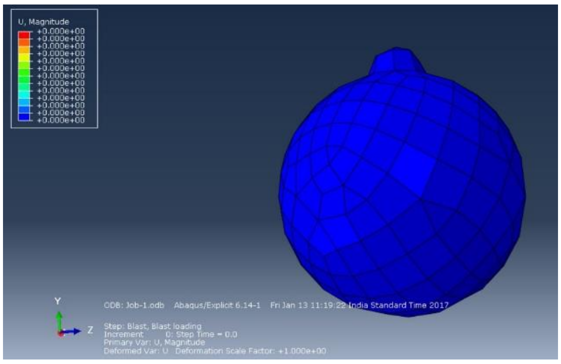

Fig. 4: Meshing

Stress on spherical vessel which is occurring due to blast load is shown in fig 6, it illustrates where the stress start to occur before it completely fails. Fig 7 shows strain energy which is occurring on the vessel due to blast load, it first increases greatly up to 0.001sec and then falls linearly from 0.002 to 0.004 sec and finally starts to disappear from 0.008 to 0.01 sec.

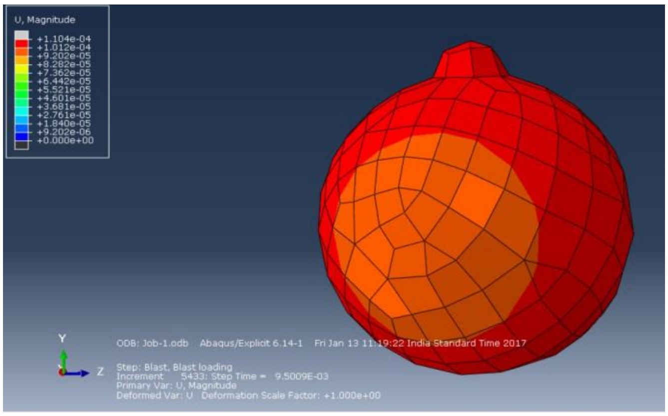

Fig. 5: Blast effect

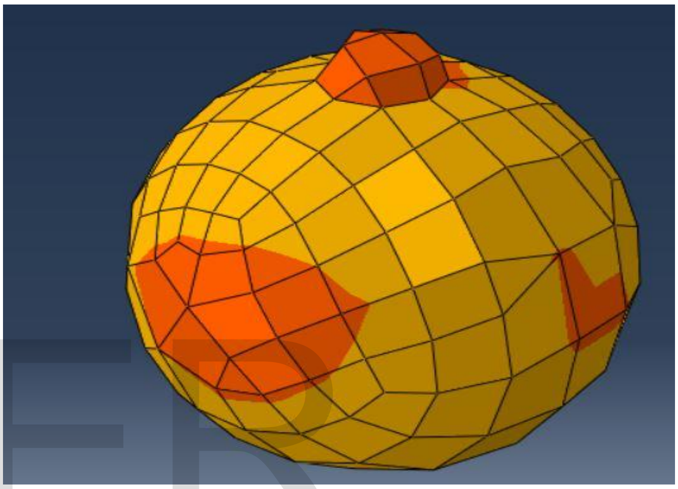

Fig 6: Stress due to blast load

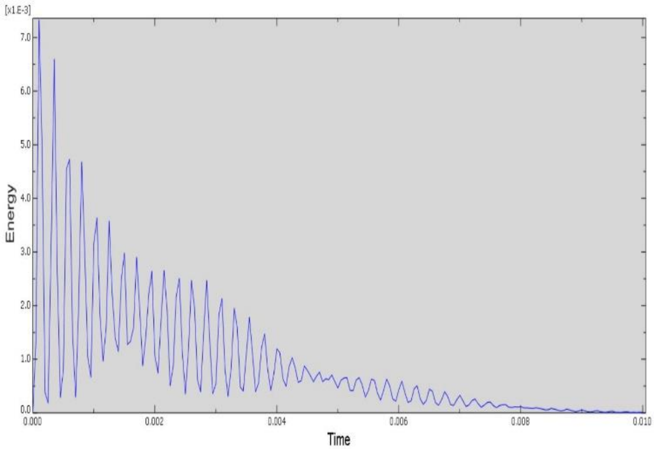

Fig. 7: Strain energy

Conclusion

Following conclusions are given below after the analysis of spherical shell under the influence of blast loading is done:

- The spherical shell is able to isolate the blast effect before it fails.
- The blast wave propagates first from the center then to the entire vessel.
- Attention has to be given at the center of shell so as to resist the internal loading.

- The material is shown to have good strength and is ductile.

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