Blast Response of Steel and Cast Iron Circular Pipe Sections Under Explosive Impact using ls - Dyna

P.N.V. Druga Prasad, N. Veerendra Babu, K. Harish Kumar

Abstract: ***There has been an immense significance of sparing structures like pipe structures which exchange oil and gas, blasts on these pipe lines may intrude on the transmission. In the current decades a lot of research is done to think about the auxiliary reaction under impact loads. Oil and gas companies must do all they can to ensure a steady supply of product to distributors and consumers. An infrastructure of pipes that carry oil and gas across the country and around the world is, therefore, essential. Parts such as piping materials, pipe shoes, and wear pads, must be durable and resilient, so maintenance and repairs do not interrupt the supply of product. Pipes are made of steel in these days as they have corrosive resistance and a strong and reliable material. Cast iron pipe is a pipe which has had historic use as a pressure pipe for transmission of water, gas and sewage, and as a water drainage pipe during the 19th and 20th centuries. The paper depicts the comparison of vonmisses stress and pressure of pipes made up of steel and cast iron subjected to different blast loads and the simulation is carried out using LS-Dyna software***

Keywords: Blast, LS-DYNA, Steel pipe, cast-iron pipe, Von misses stress, Pressure.

I. INTRODUCTION

This is a Steel circular hollow sections are made up of basic steel that has been used for structure. The hollow sections are light in weight and have significant strength properties to that of regular steel sections. Materials used for transmission of oil and gas are steel and cast-iron. Cast iron pipe is a pipe which had an historic use as a pressure pipe for transmission of water, gas and sewage, and as a water drainage pipe during the 19th and 20th centuries. It comprises predominantly a gray cast iron tube and was frequently used uncoated, although later coatings and linings reduced corrosion and improve hydraulics. Cast iron pipe was superseded by iron pipe, which is a direct development, with most existing manufacturing plants transitioning to the new material during the 1970s and 1980s.

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Pipelines are laid for many purposes like for sewage, water and for energy production natural gas, Bio-fuels and liquid petroleum are pumped from one place to another. These pipelines place a crucial role in our daily life as no machine can run without energy. Pipe lines consists a series of pipes connected to each other for transporting energy sources from one place to another. For example, crude oil is pumped to refineries in order to produce petrol and other byproducts which are essential for running of vehicles. Fuel is needed to run machines and if there is no supply of oil and gas that would affect transportation and industries which in turn affects the growth of country. That is the reason why oil and gas transporting pipelines are given great Importance so that they won't be any blockage or leakage in the supply of these energy sources.

Any interruption in oil and gas transmission may cause severe effects to those industries which depend on them. Oil and Gas are explosive in nature and the pipelines are made with pipes having no flaw. As pipes which having flaws may cause leakages which may lead to explosion when they are subjected to fire.

These explosions not only effects disruptions in transmission but also cause serious damage to human life's as well. These explosions are controlled by using pipe which is having no flaws in it and checking the pipes occasionally. In some cases, explosions occur due to human activities like accidents and terrorist activities. These types of human explosions are seen in many parts of world targeting crucial places and oil and gas pipelines are one of them. Terrorists explode oil and gas pipelines to cause financial and human losses for a nation. These type of explosions can be countered by use of strong and blast resistant pipes in the pipeline distribution. This paper focuses on observing the stresses and pressures caused on pipes of different material and thickness by vehicular blast load situated 2m near to pipe and the simulation is carried out using LS-DYNA software. The critical zones in the pipe section can be seen for cast iron and steel pipes of 10mm, 12.4mm wall thickness.

A. Blast Analysis

During the past three decades' research is carried out on structural analysis to resist blast loads. Blast loads are a threat caused by extremists, these activities may cause loss of life's and property. Structural elements are designed after undergoing complete study on blast occurrences. There are different kind of blasts can be simulated using LS-Dyna, here we used spherical air blast as the blast load.

B. Material Properties

(a) Steel:

Steel, alloy of iron and carbon in which the carbon content ranges up to 2 percent (with a higher carbon content, the material is defined as cast iron). By far the most widely used material for building the world's infrastructure and industries, it is used to fabricate everything from sewing needles to oil tankers. In addition, the tools required to build and manufacture such articles are also made of steel. As an indication of the relative importance of this material, in 2013 the world's raw steel production was about 1.6 billion tons, while production of the next most important engineering metal, aluminum, was about 47 million tons. (For a list of steel production by country, see below World steel production.) The main reasons for the popularity of steel are the relatively low cost of making, forming, and processing it, the abundance of its two raw materials (iron ore and scrap), and its unparalleled range of mechanical properties. **Steel** is the most important material in the oil and gas industry as it is strong and reliable. Most elements in oil and gas production from harvesting to refining they use steel. Steel pipes are seamless welded to improve its strength properties.

(b) Cast Iron:

Cast iron is a group of iron-carbon alloys with a carbon content greater than 2%. Its usefulness derives from its relatively low melting temperature. The alloy constituents affect its colour when fractured: white cast iron has carbide impurities which allow cracks to pass straight through, grey cast iron has graphite flakes which deflect a passing crack and initiate countless new cracks as the material breaks, and ductile cast iron has spherical graphite "nodules" which stop the crack from further progressing. Cast iron tends to be brittle, except for malleable cast irons. With its relatively low melting point, good fluidity, cast ability, excellent machinability, resistance to deformation and wear resistance, cast irons have become an engineering material with a wide range of applications and are used in pipes, machines and automotive industry parts, such as cylinder heads (declining usage), cylinder blocks and gearbox cases (declining usage).

II. LITERATURE REVIEW

Lee along with Kim [2013] Investigated that bending strength of girth-welded stainless steel circular hollow sections by numerical method. For the stainless steel hollow sections with large D/t ratio (>150), the difference between the ultimate bending capacities of circular hollow sections with or without girth weld is very small.

Ghanbari,et.al. [2014] Suggested the failure of steel hollow sections due to fatigue with an optimal diameter of a cut out. The stress concentration at the end of the tube was significantly relieved and hence the fatigue life of the specimen dramatically increased.

Rasmussen,et.al. [2017] Analyzed that in general the longitudinal bending residual stress has a more dominant effect on the behaviour of the frame than other components of the residual stress.

Karagiozova,et.al. [2014] Observed a two phase deformation model of the dynamic response of a hollow circular beam to an impulsive loading, in order to reveal the characteristic features of deformation and energy absorption of hollow section beams.

Si-weiliu,et.al. [2017] Investigated that high strength concrete is brittle, but its ductility can be dramatically increased when confined by steel tubes.

Kamtekar [2015] observed that a mono symmetric steel section becomes fully plastic under the action of an axial force and a bending moment applied in plane of symmetry acts through centroid of the material that yields to support.

Hai-ting li [2017] Suggested that existing European committee for standardization web crippling design provisions are not capable to predict normal strengths of cold formed high strength steel square and rectangular hollow sections.

Dundu [2016] Investigated that all square concrete filled tubes experience a reduction in strength with an increase in slenderness ratio of the column. The load axial deflection curves showed that all stockier specimens behaved in an inelastic manner, while the slender specimens behaved in elastic manner.

Paulo,et.al. [2017] Explained that the concrete filled hollow sections are unsafe against fire accidents after carrying out fourteen experiments focusing on influence of column slenderness, type of cross section and geometry.

Yang,et.al. [2017] Analyzed by subjecting vehicle borne ANFO mass 1500kg on the steel frame at a distance of 10m, out of 2500 simulations the steel frame is prone to column failure in 858cases.

Jun,et.al. [2013] Researched that at one-meter standoff distance the segmental column with shear key remains intact and damage concentrates around the joints rather than distal surface. while in the case of monolithic column there is damage seen on clear mid span and stress concentrates on the column distal surface.

Kyei along with braimah [2017] Suggested that by reducing transverse reinforcement spacing in RC columns results in decrease of lateral displacements when subjected to small scale or close-in explosion.

III. PRIMARY MODELLING AND DESIGN

Good quality The pipe model is with standard dimensions given by the pipe manufactures. The pipe diameter is 508mm and length is 5000mm with wall thickness 10mm and 12.4mm. These are the standard sizes used by the manufacturers for oil and gas pipe lines. Pipe manufacturers follow the standard CODE IS0 3183-2012.Mostly steel, cast iron material is used for oil and gas pipelines

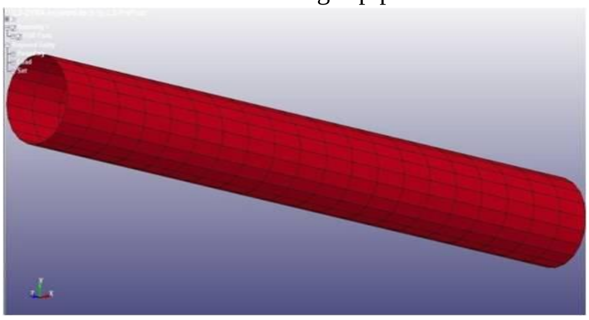

Fig. A: Model of pipe in LS-Dyna

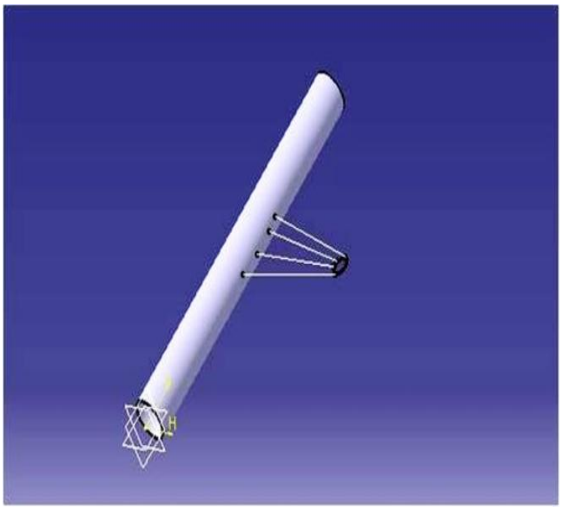

Fig. B: **Showing the blast location to the pipe**

Table I: **Material Property**

Material property	**Steel**	**Cast iron**
Yield strength(fy)	520Mpa	130Mpa
Young's modulus	2×1011 N/m	1.7x1013N/m
Poisson's ratio	0.3	0.26
Density of steel	7830kg/m3	7874kg/m3

A. Loading:

The type blast is spherical air kind of blast to simulate the blast is from a vehicle parked near to the pipe structure at a distance of 2.0m/kg1/3. By using blast enhanced key in the load options the loads are assigned at these distances in the LS-Dyna software.

Table II: Estimated Quantities of explosives carrying capacity of different vehicles

Vehicle type	**Charge mass/kg**
Compact car trunk	115
Trunk of large car	230
Closed van	680

IV. RESULT AND GRAPHS

The mass of explosion is chosen as 115kg, 230kg and 680kg and is located 5m to centre of the pipe along longitudinal direction. The shape of explosion is spherical and exposed to air. After giving all the input keys the file is saved in keyword format and is analyzed using Ansys APDL product launcher. After running the keyword file the designed model is executed to get a binary plot file. The binary plot file is opened using LS-Dyna prepost and the damage is evaluated using von moissess stress and pressure.

A. Von Mises Stress:

The vonmisses stress is a value used to determine whether the material will fracture or yield. Von moisses stress is mostly used for brittle materials. The material is steel and cast iron for the pipe model and the results obtained at different thickness and blast loads. The different colors observed on the pipe sections after carrying out simulations represent intensity of stress impact caused at the regions. Critical zones are the regions where the maximum stress occurs and represented in red color by LS-DYNA.

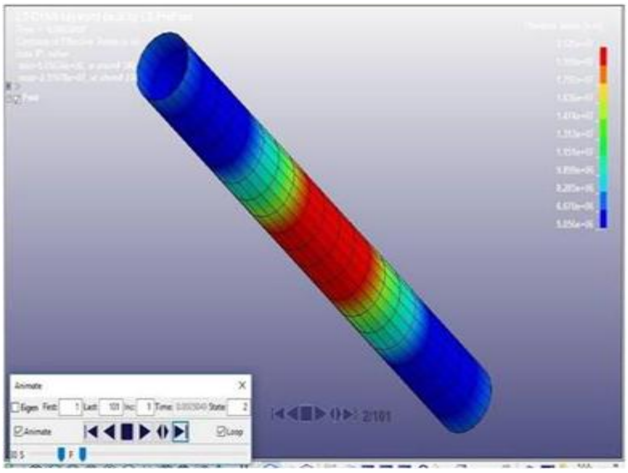

Fig. C: **Von misses stress at load 115kg at 0.05 sec**

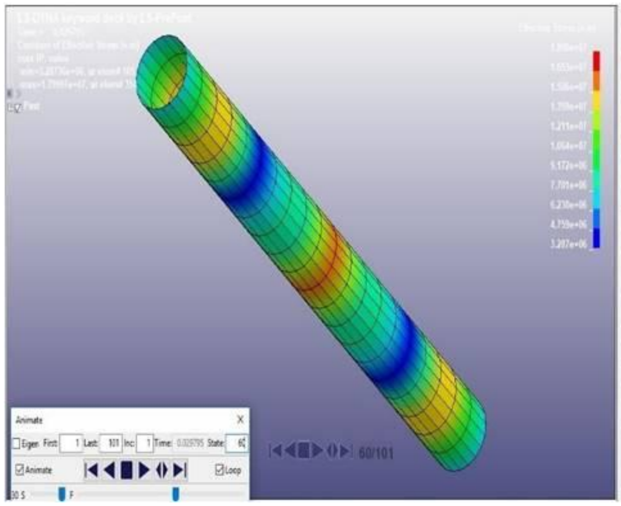

Fig. D: **Von misses stress at load 115kg at 0.19 sec**

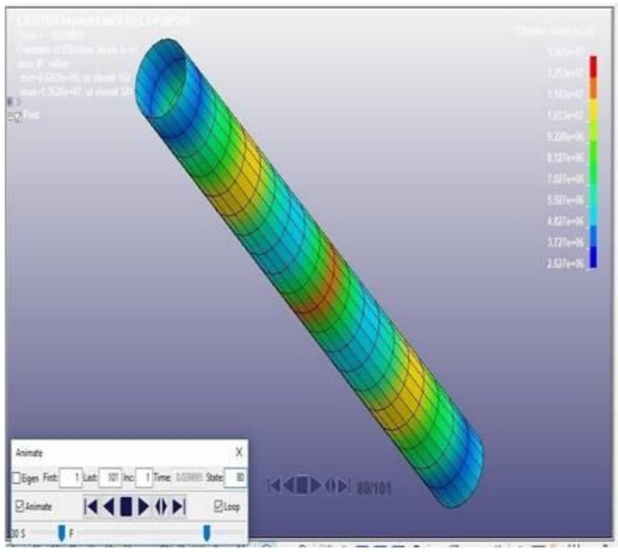

Fig. E: **Von misses stress at load 115kg at 0.29 sec**

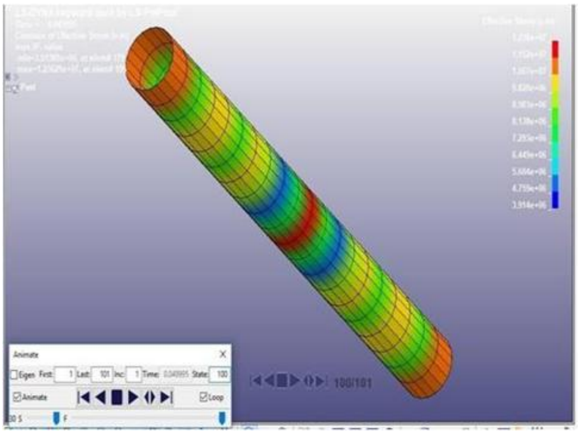

Fig. F: **Von misses stress at load 115kg at 0.44 sec**

Fig. C: Von misses stress at load 115kg at 0.05 seconds the maximum stress 2.120e+07 and it acts at the centre of the pipe and low stress at the both corners. Fig. D: Von misses stress at load 115kg at 0.19 seconds the maximum stress 1.800+07 and it acts at the centre of the pipe in thin band and low stress acts in the middle region between center and ends. Fig. E: Von misses stress at load 115kg at 0.29 seconds the maximum stress 1.363e+07 and it acts at the centre of the pipe and low stress at the both corners. Fig. F: Von misses stress at load 115kg at 0.44 seconds the maximum stress 1.263e+07 and it acts at the centre and corners of the pipe.

B. Von Mises Stress Graphs:

The Von mises stress comparison results for the steel and cast-iron pipe of thickness 10mm and 12.4 mm are

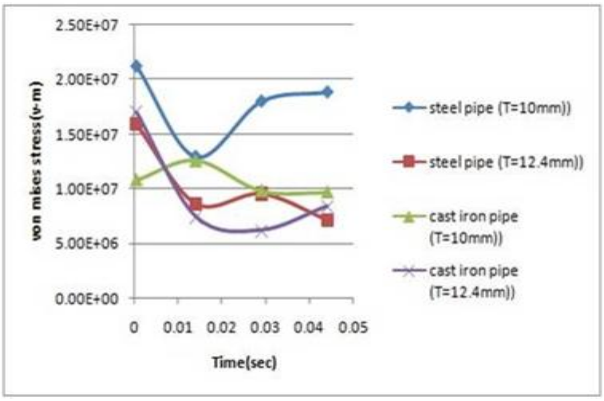

Fig. G: **Von mises stress comparison at blast mass 115kg**

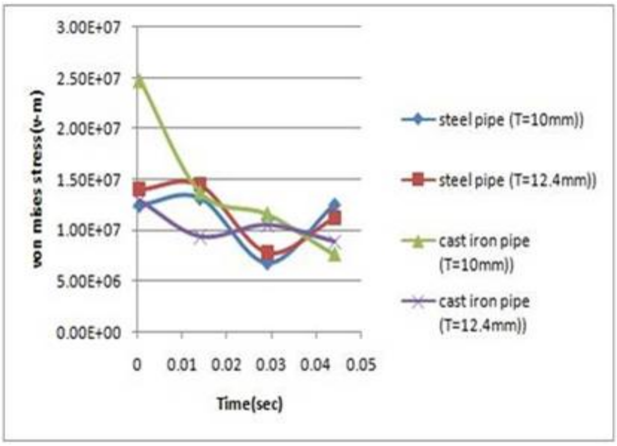

Fig. H: Von mises stress comparison at blast mass 230kg

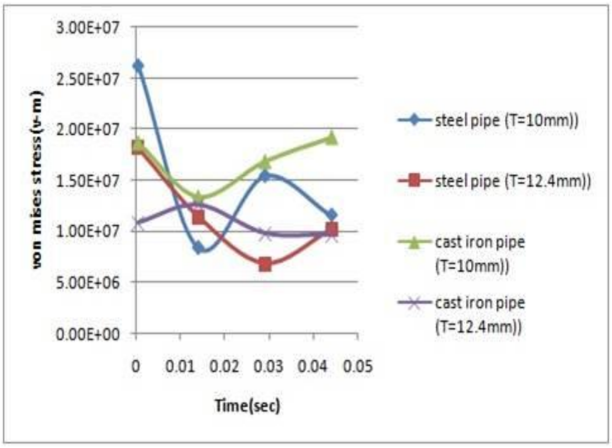

Fig. I: **Von mises stress comparison at blast mass 680kg**

C. Pressure:

Pressure is defined as the continuous force exerted on an object. Here the blast loads will act continuous for a period of 0.5sec (detention time). The different colors observed on the pipe sections after carrying out simulations represent intensity of pressure impact caused at the regions. Critical zones are the regions where the maximum pressure occurs and represented in red color by LS-DYNA

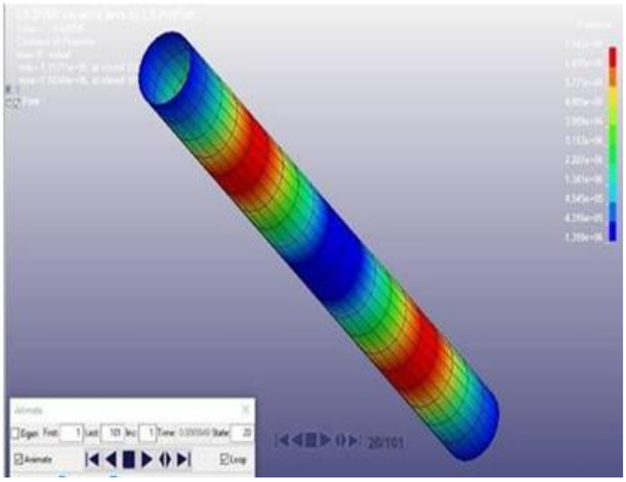

Fig. J: **Pressure at load 115kg at 0.05 sec**

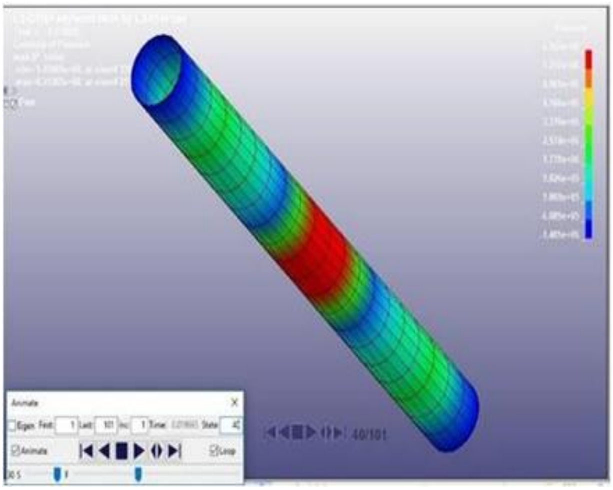

Fig. K: **Pressure at load 115kg at 0.19 sec**

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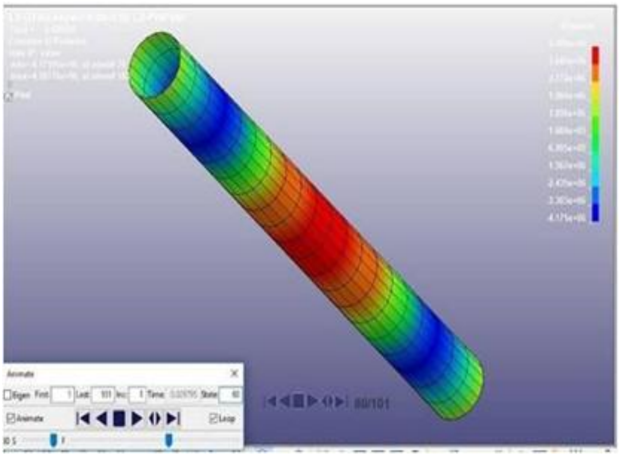

Fig. L: Pressure at load 115kg at 0.29 sec

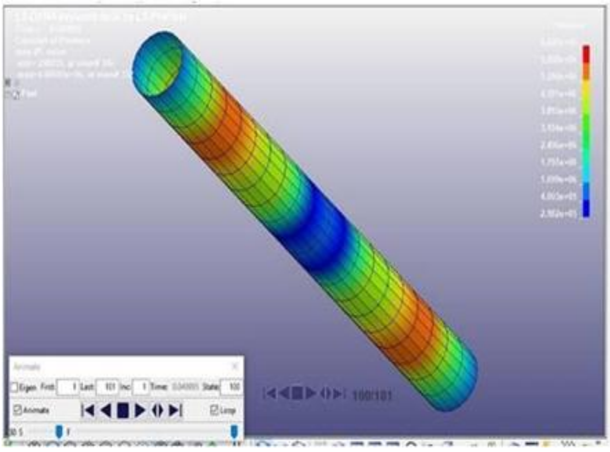

Fig. M: Pressure at load 115kg at 0.44 sec

Fig. G: pressure at load 115kg at 0.05 seconds the maximum pressure acts at the middle region between center and corner while center and edges are low pressure regions. Fig. H: pressure at load 115kg at 0.19 maximum pressure acts at the center and minimum pressure acts at the edges. Fig. I: pressure at load 115kg at 0.29 seconds the maximum pressure acts at the center and minimum pressure acts in the region between center and edge of pipe. Fig. J: pressure at load 115kg at 0.44 seconds the maximum pressure acts in the region between center and edge of pipe and minimum pressure acts at the center.

D. Pressure Graphs

The pressure comparison results for the steel and cast-iron pipe of thickness 10mm and 12.4 mm are,

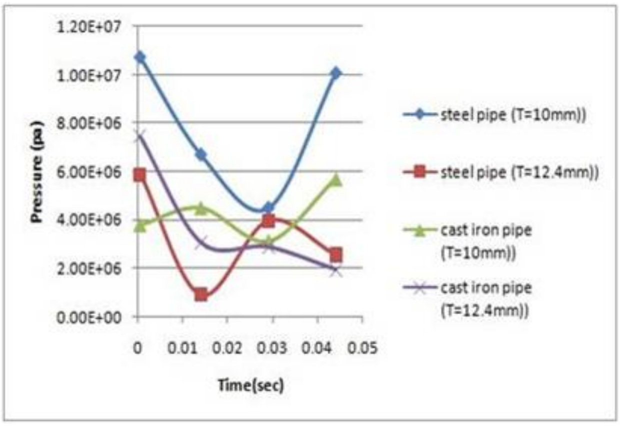

Fig. N: Pressure comparison at blast mass 115kg

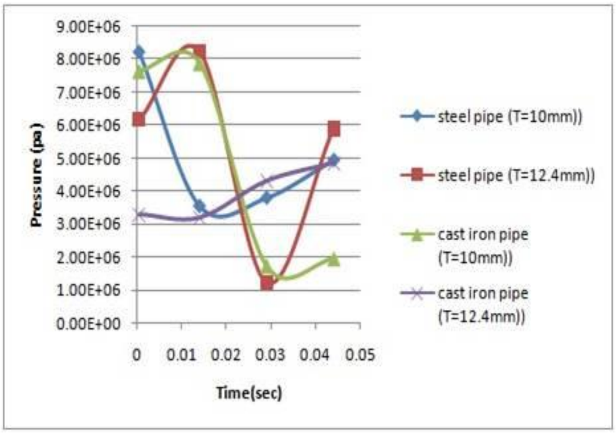

Fig. O: Pressure comparison at blast mass 230kg

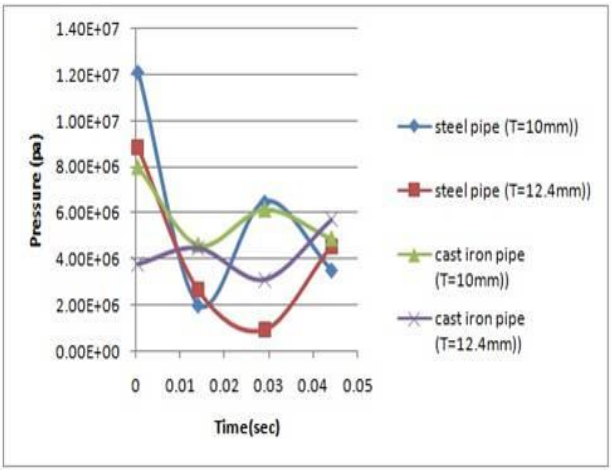

Fig. P: Pressure comparison at blast mass 680kg

V. CONCLUSIONS

- From the Fig. G it shows that steel pipe of wall thickness 12.4mm experiences less von mises stress at blast load mass of 115kg. Here the maximum stress concentrates at the middle of section.
- From the Fig. H it shows that steel pipe of wall thickness 10mm experiences slightly less von mises stress to that of steel pipe of wall thickness 12.4mm at blast load mass of 240kg. Here the critical zones where maximum stress occurs is situated at center and corners of pipe.
- From the Fig. I it shows that steel pipe of 12.4mm wall thickness experiences less von mises stress at blast load of 680kg and the critical zones which get subjected to huge stresses situates in the center and in the region between center and ends of pipe.
- From the Fig. N its clear that steel pipe of wall thickness 12.4mm experiences less pressure than other sections at blast load of 115kg. This pipe the critical zones are the centre of pipe during the detention time.
- From the Fig. O it depicts steel pipe of 12.4mm wall thickness experiences less pressures than other sections at blast load of 230kg.This section the critical zones will be seen at corners and center of the section.
- From the Fig. P it shows that steel pipe of 12.4mm impact less pressures than other sections at blast load 680kg.

Here the section experiences critical zones at the region between center and either ends of the pipe section.

By all these simulations we came to know that steel pipe sections experience less stresses and pressures than cast-iron, when these sections are subjected to blast load. This is because steel has high modulus of elasticity than cast-iron. Higher wall thickness can influence significantly the stress and pressure experienced by the material. Higher wall thickness pipe sections resist stresses and pressures better than those sections of same material with lesser wall thickness.

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