Investigation of liquid on Pressure and stress of Buried Pipe under Explosion waves

Mohsen Parviz
Visiting Junior Lecturer, Department of Engineering, Tehran shargh Branch, Islamic Azad University, Tehran shargh, Tehran, Iran, (corresponding author)

Nader Jamali
Bachelor Student, Department of Engineering, Tehran shargh Branch, Islamic Azad University, Tehran shargh, Tehran,Iran
Email: Jamalinader@gmail.com

Abstract

One of the most important lifeline is the water pipelines that may be subjected to explosion. In this paper a parametric study on the buried pipe in the soil has been performed due to blast loading. Effects of various parameters have been investigated such as physical properties of water, air, soil, pipe and T.N.T. The arbitrary Lagrangian-Eulerian method has been used by the LS-DYNA software. An arbitrary Lagrangian-Eulerian algorism is used in order to prevent the element distortion in large deformation and nonlinear structural analyses.The results shows the pressure and stress value of the pipe crown, slight increase firstly, then increases to a peak and decreases finally. That is because the explosive loading direction is opposed to the pressure of fluid in a buried pipe that causing the pressure descending. so, pressure of fluid in buried pipe can do a favor to stabilizing pipe pressure.

Keywords: Stress, Pressure, ALE, Explosion, Ls-Dyna

1. Introduction

The second of the major hazards is explosion. Explosion in the process industries causes fewer serious accidents than fire, but more than toxic release. When it does occur, however, it often inflicts greater loss of life and damage than fire. Explosion is usually regarded as having a disaster potential greater than that of fire, but less than that of toxic release. An explosion is a sudden and violent release of energy. The violence of the explosion depends on the rate at which energy is released. There are several kinds of energy which may be released in an explosion. Three basic types are (1) physical energy, (2) chemical energy, and (3) nuclear energy. Physical energy may take forms such as pressure energy in gases, strain energy in metals, or electrical energy and thermal energy. Chemical energy derives from a chemical reaction. Nuclear energy is not considered here. In the present context, it is chemical explosions, and in particular explosions resulting from combustion of flammable gas, that are of prime interest. There are two kinds of explosions from combustion of flammable gas: (1) deflagration and (2) detonation. In a deflagration, the flammable mixture burns at subsonic speeds. In a detonation, the flame front travels as a shock wave followed closely by a combustion wave which releases the energy to sustain the shock wave. At steady state, the detonation front reaches a velocity equal to the velocity of sound in the hot products of combustion; this is much greater than the velocity of sound in the unburnt mixture. A detonation generates greater pressures and is more destructive than a deflagration. Whereas the peak pressure caused by the deflagration of a hydrocarbon_air mixture in a closed vessel is of the order of 8 bar, a detonation may give a peak pressure of the order of 20 bar. Yao (2009) studied the buried pipe subjected to the blast loading , but in their investigation, there is no fluid in the pipe.Anirban (2012) studied the effect of surface blast on the dry and cohesion less soil.

1.1. Explosions and high explosives

An explosion is the sudden outward projection of a quantity of matter. Explosions can be caused by a number of phenomena, such as rupture of a container under high internal pressure. The detonation wave in the explosive trinitrotoluene (TNT) can have a pressure, temperature, and propagation velocity of 200 000 atm, 3000 deg K, and 7000 m/s, respectively. The gaseous explosive products, in turn, create a shock wave (or blast wave) in the surrounding medium. If this medium is air, the blast wave and its effects are generally termed ‘airblast’. A blast wave in air is an ‘unreactive’ shock wave and therefore attenuates with distance from the source. The blast wave propagates faster than the sound velocity in air, and its front, a compression wave, is characterized by a sudden increase in ambient pressure. This pressure increase is also called an ‘overpressure’ from airblast because it is increased over ambient pressure. At a much slower rate, the gaseous products of detonation (of the original explosive substance) may mix with air and experience additional burning, which is called afterburn or gaseous burning, and is usually manifested by a fireball. From the Encyclopædia Britannica, explosive is any substance or device that can be made to produce a volume of rapidly expanding gas in an extremely brief period. Three fundamental types can be distinguished: mechanical, nuclear, and chemical. Deflagrating explosives involve merely fast burning and produce relatively low pressures. Black and smokeless powders are exemplary deflagrating explosives. Detonating explosives are usually subdivided into two categories, primary and secondary. Primary explosives detonate when heat of sufficient magnitude is produced. Flame, spark, impact and others can cause an ignition. Secondary explosives require a detonator and, in some cases, a supplementary booster (Ngo et al, 2007).

1.2.Shock pressure

After the shock wave has propagated through the air some radial distance from the center of explosion, the air immediately behind the shock front is highly compressed relative to ambient conditions, and behind this compressed air, at a distance known as the positive wavelength Lw+, the air is rarefi ed relative to ambient conditions. The resulting pressure–time pulse, shown by the solid curve in Figure

1, is produced by the shock wave propagating at supersonic speed by a fixed point Relative to the center of the explosion. In time to, the time of arrival of the shock front after detonation, a near-instantaneous increase in ambient pressure (i.e., an overpressure) occurs due to the highly compressed air of the shock front; this pressure is called the peak incident (or side-on) pressure P_{so}.

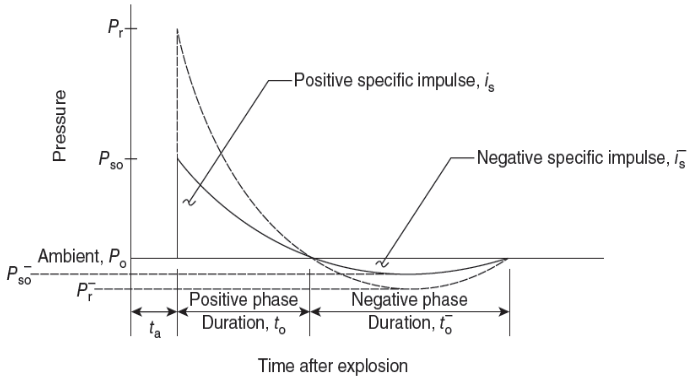


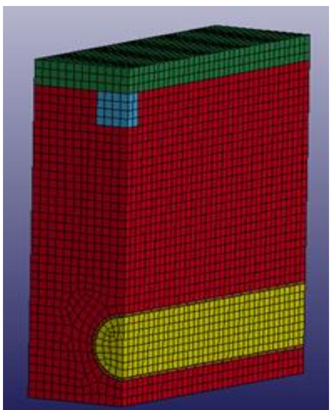
figure 1. Incident and reflected blast pressure pulses

The positive pressure decays back to ambient pressure over the period known as the positive phase duration t_0. The pressure further decays to a level below ambient pressure during the longer, negative phase duration t_0^-, resulting from the rarefaction of air a distance behind the shock front; negative pressure is associated with a reversal of air particle flow over a distance equal to the negative wavelength L_w^- and can be characterized as a 'suction' pressure. The maximum pressure amplitude of the negative phase is known as the negative incident pressure P_{so}^-. As the shock wave expands outward, its supersonic propagation velocity U and incident overpressure decrease and its wavelength and positive phase duration increase; this is due to spherical divergence, as well as dispersive effects. Peak positive pressures relatively near the explosion can be several orders of magnitude greater than atmospheric pressure, but occur over durations that last only milliseconds. The area under the pressure–time pulse over the positive phase is referred to as the positive specific incident impulse or, simply, the positive incident impulse is (MPa-ms). Similarly, the area under the pressure–time pulse of the negative phase is called the negative incident impulse i_s^-. The positive phase of the pressure pulse is typically more important than the negative phase for the design of rigid structures or rigid structural components. However, for relatively flexible structures, the negative-phase pressure pulse may also have to be included.

2. Numerical Model

In this paper pipeline has a circular cross-section of 0.36 and 0.4 m in internal.the explosive is modeled explicitly using Ls-Dyna material specifically designed for simulating a high explosive detonatio. geometrical model with a size of 0.6 m×1.8m×2m is established, In the finite element model Figure 2 the eight-node elements of SOLID 164 is adopted for the 3D explicit analysis. In this paper, an arbitrary Lagrangian-Eulerian (ALE) algorism is used in order to prevent the element distortion in

large deformation and nonlinear structural analyses. The TNT charge, the air, the soil and the liquid in a pipeline are modeled with ALE multi-material meshes But the pipeline with Lagrangian meshes and the globe uniform mesh size was set to be 5 cm. Five kinds of materials are involved in this finite element model: air, TNT charge, pipeline, water and soil.



Figurer 2. finite element model

2.1. Model of Explosive

In this paper, The TNT charge is modeled by the high explosive material model and the Jones-Wilkins-Lee (JWL) equation of state (Manual, 2006). Where A,B, R_1, R_2 ,ω were the coefficients, and V was the initial relative volume and E was the initial relative volume. Table 1 gives the parameters used in the TNT charge model:

Table 1. Parameters of the TNT charge

Material Properties	Numerical Values
ρ (kg/m^3)	1630
V_D (m/s)	6930
P_{CJ} (Gpa)	21
A (Gpa)	374
B (Gpa)	3.23
R_1	4.15
R_2	0.95
ω	0.38
V	1
E_0 (J/kg)	6.00E+09

2.2. Model of Air

Air material model was commonly modeled by null material model with a linear polynomial of state (EOS) (Manual, 2006). Where the μ is functional of ρ and $\rho_\circ$ that $\rho_\circ$ was the reference density. C_0 to C_6 were the constant coefficients. The parameter E_0 is the initial internal energy of reference specific volume per unit. table 2 gives the parameters used in the air model:

Table 2. Parameters of the air

Material Properties	Numerical Values
ρ (kg/m^3)	1.29
C_0	0
C_1	0
C_2	0
C_3	0
C_4	0.4
C_5	0.4
E_0 (j/kg)	2.5×10^5
ρ_0 (kg/m^3)	1

2.3. Model of Steel Pipe

In this paper several kinds of steel pipe and yield stress of the case are investigated. Steel pipe material model used in this paper is called Plastic Kinematic Model (Manual, 2006). Software selection is X80 and pipe modeling features are summarized in Table 3:

Table 3. Parameters of the X80 pipe material

Material Properties	Numerical Values
ρ (kg/m³)	7850
E (Pa)	2.10E+11
υ	0.3
δ_y (Pa)	6.57E+08
E_{tan} (Pa)	1.35E+10

2.4. Model of Water

The water was commonly modeled by null material model with a Gruneisen equation of state (EOS) (Manual, 2006). where the μ is functional of ρ and $\rho_\circ$ that $\rho_\circ$ was the reference density. and S_1 to S_3 , γ_0 and a are constant coefficient. E is the initial relative volume and C was the sound propagation velocity in the water. table 4 gives the parameters used in the water model:

Table 4. Parameters of the water

Material Properties	Numerical Values
ρ (kg/m³)	1025
C (m/s)	1.48E+03
S_1	142
S_2	0.33
S_3	0.7
γ_0	0.5

2.5. Model of Soil

The soil was modeled by a soil and foam model put forward by Krieg in 1972 (Manual, 2006). It was a simple model and operated in some way like a fluid, and had been demonstrated to be useful for soil modeling. Parameters of the soil in this paper include: density equal to 1800 kilograms per cubic meter, the shear modulus of 11 Mpa, Bulk modulus of 190 MPa yield function constants a_0=0.33, a_1=0.7 and a_2=0.33 (Yan, 2012).

3. The Effects of Stress and Pressure on Buried Steel Pipes under Explosion

In this part, the pressure applied to the steel pipes in globally for 4 types of steel pipes with the amount of TNT values of 3.2, 4.8, 6.5 and 8 kg was studied.

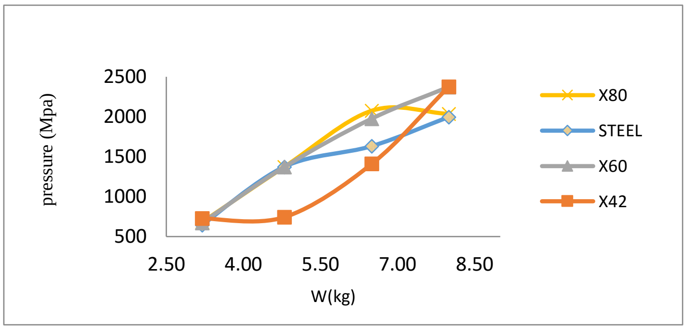


figure 3. Maximum pressure in steel pipes globally

The Figure 3 shows the most pressure applied to soil for masses 3.2, 4.8, 6.5 and 8 kg globally. According to the Figure 3, the maximum pressure applied to the steel pipes with 8 kg mass in soil is 2376 Mpa.

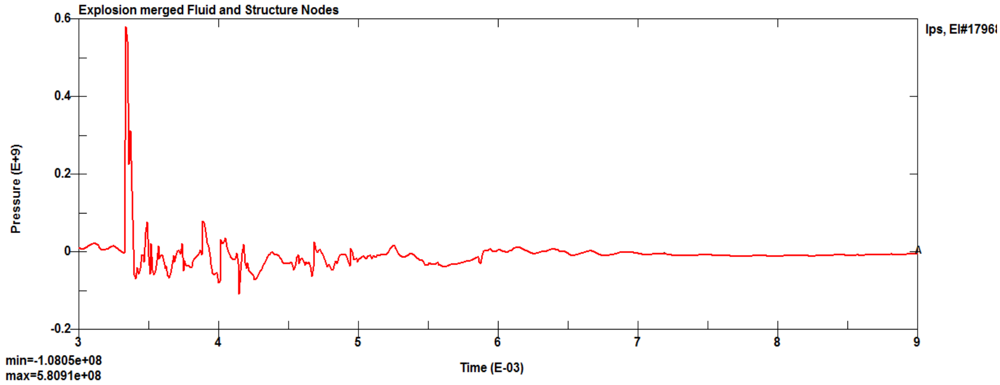


Figure 4. The pressure-time curve of buried pipe for 6.5 kg under explosion

Figure 4 shows the pressure value of pipe on crown of pipe that slight increase firstly, then increases to a peak and decreases finally. The maximum pressure peak of on crown of pipe is 580.91 Mpa. The peak pressures on crown of pipe is compressed.

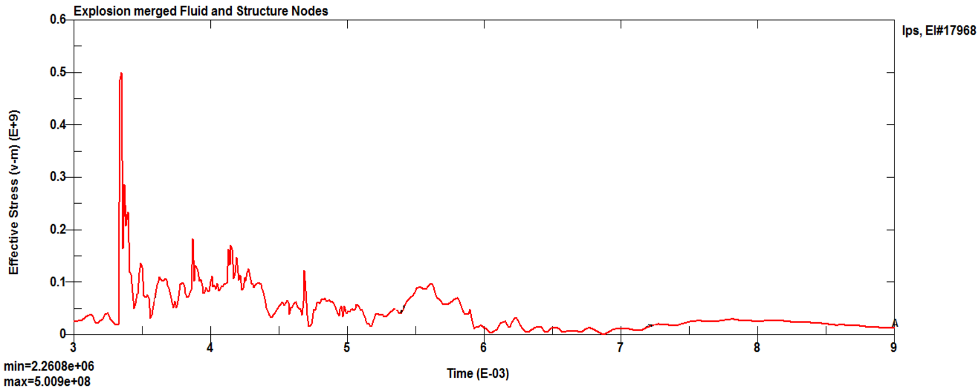


Figure 5. The Effective stress-time curve of buried pipe for 6.5 kg under explosion

Figure 5 shows Effective stress-time curve of buried pipe for 6.5 kg under explosion on crown of pipe that Figure is like the previous figure slight increase firstly, then increases to a peak and decreases finally. The maximum Effective stress peak of on crown of pipe is 500.9 Mpa.

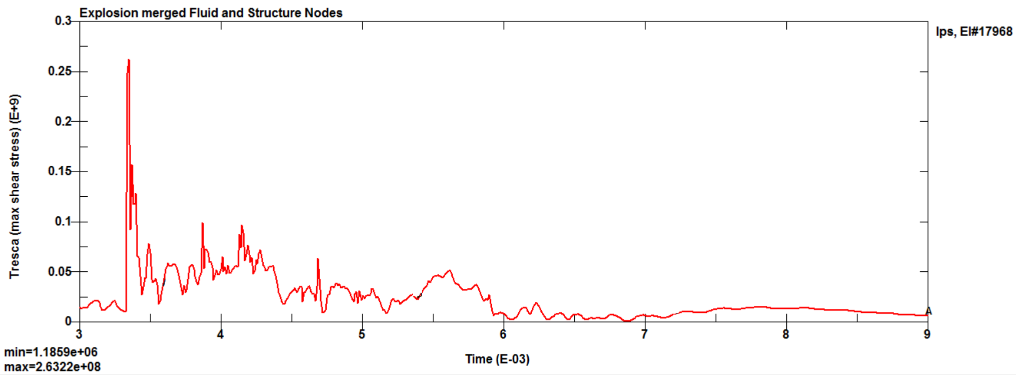


Figure 6. The Maximum shear stress-time curve of buried pipe for 6.5 kg under explosion

Figure 6 shows shear stress-time curve of buried pipe for 6.5 kg under explosion on crown of pipe that the maximum shear stress peak of on crown of pipe obtained 263.22 Mpa.

4. Conclusion

In this paper the results are as follows:

1- The all figures shows the pressure and stress value of the pipe crown, slight increase firstly, then increases to a peak and decreases finally. That is because the explosive loading direction is opposed to the pressure of fluid in a buried pipe that causing the pressure descending. so, pressure of fluid in buried pipe can do a favor to stabilizing pipe pressure.

2. In global, the maximum pressure applied to the steel pipe with 3.2 kg mass in soil is 729 Mpa, and the maximum pressure applied to the steel pipe with 4.8 kg mass in soil is 1371 Mpa.

3. In global, the maximum pressure applied to the steel pipe with 6.5 kg mass in soil is 2074 Mpa and the maximum pressure applied to the steel pipe with 8 kg mass in soil is 2376 Mpa.

4. In global, for steel pipe under explosion was observed that with an increase of 2.5 times the mass of TNT, the pressure level is 3.26 times for steel pipe progress.

5. References

1- AL, Y. (2009). Numerical simulation of dynamic response of buried pipeline by underground explosion. Journal of Southwest Petroleum University (Science &Technology Edition). 31. 168-172.

2- De, A. (2012). Numerical simulation of surface explosions over dry, cohesionless soil. *Computers and* Geotechnics, 43, 72-79.

3- Ngo,T. Mendis, P. Gupta, A. J. Ramsay.(2007).Blast loading and blast effects on structures an overview.EJSE.

4- Manual, V. L.-D. (2006). Livermore Software Technology Corporation, Livermore, CA, USA.

5- Yan, S. Xu, Y. & Chang, H. (2012). Numerical simulation of dynamic response of buried pipeline by ground explosion. Earth and space.ASCE. 1159-1166.