Experimental And Numerical Analysis Of Propagation Of Stress Wave In Sheet Metal

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Abstract: In this experiment on the propagation of stress waves on sheet metal of different material andtheir effect of casing is studied and reported. Steel and aluminum are the two different types of materials which are considered and instrumented with the strain gauges. Metal foil gauges are most commonly used to measure the strain accurately. It is then externally impacted by the ball pane. The output that is obtained is in the wave form and is stored in the oscilloscope. The stress waves are induced in sheet metal, due to the impact of ball pane. The amplitudes of stress waves which are obtained from the oscilloscope, are studied and to determine the velocity of stress wave propagation and damping capacity of the material. Propagation of stress waves are obtained from the experimental and numerical methods are then compared it with the analytical methods.

Index Terms: ABAQUS Explicit, Propagation of stress wave, Impact loading,Sheet metal, Strain gauges, Stress wave, Wave interaction.

1 Introduction

In recent years, propagation of stress waves is of fundamental importance in modern technology because it provides the primary means for the non-destructive examination of defects and in-homogeneities in opaque materials and it is the only means for studying the response of materials under the dynamic loading conditions which are associated with impact and explosions. Current work being performed to obtain dynamic response of material subjected to loading. In rigid body dynamics it is assumed that, when a force is applied to a point of a body, the resultant stress set every other point in motion instantaneously, and the force can be considered as producing a liner acceleration of the whole body, together with an angular acceleration about its center of gravity. However here we are considering the effects of forces which are applied for only very short period of time, which are changing rapidly the effects must be considered in terms of propagation of stress waves. The required experimental apparatus and construction are discussed in the further sections. It is the continual propagation and reflection of waves in a bounded solid that brings about the state of static equilibrium. We study the surface wave propagations along a sheet metal of length with thickness having different material, experimentally. Electrical resistance strain gauges are used as a sensing element with necessary instrumentation so that the stress waves in sheet metal can be detected and analyzed.

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2 Methodologies

2.1Experimental

Two types of sheet metals will be considered, namely a Mild Steel and aluminum sheet metal, both with length & breadth 0.2m. The mild steel sheet metal has Young's modulus E = 200 GPa, Poisson's ratio (ϑ) = 0.30, density ρ = 7850 Kg/m3 and thickness of 0.001. The Aluminum sheet metal has Young's modulus E = 70 GPa, Poisson's ratio (ϑ) = 0.33, density ρ=2700 Kg/m3, and thickness of 0.001m. A hardened steel ball is used as a striker to impact the sheet metal. Strain gauges are mounted on each of the sheet metals at a distance of 50mm from the center of the sheet surface to record the incident wave. In each experiment stress/strain with respect to time will be recorded at the mid position of the sheet metals. The strain will be calculated by strain gauge which will send a voltage versus time signal to oscilloscope as it experiences strain.

Fig.1 Experimental & strain gauge setup

2.2Analytical Method

In this method we calculate the wave velocity and value of stress wave transmitted, reflected and induced. The longitudinal waves are transmitted, reflected and refracted at the boundary. Wave propagates along a cylinder with cross-sectional area A in a medium with a wave velocity (C), particle velocity (Up) and stress (σ).

Incident Stress σT = ρ C Up

The effect of reflection, refraction occurs when the wave encounter a medium with different sonic impedance. The impedance is defined as the product of the medium density by its wave velocity. The longitudinal wave encounters an interface, with the formation of reflected and a transmitted wave. At the interface, we consider to be in equilibrium under the three stresses σI (incident), σR (Reflected) and σT (transmitted) [1].

We have

- σI + σR = σT
- Particle Velocity Up = $\sqrt{\{2gl\,(1-\cos\alpha)\}}$
- Transmitted stress $\frac{\sigma_T}{\sigma_I} = \frac{2\rho_2 C_2 A_1}{\rho_1 C_1 A_1 + \rho_2 C_2 A_2}$
- Reflected Stress $\frac{\sigma_R}{\sigma_I} = \frac{\rho_2 C_2 A_2 - \rho_1 C_1 A_1}{\rho_1 C_1 A_1 + \rho_2 C_2 A_2}$

Table – 1: Terminologies

Symbol	Quantity	Units
σI	Stress produced due to impact load	N/mm^2
σR	Stress produced due to reflected waves	N/mm^2
σT	Stress produced due to transmitted waves	N/mm^2
ρ	Density of the material in	Kg/m3
Up	Particle velocity in	m/s
A	Area of material in contact	m^2
C	wave velocity	m/s

2.3 Numerical Method

The Numerical analysis is simulated by commercial available ABAQUS solver. The propagation of stress waves is simulated by creating a model to the required dimension using ABAQUS. This process involves assigning a material property for the created model. The models are then constrained by applying load and the boundary conditions. Meshing is done where the model reduces its degree of freedom from infinite to finite number of elements with the help of discretization. The output file generated when the complexity of the problem being analyzed and completes an analysis run. We evaluate the results once the simulation has been completed and the displacements, stresses or further fundamental variables have been calculated. The evaluation is generally done interactively using the visualization module of another postprocessor. The displaying results, including colour contour plots, animations, deformed shape plots and X-Y plots.Create amplitude under the pressure load at any given time in the specified magnitude of the pressure load and time value is interpolated from the amplitude curve. The time/frequency of 0.018 is set with an amplitude range 1. The pressure load is applied as the step to the front surface of the circular section of the model by selecting the pressure type of load with a uniform distribution having a magnitude of 48.85 Pa (for Θ=60^0).

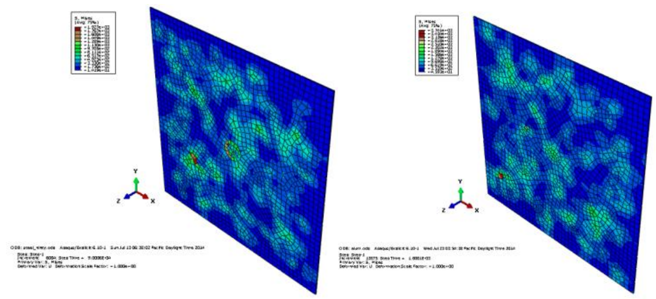

Fig 2. Finite element result for steel and aluminum sheet respectively

3 Results

Measurements were carried out by impacting the Mild steel/Aluminum sheet metal with a ball pane. The stress waves generated propagate along the sheet metal and die out over a few cycles of motion. The strain gauge bridge output was processed by the amplifier and the output was captured on a storage oscilloscope. Several such experiments were conducted and all these stress pulse were of the same shape but with slightly varying amplitudes. The output obtained is as shown in Fig. 3. A trace ofstress waves obtained during the experiment with the storage oscilloscope is as shown below. The X (time) and Y (voltage) axes sensitive are also shown in same fig.3

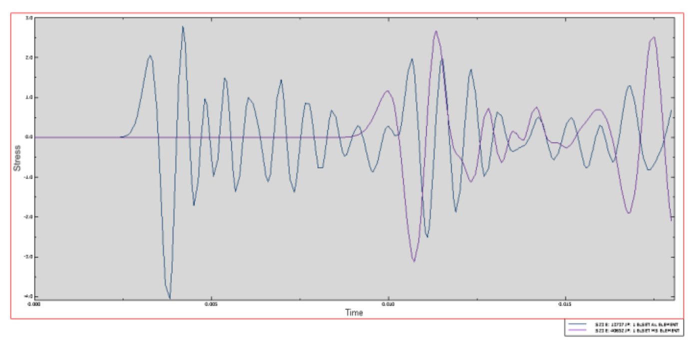

Fig. 3 Graph of propagation stress waves in steel sheet metal

The signals obtained from the experimental and numerical method are similar in nature, but we see a lot of variation in the magnitude because of the human errors while applying the load, bonding and selection of electrical resistance strain gauges and incapable of reading exact values of graph. The nature of signals will depend upon the material impedance and geometrical impedance such as by considering the load applied on the Mild Steel where the incident signal are compressive in nature as seen in the Figure 3. The wave travels further and enters the casing as transmitted wave with a lesser magnitude due to the geometrical impedance, where certain amount of energy reflects back as a reflected wave. The results obtained from the analytical method for mild steel sheet are: σ_I = 2.687 N/mm^2, σ_T = 4.538 N/mm^{2}and σ_R = - 1.811 N/mm^2 are then compared with the numerical method σ_I = 2.488N/mm^2, σ_T = 4.017N/mm^2 and σ_R = - 2.674 N/mm^{2}and experimental method. The results obtained from the analytical method for aluminum are: σ_I = 0.932 N/mm^2, σ_T = 3.523 N/mm^2 and σ_R = - 0.258 N/mm^2 then compared with the numerical method σ_I = 0.911 N/mm^2, σ_T = 3.078 N/mm^2 and σ_R = - 0.307 N/mm^2 and experimental method.

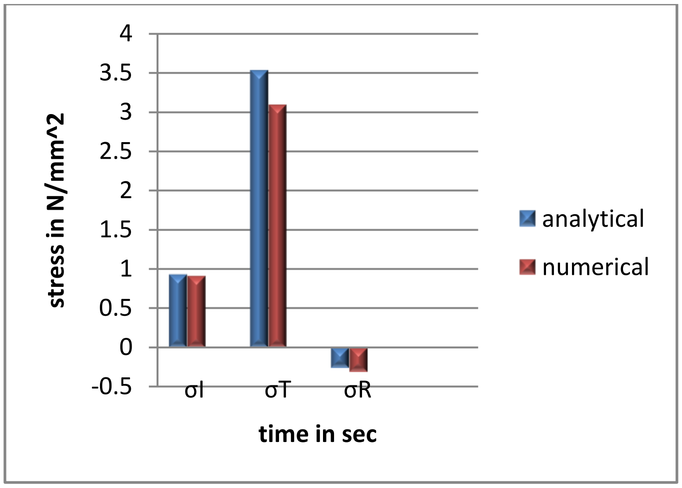

Fig. 4 comparison of propagation stress waves in steel sheet metal

The impedances of the material - ρC product determine the amplitude of transmitted and reflected signals. A pulse of the same sign as the transmitted signal is reflected. In the numerical method signals are having sharp edges because of smaller elemental length of 0.5mm compare to experimental values where the gauge length of the strain gauge is about 5mm. In the numerical method signals are having sharp edges because of smaller elemental length of 0.5mm compare to experimental values where the gauge length of the strain gauge is about 5mm.

4 CONCLUSIONS

Stress wave propagation helps in understanding the behaviour of a material subjected to impact load or collision. The results obtained from the analytical method are then compared with the experimental method and numerical method. The impedances of the material - ρC product determine the amplitude of transmitted and reflected signals. A pulse of the same sign as the transmitted signal is reflected. Both analytical and numerical values closely resemble. It is now clear that the impedances of the material and geometrical product ρCA determine the amplitude of transmitted and reflected pulses. When (ρCA) sheet > (ρCA) casing, a pulse of the same sign as the incident pulse is reflected. For future work the irregularities in the material could be found out by knowing the velocity of stress wave propagation. This could be done by providing notches and also by changing the thickness of the sheet metal. This experimental setup can be used to study the effect of variable thickness in the sheet metal. For this strain gauges have to be installed in both sections.

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