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The ComparativeAnalysisOf ANSYS And SHPB On Compression Loading.

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Abstract—The main focus of this work was to design a Split Hopkinson Bar apparatus to determine the dynamic compressive behavior of **Gray Cast Iron**. In the split Hopkinson bar test, a short barrel shaped specimen is sandwiched between two long bars. The bars are by and large made of gentle steel with distances across 20mm and a length 1500mm.The finishes of the weight bars and specimen are machined level to implement recommended limit conditions. Huge headways executed from the ranges of testing strategies, numerical techniques, and sign preparing have enhanced the exactness and repeatability of high strain rate testing.Mechanical structures undergo a wide range of loading conditions. Structures can be loaded statically or dynamically with a wide range of strain rates. With impact loading or high strain rates the relationships between stress and strain are not the same as in static loading. It has been observed that material properties are dependent upon the rate at which they are tested. Many investigators have studied the effect of high compressive strain rate loading conditions, in metals. The most common method for determining the dynamic response of materials is the Split Hopkinson bar.

Index Terms—Split Hopkinson Pressure Bar, ANSYS Workbench Software, Stimulation of Gray Cast Iron.

1 INTRODUCTION

For many years tests have been developed to determine the

Strength of materials under static loading conditions. However, there was little research on the effect that the loading rate had on tabulated material properties until about 50 years ago. Starting in the 1950s and 1960s there was a spike in interest relating to the study of high loading rate mechanical behavior. This rise in interest was driven by military research dealing with ballistics defense applications and the aerospace industry interests in meteorite pact on satellites and bird ingestion in jet engine. Prior to this research, material properties were measured using hydraulic or screw type testing machines that were only capable of obtaining a maximum strain rate on the order of 0.1 s-1.

These types of tests include, but are not limited to, pendulum impact tests, such as Charpy tests, and drop impact testing. However, these tests do not yield a complete dynamic stress-strain curve. There are several ways to determine dynamic material properties but the most common and widely used method is the split Hopkinson pressure bar apparatus.

The split-Hopkinson pressure bar was first suggested by Bertram Hopkinson in 1914. His design consisted of a long steel bar, a short steel billet (test specimen), and a ballistic pendulum. Hopkinson would impact one end of the steel bar by means of an explosive charge which would generate a compressive wave that would travel through the bar and into the steel billet.

In 1949 Kolsky added a second pressure bar to Hopkinson's original design. Instead of putting a billet at the far end of the bar he sandwiched it in between the bars. This split bar system is how the Hopkinson split bar apparatus got its name. This design has become the most common and widely used technique to determine dynamic material properties.

Charpy test is the most common method for studying thehigher rate behaviour of materials. However, the disadvantageof Charpy test is that it neither provides any informationregarding the effect of compressive-wave propagationduring impact process, nor records the energy consumed ineach strain-stage during the deformation.

1.2 Problem Statement

The Split Hopkinson Pressure Bar apparatus should eventually take measurement of both the strain and stress that a specimen will experience when subjected to high speed deformtion.Thus, this study is primarily targeted to obtain stress strain curve by using Split Hopkinson Pressure bar test (Compressive test).Currently the analysis is performed on ANSYS Workbench Software.

1.3 Objective

1. To perform a compression test on Split Hopkinson Pressure Bar apparatus to determine the compressive behavior of Gray Cast Iron material
2. Operating in a safe manner.
3. Producing striker velocities in the range of 0.5 - 50 m/sec.
4. Producing pressure-velocity calibration curve.
5. Generating impact-compression tests at strain rates ranging from 50 to 10^4 in./in./sec.
6. Generating propagation waves that can be used to determine strain-stress relationship.

2 METHODOLOGY

2.1 Review Stage

1. Designing of Split Hopkinson Pressure Bar using design analysis. (CATIA Software)
2. Selection of material. Performing test on ANSYS Software.
3. Performing dynamic compression testing on Gray Cast Iron of dimension 4mm x 5mm.
4. Measuring the deformation in specimen using strain gauge.
5. Amplifying the signal based on amplifier.

6. Obtain the stress strain curve of specimen based on software.

2.2 Final Stage.

- Conducting a compression test on **Gray Cast Iron** by using Split Hopkinson Pressure Bar Test and Ansys Workbench software the following results are expected to obtain.

- Stimulation of Gray Cast Iron using Split Hopkinson Pressure Bar Test and ANSYS Workbench Software.

Young's Modulus	E	80-150Gpa
Density	P	6800-7340 Kg/m3
Poisson Ratio	U	0.255-0.265

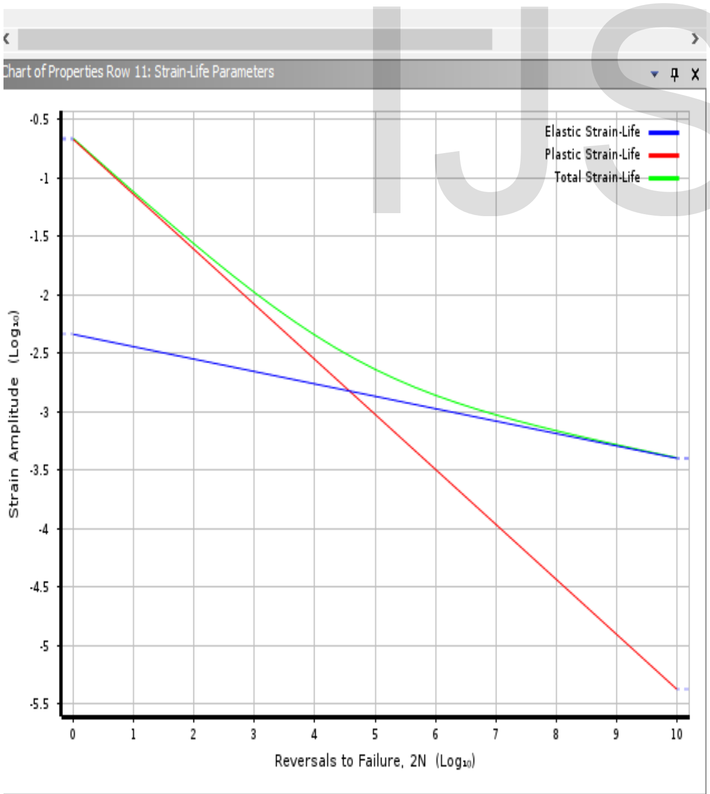

Fig. 2.2.1 Strain Rate Sensitivity Graph.

3 Material selection

Material Selection is one of the most important parameter based on material selection the simulation can be done.

1. Specimen Selection (Gray Cast Iron)

Gray Cast Iron is a type of iron that has Graphitic Microstructure. Gray Cast Iron has high compression strength compared to other materials also it has low melting point 1140°C to 1200 °C.

2. Striker Bar

The Striker Bar is made of a high strength metal such as **4340 Steel** or **Nickel Alloy** such as **Inconel.** The materials are used because the yield strength of the pressure bars determine the maximum stress attainable.

3. Incident Bar

The Indicent Bar is made of a **Stainless Steel** with Young's modulus 210 GPA, density 7830 kg/m3, elastic wave velocity 5547 m/s and poisson's ratio 0.3.

4. Transmitted Bar

The Transmitted Bar is made of same material as Incident Bar which is **Stainless Steel.**

4 Design

To achieve the objectives of the project, the design of the Split Hopkinson Pressure Bar is to progress in 4 different phases:

Phase 1: Design of the incident and transmitter bars.

Phase 2: Design for the pressure needed for the system.

Phase 3: Design of the striker assembly that provides the compressive wave.

Phase 4: Select the instrumentation to retrieve appropriate data.

Phase 1: The purpose of phase one is to design the incident and the purpose of phase one is to design the incident and transmitter bars.

Phase 2: The purpose of this phase is to determine the pressure needed for the system.

Phase 3: The purpose of this phase is to design the striker assembly.

Phase 4: The purpose of this phase is to select the instrumentation to be implemented in the apparatus.

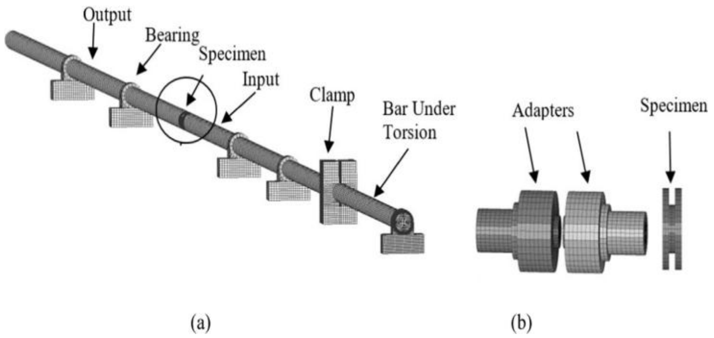

Fig.4- Finite element model of the TSHB

4.1 Design of Split Hopkinson Pressure Bar Test using CATIA Software.

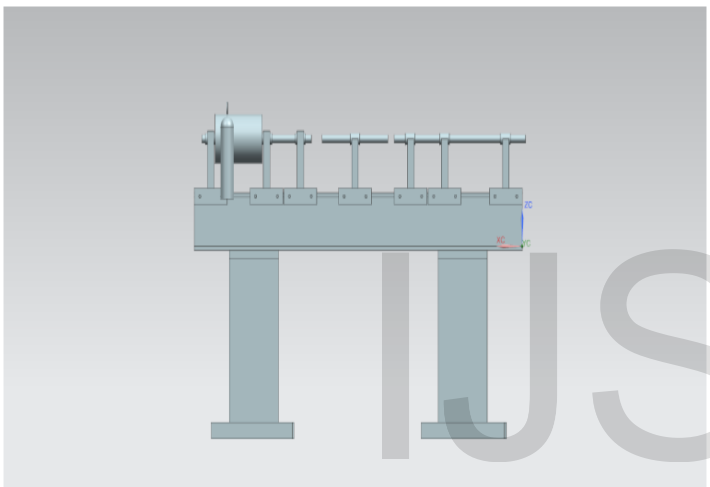

Fig. 4.1.1:3D Part-1

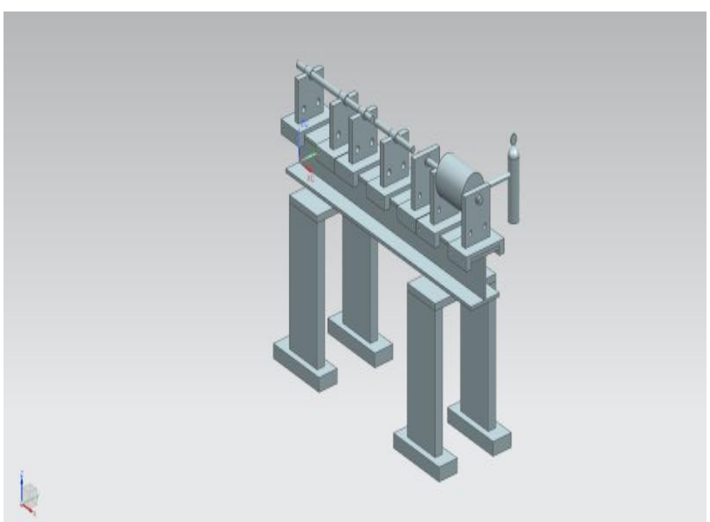

Fig. 4.1.2: 3D Part- 2

5EQUATIONS.

5.1 Testing and Specimen

In the SHPB compression test was carried out by using thespecimen size of ∅ 6 mm 5 mm. The specimen is placed between the incident bar and output bar, as shown in fig.1, the incident bar was directly hit by a striker bar of the driven explosion sending the wave into the incident bar. Theincidentstrainwasrecordedbystraingage1whilethat of the transmitted strain by strain gage2.

Theone-dimensioncompressive wave, the stress, strain, and strain-rate of the testing specimen can be represented by the following equations:

$$\sigma(t) = \frac{AE}{2A_0[\varepsilon_i(t)+\varepsilon_r(t)+\varepsilon_{t(t)}]}(1)$$

$$\varepsilon(t) = \int_0^t \dot{\varepsilon}(t)dt(2)$$

$$\dot{\varepsilon}(t) = \frac{c_0}{L_0[\varepsilon_i(t)-\varepsilon_r(t)-\varepsilon_t(t)]}(3)$$

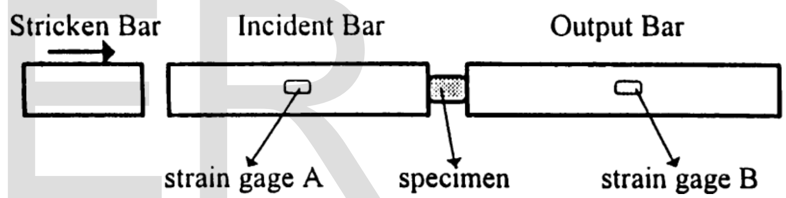

Fig. 5.1.1 Schematic diagram of Split Hopkinson Pressure Bar (SHPB) test.

In given equations (1), (2) and (3), the stress and strain of the compression are supposed as positive values. Let $\varepsilon_i(t)$, $\varepsilon_r(t)$, and $\varepsilon_t(t)$ represent the instantaneous amplitudes of the incident, reflected, and transmitted pulses, respectively.

Also, A_0 and L_0 represent the initial cross-section and length of the specimen,respectively.

Assuming SHPB specimen is in the homogeneous state, then the relation of $\varepsilon_i(t)+\varepsilon_r(t)= \varepsilon_t(t)$ exists. Under such acondition,thegiven equation.(1)and(3)canbesimplified to

$$\sigma(t) = \frac{A[E\times\varepsilon_t(t)]}{A_0} \qquad (4)$$

$$\dot{\varepsilon}(t) = \frac{2c_0[\varepsilon_i(t)-\varepsilon_t(t)]}{L_0}(5)$$

Equations (2), (4) and (5), explicitly illustrate that the stress, strain, and strain-rate of the SHPB test specimen can be derived from the measurement of the both pulses, ε_i and ε_t.

5.2) Calculation of toughness at various strain-rates.

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Integrating the area under the stress–strain (σ–ε) curve to a specific strain amount provides a datum in unit

Fig. 5.2.1 Stress–strain curves of gray cast iron under different strain-rates.

SHPB and static compression tests data in this experiment

	Strain-rate (S−1)	Energy absorbed, 3% strain (×106 J/m3)	Energy absorbed, 5% strain (×106 J/m3)	Energy absorbed, 8% strain (×106 J/m3)
SHPB test	2526	13.67	24.74	42.74
	1396	12.20	23.84	42.41
	762	11.60	22.71	41.59
Static test	2.4×10^{-4}	10.67	21.55	40.35

Of kg-m (or pound-in.) per volume that represents the Energy-absorbing capacity (i.e. toughness property) of the material at this strain [13, 14]. Thus, it is possible to describe the toughness property of specimen tested at different strains as long as its σ–ε curve can be Obtained.'

6 DISCUSSION.

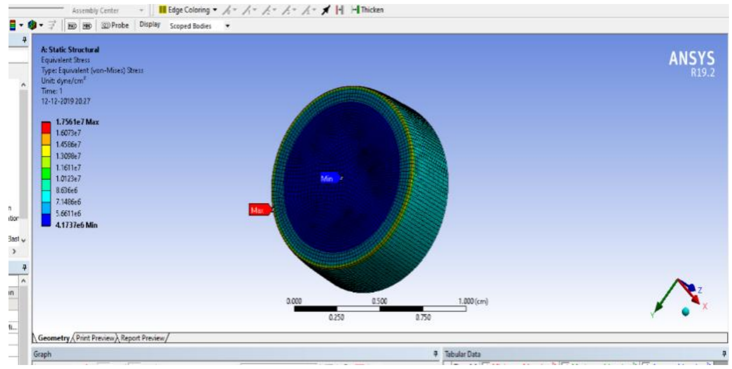
The Split Hopkinson Pressure Bar Test is the most accurate and known test used for knowing compression properties of given specimen. We studied all the properties of given specimen. We also studied the calculation of various parts which is used for fabrication of SHPB. We also got to use testing equipment such as Strain Gauge which is used in industrial application. We came to know the Gray Cast Iron has high compressive strength compare to other element. The various elements of SHPB apparatus goes under compression it consist of striker bar and incident bar which are made of same material. By conducting test on SHPB the readings are noted meanwhile the specimen is studied under Ansys Workbench Software. Based on both the readings the stimulation of Gray Cast Iron is done. By conducting test on Gray Cast Iron we came to know Split Hopkinson Pressure Bar Test has higher accuracy compare to Ansys Software.

7 CONCLUSION.

The principle motivation behind this test is to decide dynamic anxiety at high strain rate for the given specimen using Split Hopkinson pressure bar device have been examined. By conducting compression test on Gray Cast Iron based on ANSYS Software we came to know it has high compressive strength beyond certain limit compared to other materials.

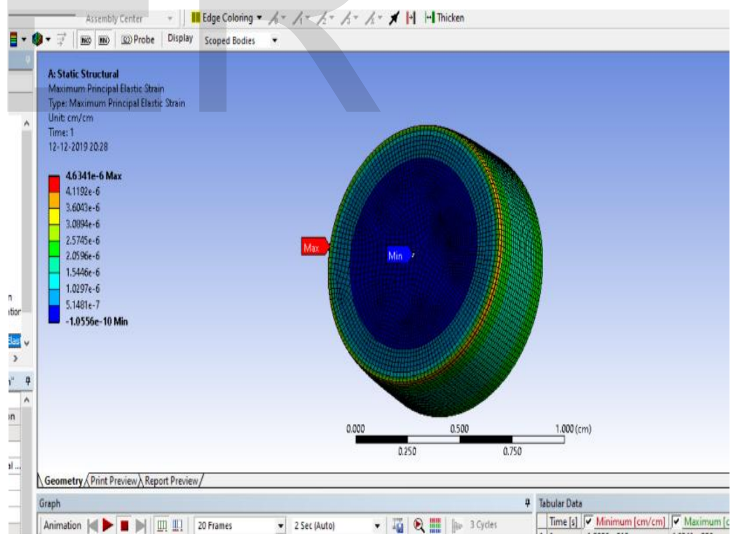
The following results are obtained based on ANSYS Software.

7.1 Equivalent Stresses on Gray Cast Iron Specimen



Equivalent Stresses on Gray Cast Iron Specimen	
Maximum	1.756e7 Mpa
Minimum	4.173e6 Mpa

7.2 Elastic Strain of Gray Cast Iron Specimen.



Elastic Strain of Gray Cast Iron Specimen.	
Maximum	4.634e-6 Mpa
Minimum	-1.055e-10 Mpa

7.3 Total Deformation in Gray Cast Iron Speci-

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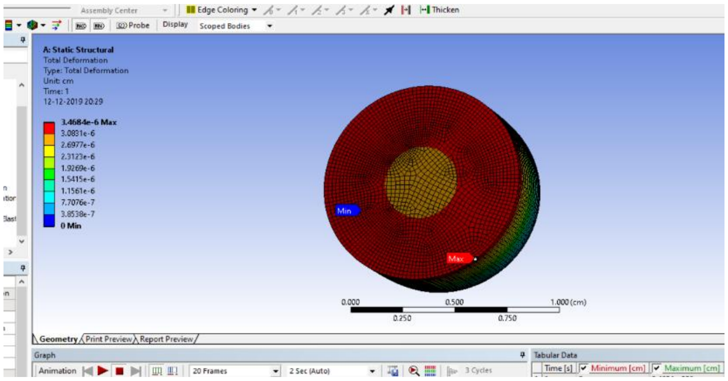

Total Deformation in Gray Cast Iron Specimen	
Maximum	3.4684e-6 Mpa
Minimum	0

8 FUTURE SCOPE.

Various conditions must exist for the specimen under investigation to deformhomogeneously. Many investigators have been concerned with this particular aspectof Hopkinson bar testing and have made significant advancements. A comprehensivestudy of the dynamics influencing specimen deformation should lead to a morecomplete understanding of how to improve tests. Further an investigation of thepressure bar – specimen interface area mismatch is expected to lend valuable insighttowards smarter testing. Though many investigators have examined the effects of specimen length-to-diameterratio, none have arrived at exactly the same conclusions.

Further efforts should be made towards impact pulse shaping. By placing variousmaterials between the striker bar and pressure bar, the rise time of the impact pulsecan be extended, which in effect reduces the overall frequency bandwidth of the pulse. As the bandwidth is decreased, so too are the effects of dispersion. Many materialsstrain harden as they are plastically deformed. This hardening manifests itself as aninclined slope on the stress-strain curve. The use of strain gages for pulses of very short duration becomes limited in theHopkinson bar due to inherent properties of the gage.

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