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COMPARISON OF STRAIN RATES OF ADVANCED HIGH STRENGTH STEELS WITH DIFFERENT ALLOY STEELS

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ABSTRACT
Although steel has been utilized in automobiles since the beginning of the automotive industry, new steel grades are always being created to meet evolving fuel economy standards. The excellent strength/weight ratio of advanced high strength steel grades (AHSS) makes them popular. In this paper, the dynamic impact of advanced high strength steels, and other five different alloy steels (EN19, EN24, EN31, EN36, MS) was carried out at different pressures using Split Hopkinson Pressure Bar Test. When exposed to various strain rates, steel grades exhibit distinct behaviours due to their varying microstructure composition. Compression tests were conducted using SHPB equipment and obtained stress-strain graphs experimentally. In this work, Among all the materials, AHSS exhibit high strain rates which significantly have strength.

Key words: AHSS, SHPB, high strain rates.

I. Introduction
The development of a new generation of AHSS steels with even higher strength and acceptable formability is still in progress. The necessity for steels with ever-increasing strength without sacrificing toughness and ductility properties has arisen as a result of the automotive and machine construction industries' ongoing development. Conversely, these steels must have great strength even at elevated temperatures. Several alloying elements are present in alloyed steels, but only one of them determines the steel's primary use attribute. The other alloying elements aid in purity, behavior during thermal or plastic processing, or in meeting mechanical requirements.

The present work aims to analyse the strength of different alloy steels like AHSS, EN19, EN24, EN31, EN36 and MS by applying compressive loading conditions at different pressure values of 0.5, 1, 1.5, 2, 2.5 and 3 Bars. The results of strain rates of all the materials were compared and discussed.

II. Materials:
The materials analysed in this are AHSS, EN19, EN24, EN31, EN36 and MS. Round bars of same slenderness ratios (L/D) were considered for all the materials.

Table 2.1: Dimensions of specimens of all the materials.

Length(mm)	Diameter(mm)	Slenderness Ratio
10	10	1

Advanced High-Strength Steels (AHSS) provide a special blend of excellent ductility and high strength, as well as other important qualities like formability and fatigue resistance. These characteristics, which are appropriate for lightweighting automobiles and other applications, are attained via meticulously regulated microstructures and chemical compositions.

Table2.2: The chemical composition of AHSS steel is

Grade	C	Mn	W	V	Co	Cr	Mo
AHSS	0.85	1.20	5.50	1.00	0.30	4.0	1.20

EN19, which is also known as 708M40 in the BS 970 standard, is a premium alloy steel used in engineering and general mechanical applications. It has a 1% chromium and molybdenum content. Additionally, it is considered to be of the same grade of steel as 42CrMo4 steel in EN standards or

ASTM 4140 steel. EN19 steel is renowned for its exceptional strength, hardness, and resistance to wear. It is extensively utilized in the production of gears, shafts, axles, automobile parts, and equipment components.

Table 2.3: The chemical composition of EN19 steel is

Grade	C	Mn	P	S	Si	Cr	Mo
EN19	0.35-0.45	0.50-0.80	0.05	0.05	0.10-0.35	0.90-1.5	0.2-0.40

EN24 is also known as 817M40T is a hardened and tempered steel alloy with extremely high strength. The grade is a combination of nickel, chromium, and molybdenum, which provides excellent ductility, wear resistance, and high tensile steel strength. EN24 is appropriate for a range of applications requiring higher temperatures due to its rather acceptable impact qualities at lower temperatures. is a hardened and tempered engineering steel that is simple to treat and temper. The alloy provides a good combination of wear resistance, ductility, and strength. It is an alloy engineering steel with extremely high strength.

Table 2.4: The chemical composition of EN24 steel is

Grade	C	Mn	P	S	Si	Cr	Mo
EN24	0.35-0.45	0.45-0.70	0.05	0.05	0.10-0.35	0.90-1.40	0.2-0.35

EN31 steel, sometimes referred to as AISI 52100 or Bearing steel, is a high-carbon alloy steel that is mainly categorized as medium-carbon. Excellent high carbon alloy steel with compressive strength, abrasion resistance, and a high degree of hardness. This type of alloy steel is frequently used for press instruments and wear-resistant machine components. Because it contains nickel, chromium, and molybdenum, EN31 is an extremely strong steel alloy that is hardened and tempered before being supplied. It also has good ductility and wear resistance.

Table 2.5: The chemical composition of EN31 steel is

Grade	C	Mn	P	S	Si	Cr	Mo	Ni	Cu
EN31	0.93-1.05	0.25-0.45	0.025	0.015	0.15-0.35	1.35-1.60	0.1	0.25	0.3

EN36 also known as 655M13, is a grade of carburising steel that has a soft but robust core and extremely high surface strength. A notable level of hardness is maintained by the material. Because of its high tensile strength, EN36 is used to make a variety of high-strength components, such as crankshafts for the automotive and aerospace industries.

Table 2.6: The chemical composition of EN36 steel is

Grade	C	Si	Mn	P	S	Ni	Cr
EN36	0.14-0.20	0.10-0.35	0.70-1.00	0.035	0.040	3.00-3.75	0.60-1.00

Mild steel, sometimes referred to as plain carbon steel or low carbon steel, is a kind of steel with a comparatively low carbon content (usually less than 0.25%). Because of its low cost, adaptability, and simplicity of manufacture, it is the most widely used type of steel. Mild steel is appropriate for a variety of applications due to its good mechanical qualities, which include strength and ductility.

Table 2.7: The chemical composition of Mild steel is

Grade	C	Si	Mn	P	S
MS	0.16-0.18	0.40	0.70-0.90	0.040	0.040

III. Methodology:

Dynamic compression tests were performed using a split-Hopkinson pressure bar (SHPB). An amplifier, a tachometer, a hyperdynamic strain gauge, a digital oscilloscope, and a computer processing system are all part of the data acquisition and processing system, while the rod assembly consists of an incident rod, a sample, a transmission rod, and an absorbing rod as shown in figure 2.1. A cylinder with a diameter of 10 mm and a height of 10 mm is used as specimen for the SHPB test for all the six materials. Same slenderness ratios are being utilised. The dynamic compression experiment was conducted at six different pressures such as 0.5, 1, 1.5, 2, 2.5 and 3 bars to all the six materials.

When an impact bullet collides with an incident rod at a specific speed, the rod generates incident waves, which continue to propagate to the right until they come into contact with the sample end face. On the one hand, this causes the incident wave to return to its own wave, which is known as the reflected wave; on the other hand, it forces the sample to occur in the compression of the situation.

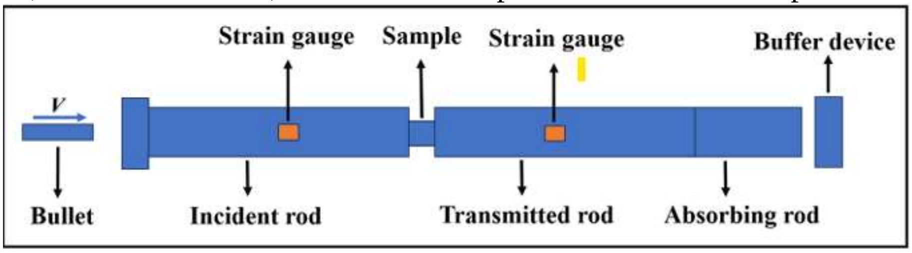

Figure:3.1: Schematic diagram of Split Hopkinson Pressure Bar Equipment[3]

The process is brief, so the wave continues to propagate to the right until it reaches the buffer device and eventually forms transmissive waves until the last one disappears. The purpose of this apparatus is to assess the dynamic properties of the specimens at a characteristic strain rate by applying a specific impact pressure between the incident and transmitted bars. To ascertain the dynamic characteristics of the material being evaluated under dynamic compression trials at various strain rate levels, the SHPB signals are captured and processed.

IV. Results:

A summary of the experimental conditions for each designated experiment in the series is provided in Table 4.1, which includes type of material, different pressures applied (0.5, 1, 1.5, 2, 2.5, 3 bars) and strain rates.

Table:4.1: Representation of Strain rates for different materials.

Material	Pressure Ranges					
	0.5 bar	1 bar	1.5 Bar	2 Bar	2.5 Bar	3 Bar
AHSS	69.29	75.16	89.73	90.55	105.43	105.74
EN19	51.68	43.41	72.03	72.42	99.15	94.97
EN24	72.07	63.12	72.44	85.26	79.87	75.53
EN31	56.72	66	80.41	88.74	82.35	102.84
EN36	65.95	64.05	79.5	89.5	100.7	103.42
MS	69.8	67.96	69.18	89.23	97.37	97.52

According to the values provided, it is clearly observed that AHSS material is having high strain rates which represents that it has more strength. Strain rate is the change in strain of a material with respect to time. The modulus and yield strength both rise with increasing test speed. As the strain rate increases, the material's stiffness also increases. Under high strain rate conditions, the material seems to be becoming more resilient and robust.

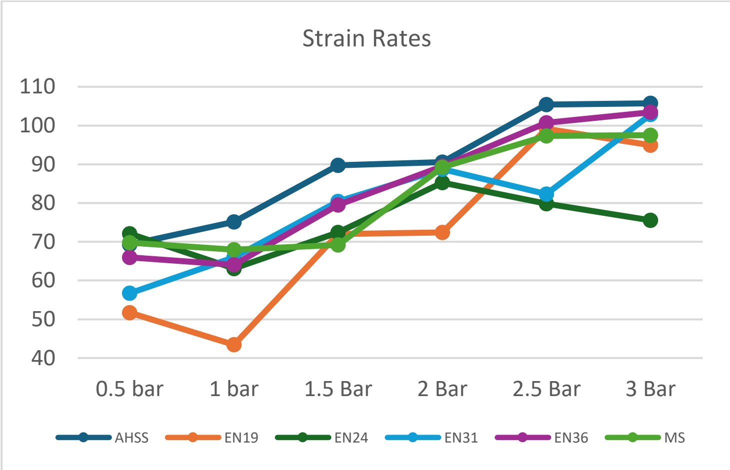

Figure 4.1: Graphical representation of strain rates for six materials AHSS, EN19, EN24, EN31, EN36 and MS at different pressures values ranging from 0.5 to 3 bar.

Figure: 4.2. Representation of graph of strain rate of AHSS material at 2.5 bar pressure.

The graph shows steady strain rates over a specific time period, followed by a rapid increase in strain rate, which indicates strain hardening and increases the material's resistance to strain. The AHSS material is excellent for energy absorption in automobile collision applications because it exhibits considerable strain hardening and retains a significant amount of stress even at high strain levels. High dynamic strength is shown by the steep slope following yielding.

V. Conclusion

Under the same pressure values for all the six materials with same slenderness ratios, AHSS exhibits high strain rates indicating its high strength. As the pressure increases, its strain hardening increases. This high dynamic strength of AHSS makes it suitable for automotive applications than any other alloy steels.

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