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Investigation on the Dynamic Performance of the Engineering Materials

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ABSTRACT:

The engineering materials dynamic performance is an important parameter which is greatly effects on the behavior of these materials. To determine the materials performance , the effects of test speed (rate of loading) effect should be taken into accounts. It was found that in case of test speed increasing , the behavior of dynamic or yield strength of materials is increased, also it was noted that the stress-strain versus the common logarithmic of test speed may be subdivided to three effective zones. Saturated zone ,weak sensitivity zone and strong sensitivity zone. From results it was summarized that for polymeric ,metals , and composite materials in this study, without taken into account the type of materials, such three zones behavior are exists. In the high strain rates area , the materials dynamic performance is characterized by increasing load rate sensitivity, by increasing effects of inertia forces and the adiabatic character of the mechanical deformation.

KEYWORDS: *Dynamic force, strain rate, tensile test, stress strain behavior, mechanics of materials*

1. INTRODUCTION

Mechanical dynamic property of the material under dynamic loading is an important point[1]. Material behavior is greatly affect by increasing in the test speeds in most of engineering materials. This is known in all relevant test standards for tensile test by determining the maximum testing speed. For steels, the main effect of loading rate increasing is yield and tensile strength increasing which tends to reduce the cleavage fracture toughness [2]. Most of the engineering are subjected to high energy due to impact loading and hence higher dynamic loading speed that can tends to multi-axial dynamic stresses [3]. Composites materials such as Poly methyl methacrylate (PMMA) is anisotropic material, so the mechanical failure due to these stresses are complex involving various fracture mechanisms in micro scale. Numerous methodologies have been discussed and ,approved including failure mechanics, nonlinear viscoplastic constitutive modeling, fracture mechanics, and macroscopic (global) failure criteria are presented to investigate the dynamic load behavior of the materials . Under certain biaxial stress states and under strain rate in dynamic phase, available fracture characteristics are still not promising and fully reliable [4]. These test speeds are usually transient in highly manner and the material structural response occurs suddenly (dynamic case) in milliseconds or microseconds.

This investigation studies the test speed sensitivity of different engineering materials at different loading rate of loading values and continues monitoring for force-displacement performance of these materials.

2. EXPERIMENTAL WORK

2.1 Testing materials

Different testing materials were used for this investigation the mechanical characteristics of these materials can be summarized as follow;

- Poly (methyl methacrylate) (PMMA): PMMA is a strong material. It is behave as a good impact behavior. PMMA Density is 1.18 (g/cm3), Tensile Strength 70 MPa [6].
- Copper :Copper alloy with grade of C106/CW024A. The yield strength for copper alloys is not accurately defined. So it usually to be determined as either 0.2% offset or as a 0.5% extension under load [7].
- Steel rode: St37 were used in this investigation in the form of dumbl shape with Yield stress of 235 N/mm^2 and Tensile stress of 360 N/mm^2 [8] .
- Aluminum : Aluminum 6061-T6 samples were used in this investigation with Yield Strength of 276 MPa, 68.9 GPa Modulus of Elasticity, and 17 % Elongation at break [9].
- Polyamide :Nylon garde 6 : Is a semi-crystalline, white engineering thermoplastic and it is in many respects interchangeable. Tensile stress : 78 N/mm^2 [10].
- Medium Density Polyethylene - MDPE: It is Thermoplastic with a good shock and drop resistance. Low notch sensitive, stress cracking resistance is relatively good. MDPE Tensile Strength is 14 MPa [11].

2.2 Testing apparatus

The rate of loading effects on the tensile and failure characteristics is very important.

- There are two points for tensile testing at high loading rates
  – High oscillation load deteriorates quality of stress-strain curve;

  –Continues monitoring of the existing strain and force (dynamic force measuring amplifier, or extensometer) is not easy to be estimated with an accurate and reliable results.
- Results of investigating the effect of loading rate on tensile properties/fracture strain is infrequent due to difficulties.

Due to these difficulties the following apparatuses were used in this investigation

- Fully computerized tensile testing machine is used to perform the required tests this machine was classified as 0.5 accuracy class in accordance with ISO 7500-1.This machine was provided by high precision extensometer to measure the displacement (see Figure.1).

Fig 1. 5 kN Tensile testing machine **Fig** 2. High Speed Recorder

- High speed transient recorder and data acquisition system is the modular platform for fast measurements of mechanical parameters. A transient recorder, data recorder and data acquisition system provide all the features expected from a transient recorder. Genesis High Speed is provided with data acquisition cards with sampling rates of 20 KS/s to 100 MS/s . This modular platform (interfaced with 5 kN dynamic force transducer) was used to monitor the testing force utilizing the fast sampling rate to monitor the behavior of the tested material from force point of view. See figure 2.

- Dynamitic Load Cell: for measurement of tensile dynamic force a miniature load cell allows for both dynamic and static force measurement to be monitored. Due to the high fundamental frequency, this force transducer is also suitable for very fast measurements . the capacity of this force transducer is 5 kN with accuracy class of 0.5.The setup of the testing system were identified to be as follow. See figure 3.

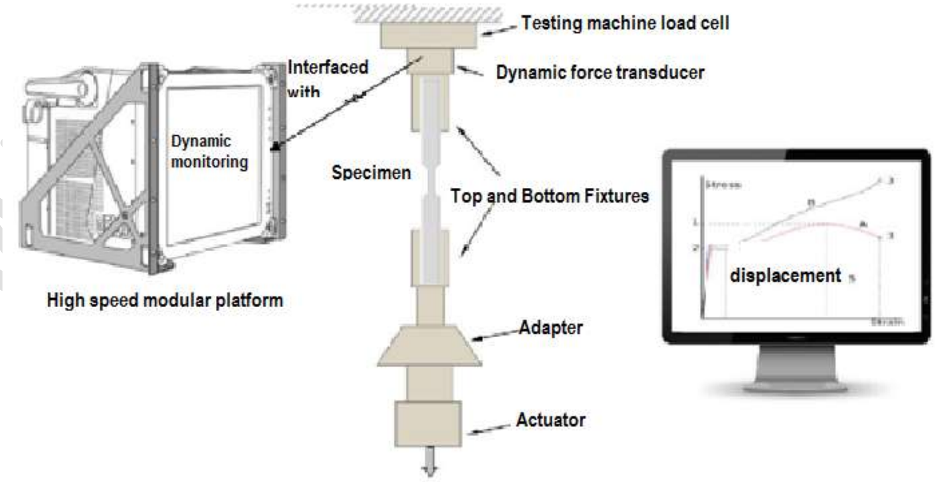

Fig 3. Setup of the measuring system

2.3 Testing Procedure

The selected samples were tested as indicated in table 1. Where ten samples were selected for each selected material per each loading rate .Results were analyzed and force displacement curves were monitored. In case of lower loading rates, a load cell with dynamic characteristics interfaced with reading amplifier for fast measuring of force and LVDT could be used to monitor the force and the strain, respectively.

Table 1. Testing scheme

Tested materials	Loading rate (mm/min)	Number of the tested samples
Steel	5	10
	10	10
	20	10
Copper	5	10
	10	10
	20	10
PMMA	5	10
	10	10
	20	10
MDPE	5	10
	10	10
	20	10
Polyamide - Nylon 6	5	10
	10	10
	20	10

3. RESULTS AND DISCUSSION

As shown in Figures from 4 to 9 at minimum strain-rates, 5 mm/min , the effect of test speeds and strain rate sensitivity on breaking force is very low. However, at medium strain rates, 10 mm/min, the yield strength is more sensitive to the effects of strain rate than in a lower range . When the strain-rate is 20 mm/min or greater than 20 mm/min , the strain rate effectiveness became saturated, and the yield stress is no longer increases in clearly manner as the strain rate increasing. In general as it was noted from figures , that test speeds increasing result in higher tensile strengths & yield of the engineering material under test. varying test speed (loading rate) is greatly effects on tensile properties of the materials , especially at very high test speeds. Generally, positive loading rate dependence means increasing loading rate tends to increase strength, but dynamic strain ageing can results in negative strain rate dependence.

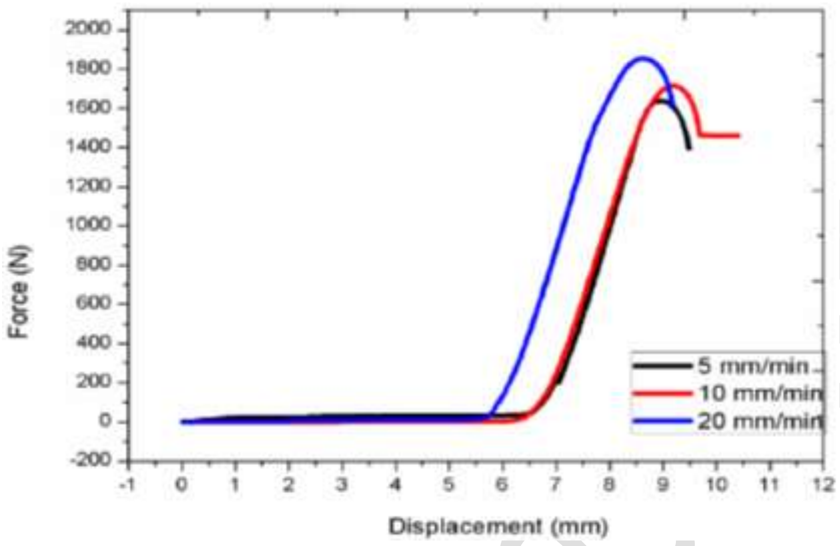

Fig 4. Force displacement curve for Steel

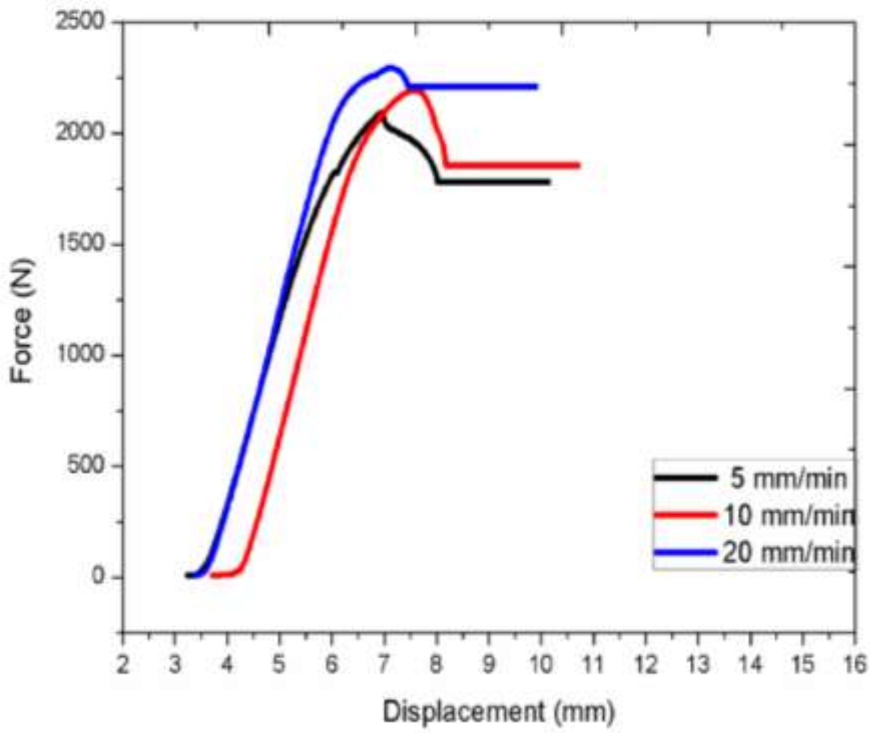

Fig 5. Force displacement curve for copper

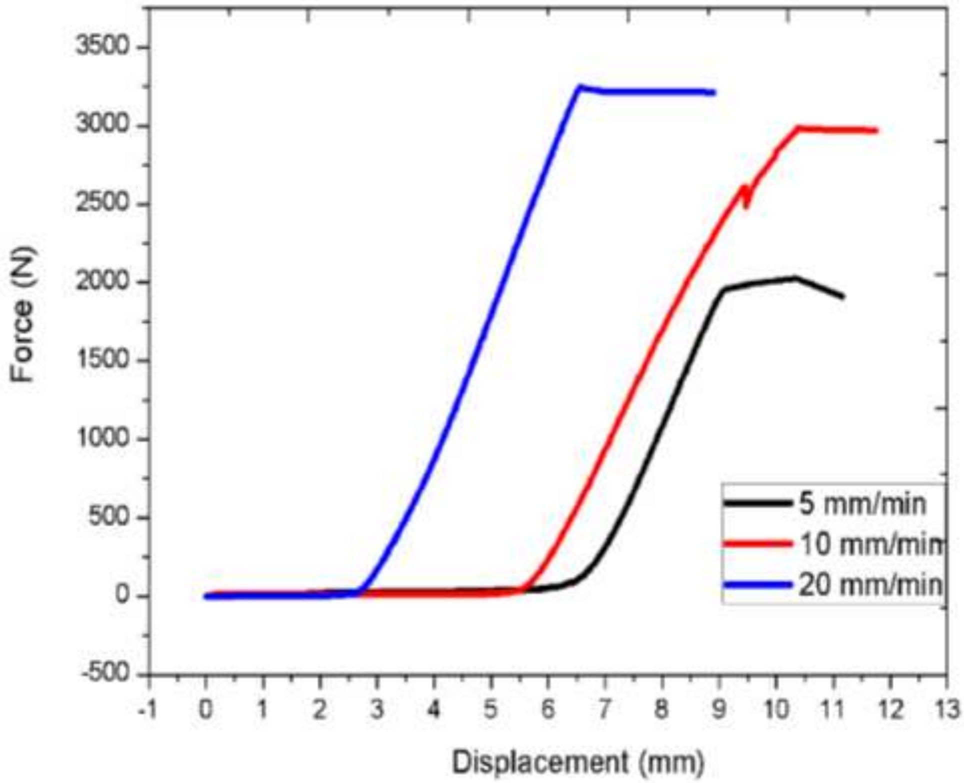

Fig 6. Force displacement curve for Aluminum

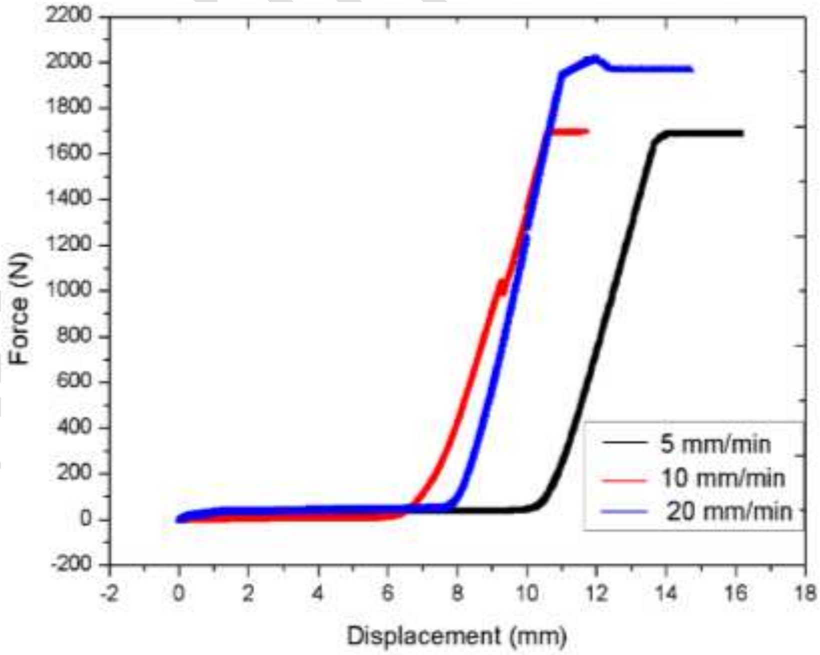

Fig 7. Force displacement curve for PMMA

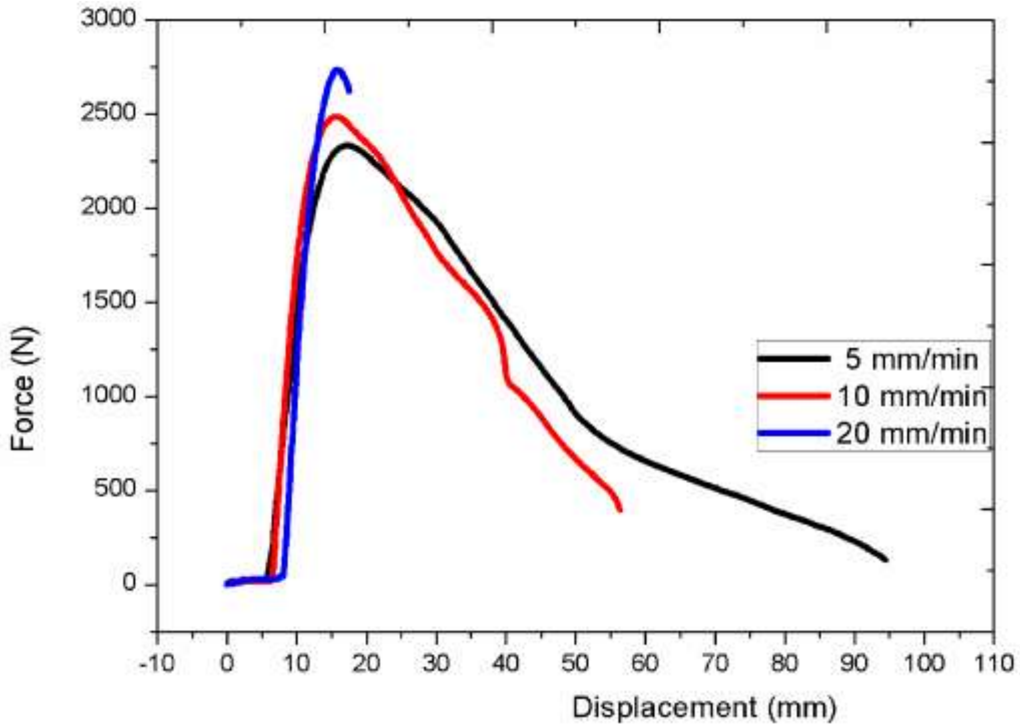

Fig 8. Force displacement curve for MDPE

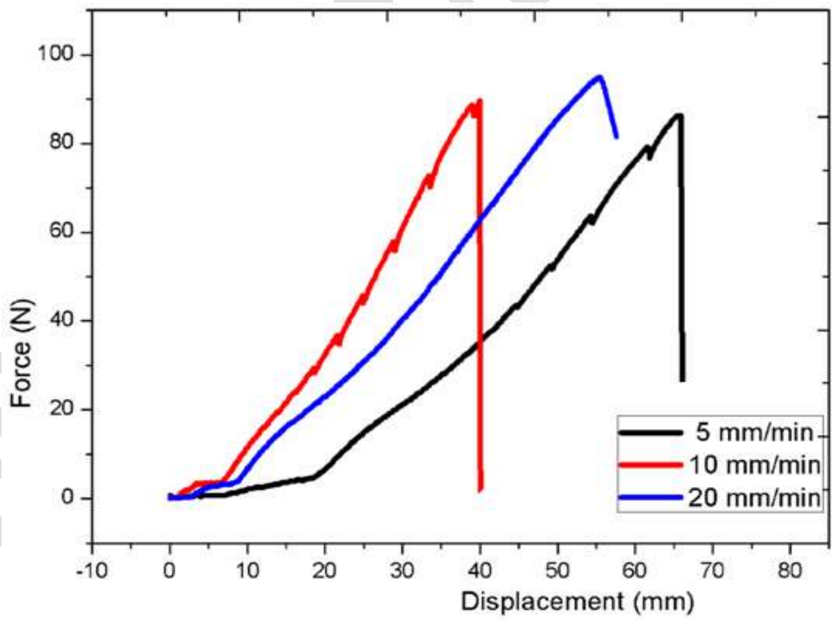

Fig 9. Force displacement curve for Polyamide - Nylon 6

In general the mechanical properties of materials subject to quasi-static , static and dynamic loading, is a relevant research work of dynamic behavior of materials. The different performances of materials under those loading mechanisms is that the dynamic behavior or yield strength increased as the strain rate increased . Figure10 explains the general features of different loading rate on the breaking force and the yield stress reliance on test speed.

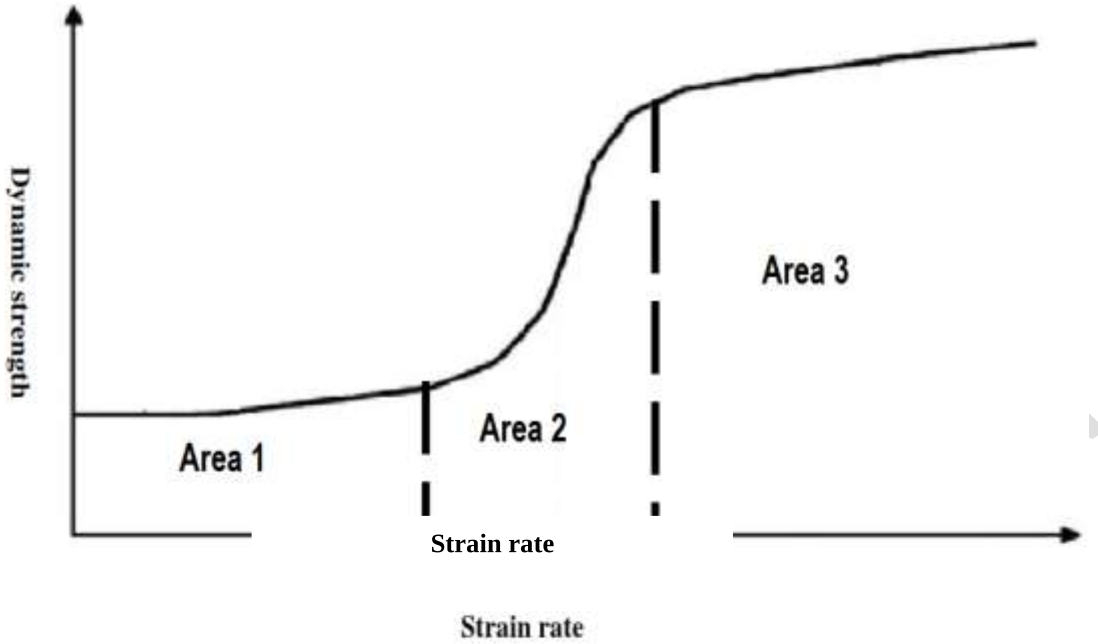

Fig.10 The yield stress effects on strain-rate against dynamic strength.

At the low range of strain rate, the material dynamic and yield strength increasing slowly but surely with strain rate increasing (Area 1, with low sensitivity). As shown in Fig.10, Area 2 (area with a high sensitive) is defined by a rapid behavior material strength and yield increasing when the strain-rate is more than the expected threshold level, At strain-rate with very high value in area 3 (saturation), the yield and the dynamic strength dependence became weak again, like Area 1.

4. CONCLUSION

From the previouse experimental work it was concluded that ,

- The engineering materials yield stress and dynamic behavior (dynamic strength) is greatly affected by strain-rate increasing where it is increased as strain-rate increased
- The engineering materials strain rates behavior is divided into two stages of transition (transition areas) to describe the behavior of increasing the yield strength. When the strain rate is located in the first transition stage , the dynamic and yield strength are increasing with increasing test speed. And when the loading rate is fall in the second transition stage, the dynamic , yield strength and strain rate increasing quietly and resulting in saturation zone.
- The engineering materials, stress-strain behavior against the logarithmic common of the strain rate can be splited into three stages,. low sensitivity stage, high sensitivity stage and saturated stage.
- In this study, Composite and polymeric materials, are could be observed that regardless of what type of materials is , such a normal behavior of three zones exists.

- The engineering materials high strain rates, and the dynamic performance of the enginerring materials are determined by increasing strain-rate sensitivity, which increases effects of inertia forces and by the adiabatic character of the mechanical deformation.

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