

Experimental Study on the Rate Correlativity of Particulate-filled Composite

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Abstract. The effects of strain rate on the mechanical properties of the particulate-filled composite have been studied. Tests in uniaxial tensile condition were carried out over a range of tensile rates. Results show that the mechanical properties of the particulate-filled composite are distinctly influenced by strain rate. Yield stress, initial modulus, and fracture stress increase linearly with the logarithm of strain rate. But yield strain is less sensitive to strain rate.

1. Introduction

Composite propellant, as a kind of typical high-particulate-filled composite, is composed of adhesive system and fuel particles, which would result in the nonuniform of its microstructure. This special microstructure may be the leading cause of the complex mechanical performance^[1]. Under finite deformation, the dewetting of the particle^[2-4] would lead to the nonlinearity of the stress-strain relationship. The cavities caused by dewetting are the main characteristic if the dilatation. S. Özüpek^[1,5] and E.J.S.Duncan^[6] pointed out that investigation on the rate correlativity of the particulate-filled composite was the foundation of its application and the essential mean for the constitutive model study. Zhang J B^[7-9] studied the rate correlativity of double based propellant under various conditions, such as uniaxial tensile and compression condition and high rates condition. Wang Y Y^[10] and Lai J W^[11] analysis the influences of the strain rates on the dissipated energy of composite propellant. Guo X^[14] investigated on the breaking strain and breaking stress change under different strain rates. But the study didn't involve in the difference of the stress-strain relationship.

Based on the study of predecessors, the influence of the strain rates on the mechanical properties of composite propellant was studied, to lay a foundation of the study on the constitutive model.

2. Experimental material and method

Composite propellant, as a heterogeneous propellant, the differences of formula would cause the change of the mechanical properties, but would not have intrinsic distinction^[12]. Thus, the composite propellant of the same batch, consisting of polyether polyurethane and diethyleneglycol dinitrate as adhesive and ammonium perchlorate, aluminum powder, cyclotetramethylene tetranitramine as fuel particles. Referring to QJ924-85 standard, the material was cut to dumbbell specimens, as pictured in Fig 1. Experiments were carried out on QJ211B electronic universal test machine in room temperature under the tensile rates of 5mm/min, 20mm/min, 50mm/min, 100mm/min, 200mm/min, 500mm/min.

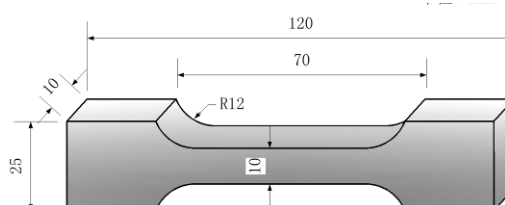


Fig 1 Diagram of test specimen

3. Experimental results

3.1 Typical stress-strain curve

Fig 2 illustrates the typical stress-strain curve for the composite propellant. The stress-strain curve exhibits an initial elastic response followed by yielding and strain hardening. The curve could be divided into three parts, elastic strain region, yielding region, strain hardening region, using double tangent method as shown in Fig 2. The strain at point A should be viewed as yield strain ε_s , and the corresponding stress should be yield stress σ_s . Serial other mechanical parameter could be acquire, initial modulus E_{in} , breaking strain ε_m and breaking stress σ_m . as shown in Fig 2.

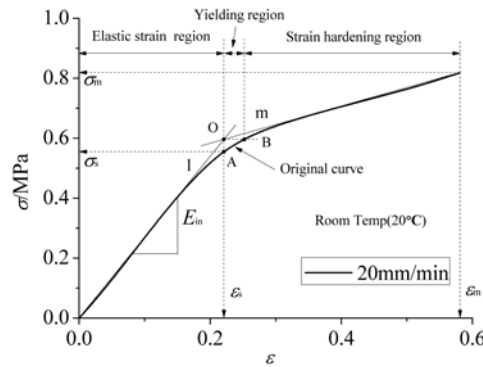


Fig 2 Stress-strain response at 20mm/min

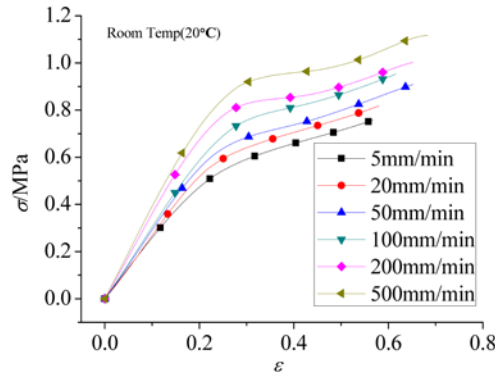


Fig 3 Stress-strain responses at different strain rates

The corresponding stress versus strain behavior shows the expected increase in initial slope representing modulus and yield stress increase with the strain rate, as shown in Fig 3. But a dramatic softening at high strain rate is observed after yield due to the combined result of strain softening and thermal softening.

3.2 Rate dependence of yield strain

The yield strain of all specimens was collected, as shown in Table 1. It is obvious that there is little difference between different groups. The ANOVA of yield strain turns out that yield strain are not changed with the strain rates, the mean of the yield strain equals 0.205.

Table 1 Collection of yield strain

5mm/min	20mm/min	50mm/min	100mm/min	200mm/min	500mm/min
0.205	0.203	0.194	0.178	0.185	0.238
0.208	0.192	0.200	0.213	0.178	0.216
0.186	0.188	0.209	0.198	0.177	0.184
0.200	0.190	0.192	0.204	0.206	0.222
0.196	0.193	0.199	0.200	0.185	0.218

3.3 Rate dependence of breaking strain

The breaking strain of all specimens was collected, as shown in Table 2. It is obvious that there is little difference between different groups. The ANOVA of breaking strain turns out that breaking strain are not changed with the strain rates, the mean of the breaking strain equals 0.630.

Table 2 Collection of breaking strain

5mm/min	20mm/min	50mm/min	100mm/min	200mm/min	500mm/min
0.595	0.547	0.652	0.508	0.656	0.600
0.5455	0.633	0.684	0.712	0.648	0.692
0.582	0.586	0.679	0.581	0.491	0.734
0.595	0.555	0.697	0.600	0.795	0.728
0.621	0.580	0.678	0.681	0.672	0.658

3.4 Rate dependence of initial modulus, yield stress, breaking stress

There is distinct rate dependence of initial modulus, yield stress, breaking stress, the mean values of which are shown in Table 3.

Table 3 Collection of mechanical parameter

Tensile rate(mm/min)	5	20	50	100	200	500
Strain rate(s ⁻¹)	0.00167	0.00667	0.0167	0.0333	0.0667	0.167
E_{in} (MPa)	2.601	3.143	3.194	3.494	3.873	3.971
σ_s (MPa)	0.566	0.636	0.721	0.743	0.821	0.911
σ_m (MPa)	0.758	0.821	0.908	0.955	1.001	1.127

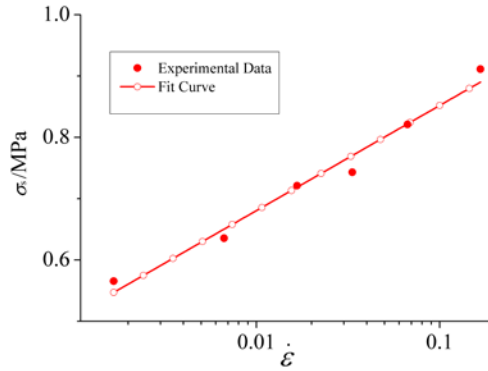


Fig.4 Fit curve and test data for yield stress

On the basis of Eyring flow model, the relationship between yield stress and strain rates could be written as

$$\sigma_s = \sqrt{3}\tau_0 \ln(2\sqrt{3}A_0) + \sqrt{3}\tau_0 \ln \dot{\epsilon} \quad (1)$$

Where A_0 and τ_0 are material parameters. The yield stress at different strain rates were fitted by minimization of least square of errors using equation (1), as shown in Fig 4

Similar equation was grabbed to fit initial modulus and breaking stress at different strain rates, as shown in Fig 5 and Fig 6. It is observed that Yield stress, initial modulus, and fracture stress increase linearly with the logarithm of strain rate.

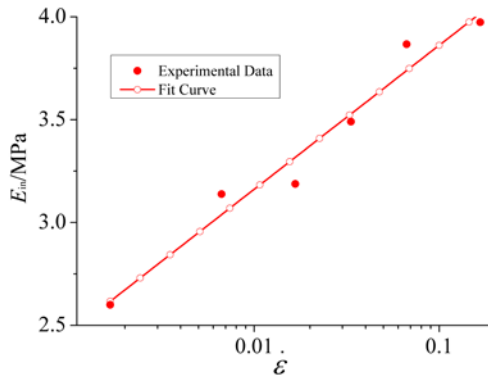


Fig 5 Fit curve and test data for initial modulus

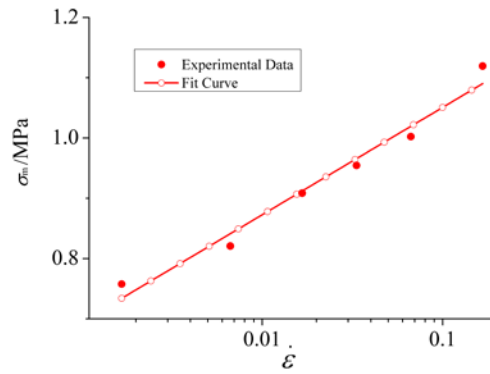


Fig 6 Fit curve and test data for fracture stress

4. Summary

The effects of strain rate on the mechanical properties of the particulate-filled composite have been studied. Tests in uniaxial tensile condition were carried out over a range of tensile rates. Results show that the mechanical properties of the particulate-filled composite are distinctly influenced by strain rate. Yield stress, initial modulus, and fracture stress increase linearly with the logarithm of strain rate. But yield strain is less sensitive to strain rate.

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