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Research Article

Experimental Studies on Compressive Behaviour of Granite Using Quasi-Static and Split Hopkinson Pressure-Bar Test.

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ABSTRACT

The mechanical characteristics of the materials will change because of the shift in strain rates. This study employs several compressive experiments to investigate the static and dynamic behaviour of the granite specimen at various strain rates. The results of the experiment showed that the granite's mechanical properties and fracture behaviour had changed dramatically. However, the findings of compressive behaviour in the SHPB test revealed more micro-cracks as the strain rates increased. Additionally, the phase pattern of a granite specimen captured using a scanning electron microscope (SEM) shows intergranular fractures, and the grain-scale river pattern is observed in the data.

Keywords: Mechanical properties, strain rate, quasi-static and SHPB, SEM ;

INTRODUCTION

Rock materials are excessively used in the construction industry. Granite is an igneous rock. It has grains that can be seen with the naked eye. Granite is made up of two primary parts. They are quartz and feldspar. Other elements, like as amphiboles and mica, are also found, albeit in less concentrations. Numerous interior and outdoor projects employ granite. Pavement, structures, bridges, and monuments are examples of outside construction projects. Indoor improvements include floors and counters. It is also ——— used in curling balls and gym walls for mountain climbing training, in addition to being used to build monuments. Granite is used in several forms, including: Constructing monuments, using granite in jewellery, Floor and fireplace mantle are both made of granite. Granite is utilized in bathroom countertops, shelving and sinks. In order to use granite in engineering, it is crucial to understand its compressive qualities. For instance, the compression behaviour under high strain rates. Rock material deformation and failure occurred quickly during the SHPB testing. [1] The pattern of dynamic stress distribution in the specimen was examined as symmetric and similar to that of the counterpart static loading. [3]The dynamic *Corresponding author. Vasavi college of engineering, Ibrahimbagh, Hyderabad, Telangana-500031, India. E-mail: vengalakarthikeya9@gmail.com. 2 compressive strength and dynamic tensile strength of rocks measured using SHPB. For compression tests, examined data was the shape effect (length to diameter ratio) and the friction effect during SHPB tests. [5] With the use of Brazilian disc specimens that have been flattened and a large diameter SHPB, the marble's fracture toughness and tensile strength are investigated. The cracking and failure processes under quasi-static and dynamic loading show some clear changes in the white patch shape and initiation load. The extent of the compressive failure zones around the contact points between the loading platens and specimens is found to increase with the strain rate. In the current research, eighteen specimens were used in the SHPB test, each with a different impact velocity, and the necessary data was gathered. They are included in the techniques and results section. [8] The marble's tensile strength and fracture toughness are assessed using SHPB at high strain rates. When comparing the cracking and failure processes under quasistatic and dynamic stress, it's critical to be aware of a few distinct distinctions. One main fracture, for instance, predominates the failure process under quasistatic stress. As the strain rate rose, however, additional micro-cracks appeared in the specimens under dynamic loading. As the strain rate rose and the ultimate compressive strength increased, the rock fragment's grain size shrank. [2]The marble is explored for the fracture toughness and tensile strength with high strain rates using SHPB. Comparing the cracking and failure processes under quasistatic and dynamic loading, some distinct differences noted are, in quasistatic loading the failure process is dominated by one main crack. Where as in dynamic loading there were more micro-cracks generated in the specimens with the increase of strain rate. [18] The "main fibre" system and the "tension fibre"

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system, two functionally separate sets of zonular fibres, were discovered by SEM investigations of the zonular apparatus in 10 human and 17 monkey eyes. [15] Scanning electron microscope is used to study the granular level grains and ore structures of the sandstone. [14] Electron beam and TEM microscope were used to study the foil properties of microdiamond that were reared in the lab by larissa, Mathew. Density/(g/m3) Elasticity/ GPa A series of dynamic compression experiments with a 16 mm SHPB diameter were conducted in this work, with strain rates ranging from 21 sec−1to 34 sec−1. This research tries to explain the mechanisms and processes of granite collapse under high strain rates. SEM tests were also conducted along with quasi-static and spilt Hopkinson pressure bar to find out the grain structure and failure pattern of granite surface.

2. SPECIMEN PREPARATION AND EXPERIMENTAL SET-UP

2.1. Specimen preparation:

Black granite from the Taralapally region of the Indian state of Telangana was collected for the study's test granite material. The microstructure of the material is examined by using an optical microscope (METZER OPTIX) shown in Fig 1(a). The composition of the black granite is Iron and magnesium (gabbro) 70% with 20% quartz and 10% feldspar. The main minerals have grains between 1mm and 5mm in size. Table 1 displays the static Mechanical characteristics of granite. The cylindrical and cuboid specimens were worked at a 1:2 diameter-to-height ratio. And several pieces were prepared for the test. To be carried on the Splits Hopkinson pressure bar and quasi-static apparatus. In total, there were eighteen specimens (Fig. 1(b) were prepared using an angle grinder with the help of bits 1inch 1.5 inch. Finally, the diameter of the granite specimen was 16, and the height dimensions were 32, as shown in Fig 1 (c).

Fig: 1 (a) Fig: 1(b) Fig: 1(c)

Fig. 1. (a) Specimens Microstructure; (b) Geometric requirements of specimen; (c) rock specimen in the experiment.

Density/(g/m3)	Elasticity / Gpa	Compressive strength/ Mpa	Tensile strength/ Mpa	Mohs hardness
2700	40	310	7	6

Table 1: Mechanical Characteristics of Granite:

2.2 Split hopkinson pressure bar system

Spilt Hopkinson pressure bar consists of striker, incident and transmission bar Fig: 2. along with the motor and air compressor.

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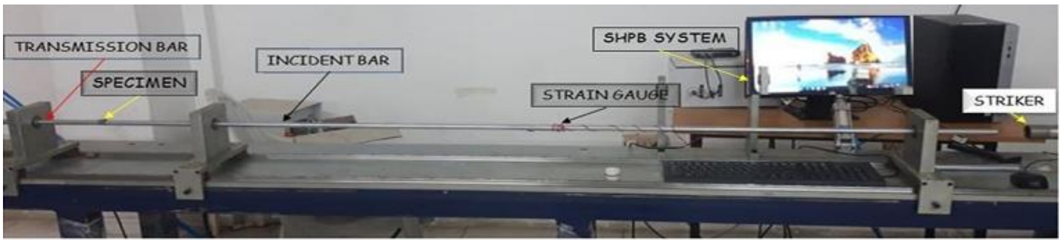

Fig: 2 Split Hopkinson pressure bar (SHPB) Apparatus

The test is conducted on 6 specimens, considering various pressure values such as 1, 1.5, 2, 2.5, 3, and 3.5. As per the test, the specimen under loading is subjected to the incident and transmission bars. The strain pulse wave propagation is shown in fig: 3. Before firing the striker bar, the pressure value must be set using the pressure valve, and locking the valve helps in maintaining the constant value throughout the test. This process of setting pressure value and hitting the incident bar by firing the striker bar with the help of the motor is continued with different air pressures and various specimens.

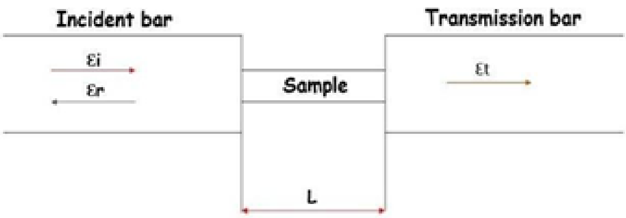

Fig: 3. Strain pulse diagram in shpb system.

The three bars in SHPB system are manufactured by maraging steel, with a young's modulus of 210 GPa, and a density of 8000 kg/m3. The stress, strain and strain rate of the specimen can be calculated by using following equation:

$$\sigma s = EA/\, 2As\, (\varepsilon i + \varepsilon r + \varepsilon t) \qquad - (1)$$
$$\varepsilon s = Ce\, /ls\, \int(\varepsilon i + \varepsilon r + \varepsilon t)dt \qquad - (2)$$
$$\varepsilon = d\varepsilon/\, dt = Ce\, /ls\, (\varepsilon i + \varepsilon r + \varepsilon t) \qquad - (3)$$

Where A and As is the sectional area of the bar and the specimen, respectively. E is the elasticity modulus. Ce is the velocity of the elastic wave in one dimension, and ls is the specimen's length.

2.3. Test procedures

An electronic universal testing machine (UTM 602, 4CAL SOFTWARE) was used in this work to conduct the quasi-static compressive tests at room temperature. Three repetitions were run through the quasi-static compressive test with the displacement loading set at 0.2 mm/min. During the test, the load-displacement curves were recorded, as seen in Fig.4

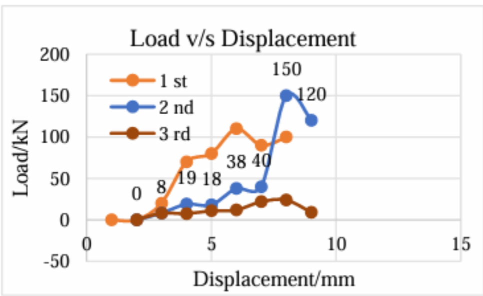

Fig: 4. Load-displacement curves in quasi-static uniaxial compression test.

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Dynamic compressive tests on the SHPB system were conducted. The motor's air pressure channel oversaw managing the pace of impact loading. To confirm the impact of strain rate, six specimens were examined at six different air pressures. And on each pressure test, three times to verify the similar impact rate.

3. RESULTS AND DISCUSSION

3.1. Strengths of Granite and Crack Propagation

The stress-strain curve of granite under various impact loading as determined by the SHPB tests is shown in Figure 5.0 (a) to (f). Two strain gauges were used in the test, which resulted in a strain rate range of 21 sec−1to 42 sec−1. As we can see, initially the stress in the material is increasing and reaching peak value at a low strain rate, and reaching low as the wave passes out from the transmission end. The experiment is evaluated under air pressures ranging from 1 to 3.5 MPa by controlling and locking the air pressure using the air compressor valve at the start of the test. To know more about the strain rate, the crack formation of the specimen is important, which is known as crack propagation. Since the pressure used varies from sample to sample, it is possible to see cracks in the specimen under high pressure. This indicates that as the applied air pressure is increased proportionally, the strain rate is also increasing, leading to more microcracks and specimen failure. That comes to the relation, failure of material is directly proportional to strain rate. Also, as the strain rate increases, we can observe an increase in compressive stresses, shown in Table 2.

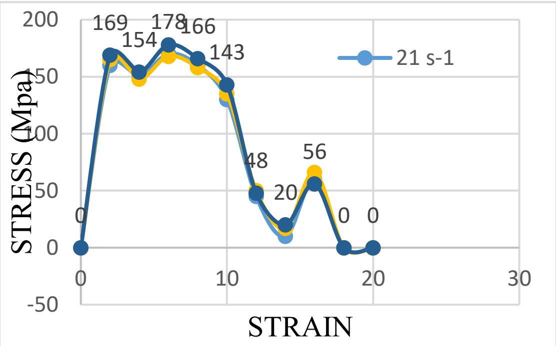

Fig. 5 .0 (a) Stress vs strain at 1 MPa

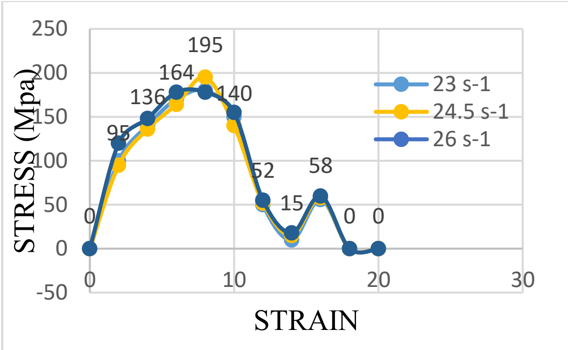

Fig. 5 .0 (b) Stress vs strain at 1.5 MPa

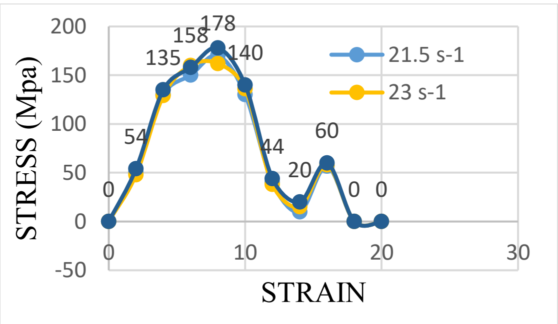

Fig. 5 .0 (c) Stress vs strain at 2 MPa

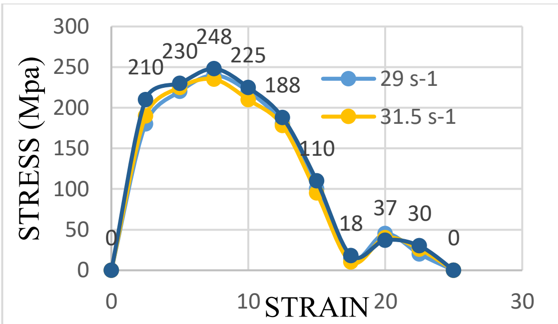

Fig. 5 .0 (d) Stress vs strain at 2.5 MPa

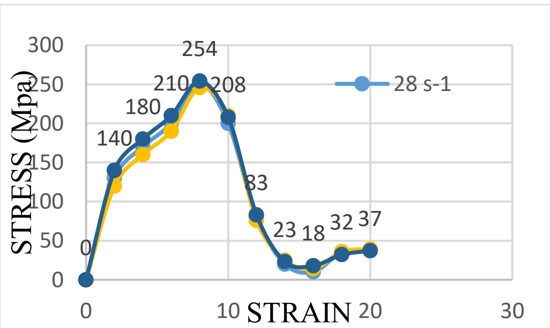

Fig. 5 .0 (e) Stress vs strain at 3MPa

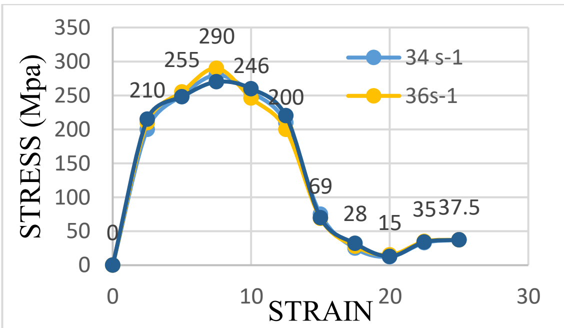

Fig. 5 .0 (f) Stress vs strain at 3.5MPa

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Fig 5 Dynamic stress-strain response in SHPB under different impact loadings: (a) 1MPa, (b) 1.5MPa, (c) 2MPa, (d) 2.5MPa, (e) 3MPa, (f) 3.5MPa.

Table 2: Mechanical characteristic results from the experiment.

No	Length/mm	Diameter/width mm	Impact loading/Mpa	Strain rate/ s-1	Strength/Mpa
1	16	32	Quasi-static	10	101.83
2	16	32	Quasi-static	10	105.3
3	16	32	Quasi-static	10	115.9
4	16	32	1	21	170
5	16	32	1	22.5	168
6	16	32	1	23.8	178
7	16	32	1.5	23	150
8	16	32	1.5	24.5	140
9	16	32	1.5	26	155
10	16	32	2	21.5	170
11	16	32	2	23	162
12	16	32	2	24.5	178
13	16	32	2.5	29	240
14	16	32	2.5	31.5	235
15	16	32	2.5	33	248
16	16	32	3	28	250
17	16	32	3	30	246
18	16	32	3	33.5	254
19	16	32	3.5	34	270
20	16	32	3.5	36	282
21	16	32	3.5	42	290

3.2 Fracture surface morphology

The specimens with breaks are passed through a SEM apparatus after the dynamic compressive strength test and quasi-static to assess how rapidly the fracture spreads throughout the specimen. Figures 6(a)–(d) show the emergence of fractures at grain boundaries as well as the emergence of a river pattern. This implies that fractures propagate across grains. The grains and borders become increasingly obvious as we raise the micron size. Images (e) to (h) show intergranular fracture along the grain boundary. Additionally, in Fig. 6(g), we can see that the rough surface has a tortuous structure and that the river pattern can be seen around the edges of the grain surface. We can conclude that the behaviour of granite fractures is rate dependent.

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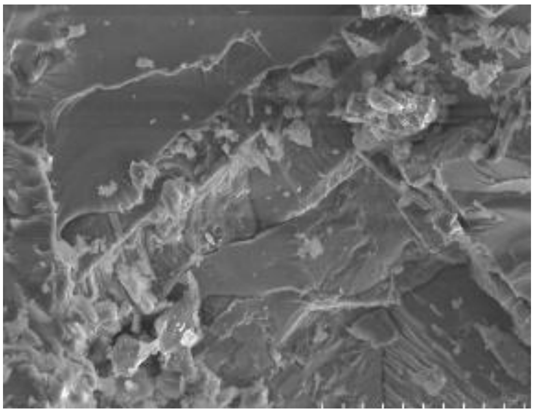

Fig 6 (a) 100 µm

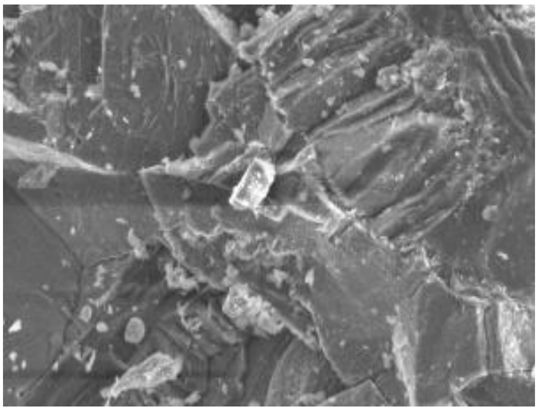

Fig 6 (b) 50 µm

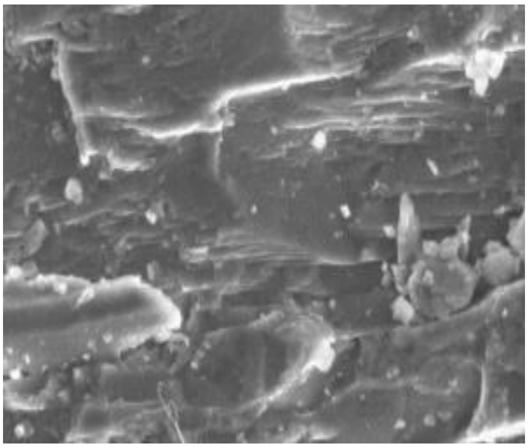

Fig 6 (c) 40 µm

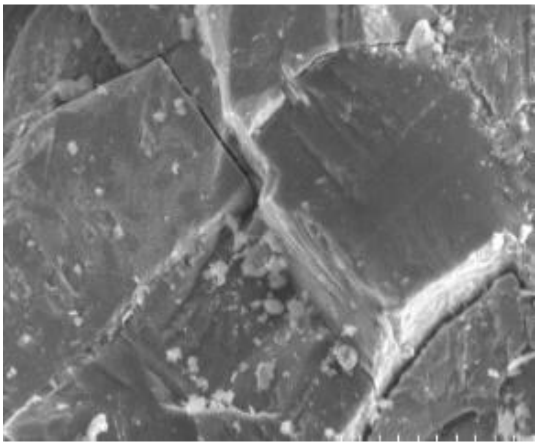

Fig 6 (d) 30 µm

From the pictures (e) to (h) we can see intergranular fracturing along the grain boundary. In addition, Fig. 6 (g) shows the remnants of a river pattern that ran along a grain surface corner and a rough surface with a tortuous form. We can infer that granite fracture behaviour exhibits rate dependence.

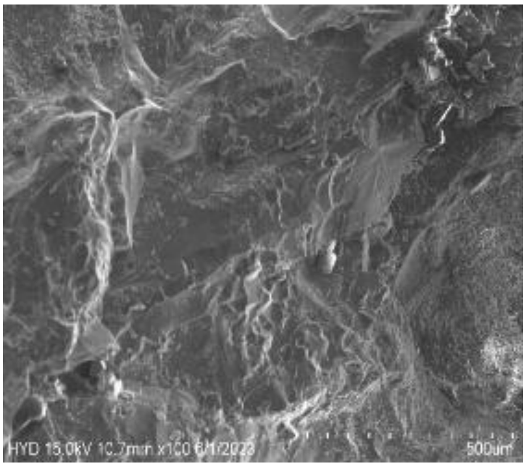

Fig 6 (e) 100 µm

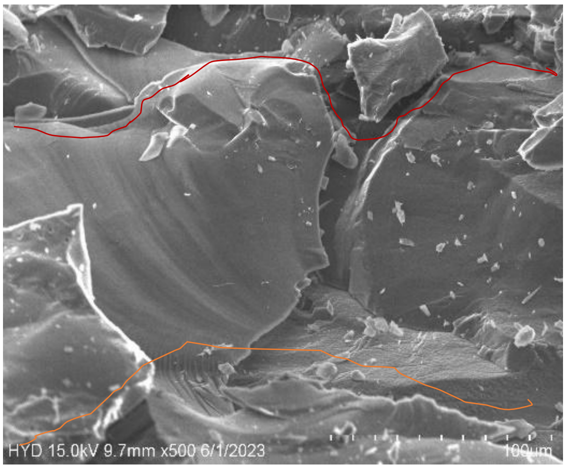

Fig 6 (f) 50 µm

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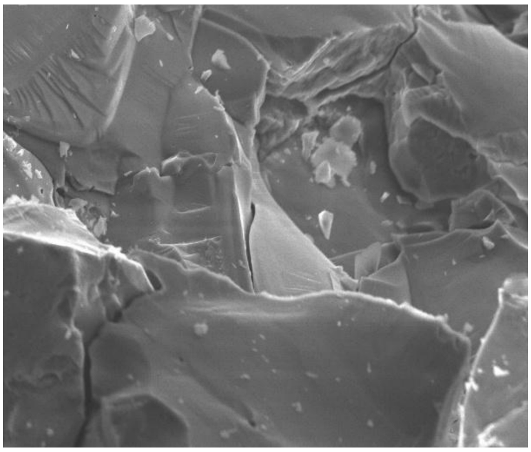

Fig 6 (g) 40 µm

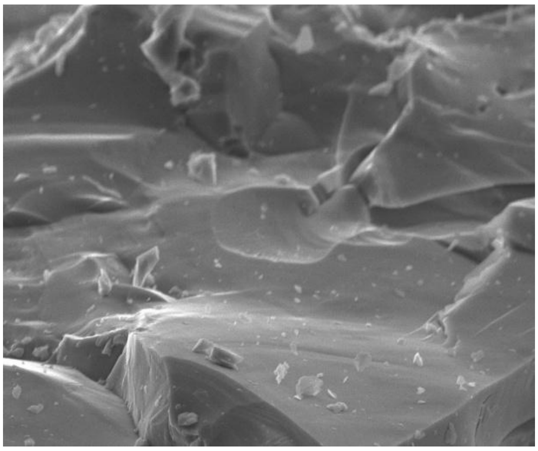

Fig 6 (h) 30 µm

Fig: 6 SEM images showing the surface of the fracture: (a)-(d) SHPB test (21 sec−1); (e)-(h) Quasi- static compression.

4. CONCLUSIONS

In this work, quasi-static and SHPB conducted a number of dynamic compression experiments to examine the compressive behaviours of granite. The fracture propagation and failure mechanisms of granite were observed based on the test results. The conclusions are as follows: 1) A substantial relationship between the final stress, material failure, and the strain rate has been observed. The ultimate compressive stresses in the material grow with an increase in strain rate, and the micro-cracks in the specimen exhibit a rising trend. This additional increase in strain rate causes the specimen to be crushed between the wave transfer bars.

2) In a quasi-static test, the specimen's granules are initially tightly packed together while the pressure is applied. However, after the granules have achieved their load-bearing capacity, the specimen fails with one big fracture at its weakest corner, and fracturing of the specimen is visible. In contrast, more microcracks were seen in the SHPB test during the dynamic compression test as the strain rate and impact load rose.

3) Granite's fracture behaviour is influenced by the strain rate. Under the dynamic compression test, the fracture surface was intergranular, and we can also observe a river pattern. Under high magnification, the cleavage steps of the specimen are seen clearly. Under the quasi-static test, we can observe intergranular fracture along the grain boundary, and while the specimen is subjected to high scope, a rough surface with tortuous shape was observed.

5. ACKNOWLEDGEMENTS

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6. DECLARATIONS

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