A NEW TESTING MACHINE FOR ACOUSTIC EMISSION DETECTION DURING TENSION

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ABSTRACT

A new testing machine is designed and constructed for detection of acoustic emission signals during material straining. The available testing machines are not suitable for this purpose the mechanical and the electrical noise of these machines are relatively high compared with the acoustic emission level. The experimental results conducted on aluminium alloy 7075-T6 fit very well with J.J. Gilman's theoretical model for mobile dislocations density.

INTRODUCTION

More than hundred years ago the universal testing machines were known.

Now these machines are widely used all over the world with different models, capacities and specifications. The loading system of the majority of these machines depend on power screw and electric motor.

Some investigators try to study acoustic emission phenomena during material straining, but the actual results were not reliable, that is because the mechanical and the electrical noise which produced from the loading system is higher than the normal acoustic emission signals. Attempts are made to built a testing machine with low noise, but it was bully and costly [1-3].

So to study acoustic emission phenomena during tension, it becomes important to design a new testing machine with very low level of noise as we can.

During the design and construction of the new machine different sources of mechanical and electrical noise were discussed and minimized and the main characteristics of this machine are presented in this paper.

Test is conducted, using the new machine, on aluminium alloy 7075-T6 to describe and explain the relation between Gilman's dislocation model [4,5] and the acoustic emission represented in the ring-down counting number.

THE NEW TESTING MACHINE

A photograph of the testing machine is shown in Figure (1). Figures (2-4) represents a general layout of the machine.

To solve noise problem, which is the main problem in acoustic emission detection, bouncy force technique was used. Two water tanks were used, the inner one (6) is filled with water to a prescribed level floats inside the outer one (5). Specimen clamp (9) was connected to inner tank through silk tape (18), nylon rope (17) and pulleys (8), which permit transmission and magnification of force. Once the water level inside the outer tank is dropped, the difference between the bouncy force and the weight of the inner tank give the required load.

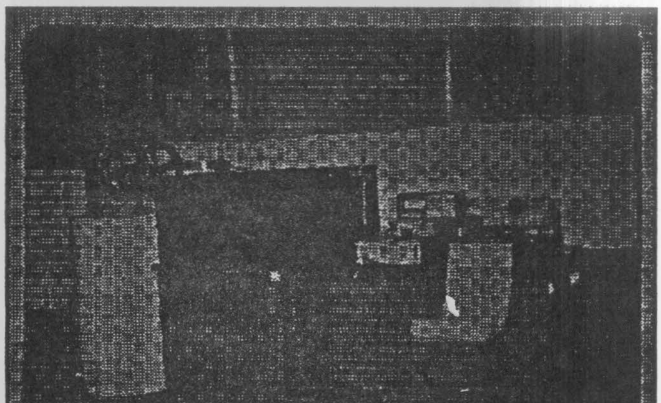
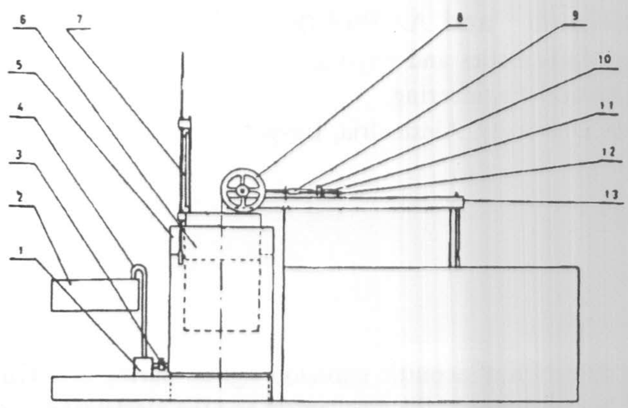
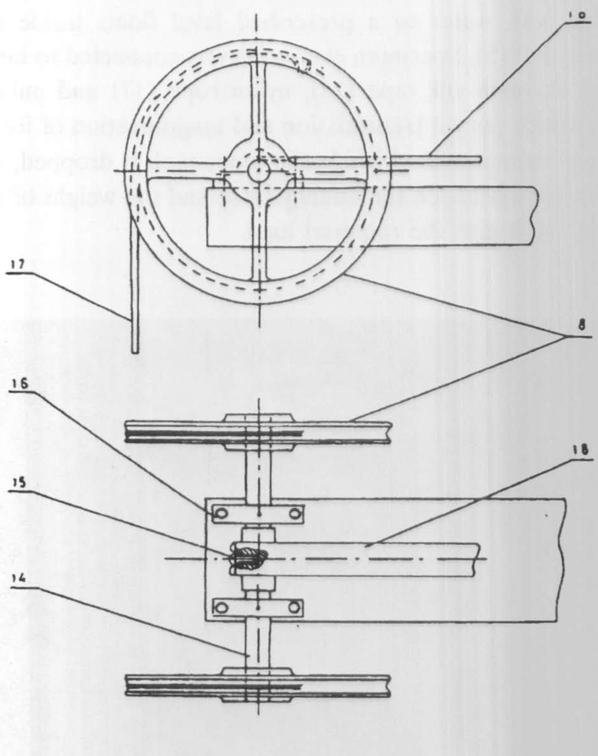


Figure 1. General view of the testing machine.



1 Water Pump
2 Water Sink
3 Valve
4 Flexible Hose
5 Outer Tank
6 Inner Tank
7 Resistance Wire
8 Two Pulleys Shaft
9 Free Clamp
10 Holder of Displacement Transducer
11 Fixed Clamp
12 Displacement Transducer
13 Chassis

Figure 2. Schematic diagram of the tensile testing machine.



14 Shaft 15 Bolt M7 16 Ball Bearing
17 Nylon Rope 18 Silk Tape

Figure 3. Force Amplification System.

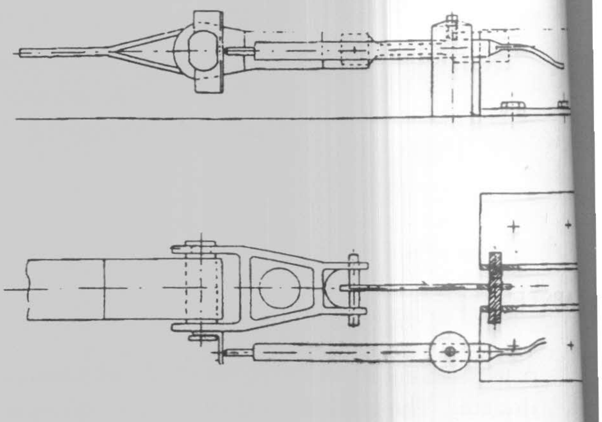


Figure 4. Specimen with clamps and strain transducer.

Force measurement system.

Figure (5) shows a scheme of the force measuremen[t] system which consists of, DC power supply, resistance R, level indicator (variable resistance) and recorder. The resistance wire was used as a potential divider, in which the voltage across the whole wire is constant and is determined by the value of the resistance of the wire and the resistance R. The voltage between A and C changes according to the water level in the outer tank.

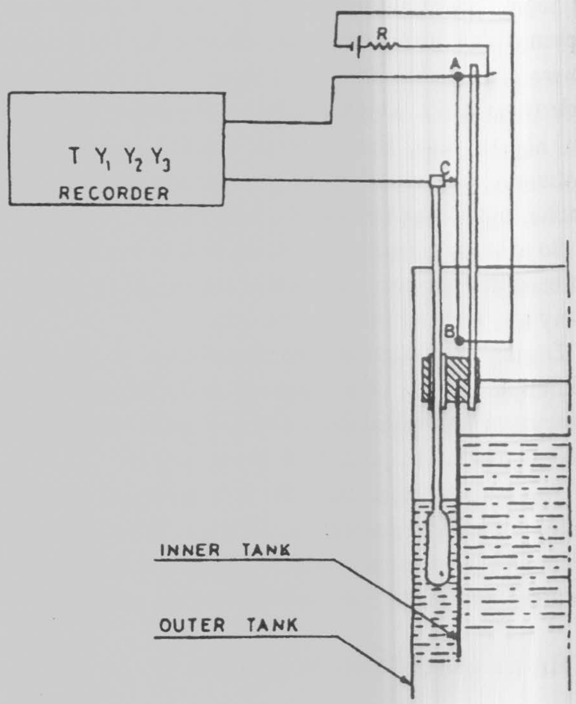


Figure 5. Force measurement system.

Displacement Measurement System

Figure (6) shows a diagrammatic layout of dilatation measurement system which consists of:
displacement transducer and bridge amplifier connected to T-$Y_1Y_2Y_3$ recorder.

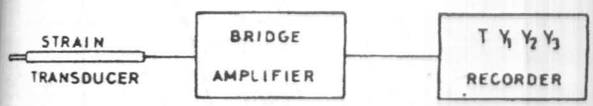
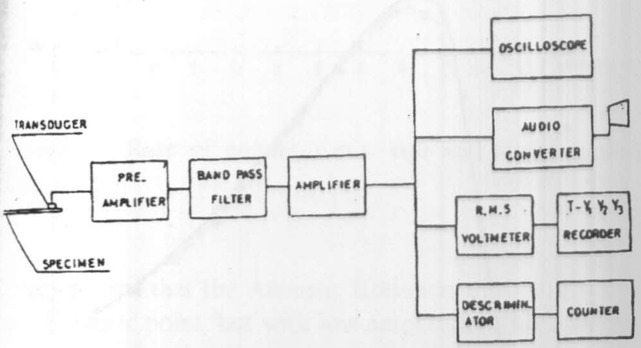


Figure 6. Block diagram of strain measurement system.

Acoustic Emission Measurement System

Figure (7) shows the black diagram of the acoustic emission detection and measuring system which consists of: 200 KHz PZT resonant transducer, preamplifier (40dB), band-pass filter, amplifier (to 60 dB) and a root mean square value converter or a discriminator and counter connected to the T-$Y_1Y_2Y_3$ recorder.



The main problem of any acoustic emission testing is noise. In this system it was decreased to a minimum by using the pre-mentioned loading system, teflon washers, between pins and specimen, rubber layer between clamp and chassis, nylon rope between tank and pulleys and silk tape between free clamp and shaft.

TEST SPECIMENS

Sheets of aluminium alloys of thickness equal to 2 mm were cut to pieces of dimensions 120×22 mm, then shaped to the final configuration as in Figure (8) by using a milling machine.

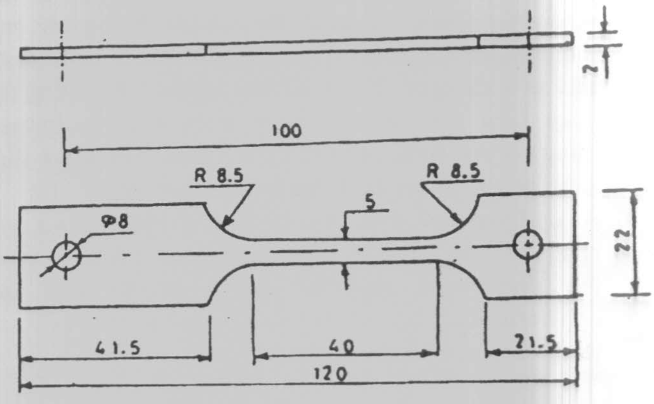


Figure 8. Specimen dimensions.

CHECKING THE TEST MACHINE

A special specimen (A) made from aluminium alloy with dimensions (4×20×40)mm, which is much thicker and wider than the normal specimen (2×5×40) mm was used. This specimen (A) was loaded with the maximum load for several times to check:

a) Friction noise.
b) Slip of loading system.

Friction noise

Normal tension test was conducted on test specimen (A) some acoustic emission signals appeared just before maximum load. By removing the load and repeating the tension test again, the acoustic emission signals vanished (this phenomenon was explained as kaiser effect) [6]. This means that all signals recorded in the first test resulted from the specimen itself and there is no effect of the background noise. To verify this conclusion, this test was repeated several times to be sure that there is no friction noise exists from the test machine.

Slip of Loading System

During the experimental tests on normal specimens, internal slips were observed clearly in some of these specimens under certain conditions. These tests were repeated several times and gave same results. In the mean time, verifying tests were applied to check the apparatus, these tests were conducted as follows:

a) The loading procedure was applied in a different manner. In normal tests, the filled inner tank was floated inside the outer tank then the water was discharged from the outer tank. Thus, changing the water levels inside and outside the inner tank. In the second loading procedure, water from both tanks was removed leaving some quantity in the outer tank which acts as a damper. The load was applied by filling the inner tank with water. These tests were performed using normal specimens (2×5×40) mm. The same slips were observed for both loading procedures.

b) A verifying test with special test specimen (A) was conducted. In this test, both loading system were used. No slips were observed which proves that the apparatus itself contributes no slip and all the recorded slips were due to the specimens only.

EXPERIMENTAL WORK

Material used

Test specimens used are made from 7075-T6 aluminium alloy with the following chemical composition:

SI = 0.50 % CU = 1.6 %
MN = 0.30 % MG = 2.5 %
CR = 0.30 % ZN = 5.6 %
AL = Remaining

The mechanical properties of this alloy are as follows:

Tensile strength	= 572	[MPa]
Yield strength	= 503	[MPa]
Elongation percent	= 11	[%]
Shearing strength	= 331	[MPa]

RESULTS AND DISCUSSION

Figure (9) is the record of the rms voltage, force and elongation to a time base, while Figure (10) shows the t total number of ringdown counts to the some time base.

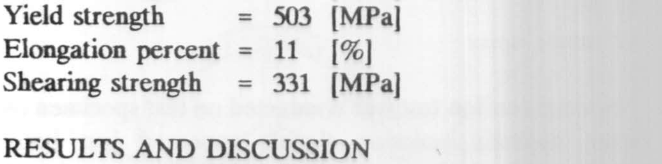


Figure 9. Force, elongation and acoustic emission root mean square volt against time.

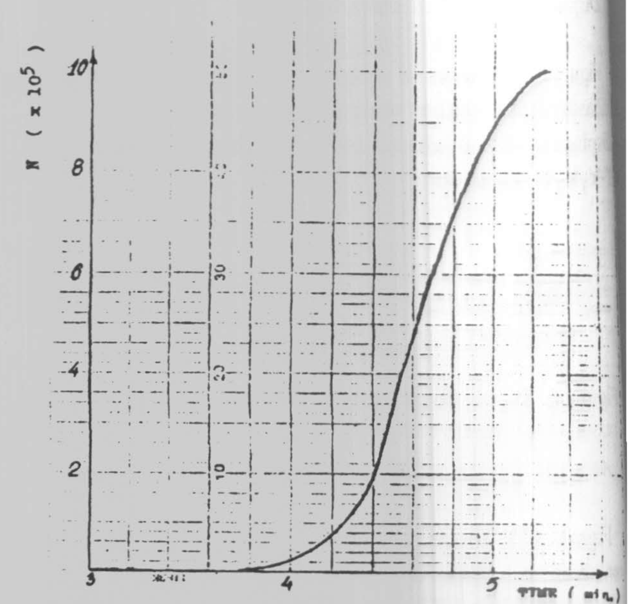


Figure 10. Summation of number of counts against time

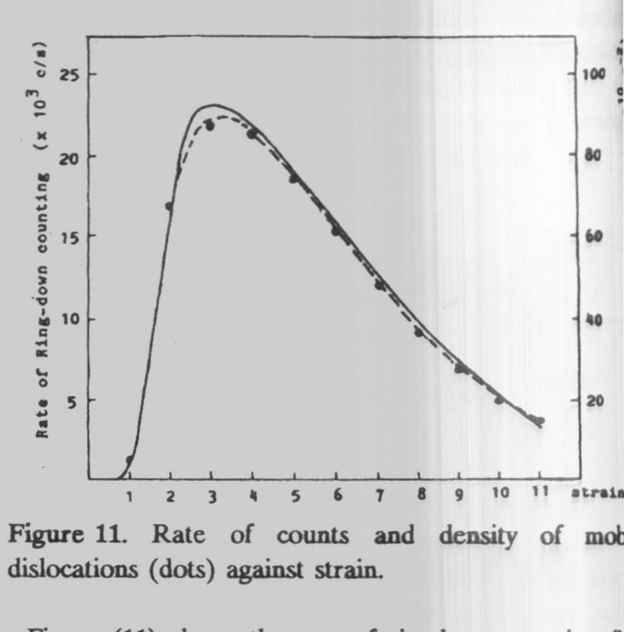


Figure 11. Rate of counts and density of mob dislocations (dots) against strain.

Figure (11) shows the rate of ringdown counting (N against the strain, drawn as solid line, while the dot line shows the mobile dislocation density calculated fr the Gilman's model [4]:

$$N(e_p) = M e_p e^{-\phi/e_p}$$

where,

$N(e_p)$ is the mobile dislocation density.
e_p is the plastic deformation.
M and ϕ are material constants.

The reported values of M and ϕ are 10^{-10} and 50 respectively. In the present work the constant ϕ takes the value 42, this is due to the use of different heat treatment. Figure (12) is the plot of vms volt, rate of ringdown counts (N^*), and the stress, against the strain. One can notice that Acoustic Emission starts near the yield point, while the vms voltage is started earlier.

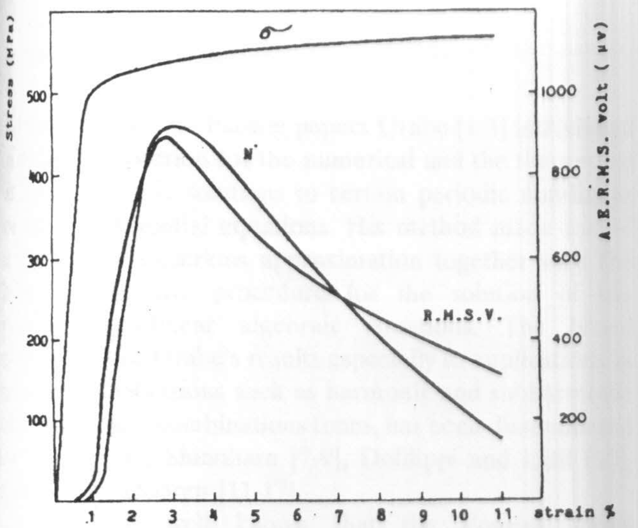


Figure 12. Rate of counts, r.m.s. volt and stress against time.

This proves that the Acoustic Emission starts at the end of the elastic point, but with low amplitude. This does not appear in the ringdown counting number because the number of counts are measured above the trigger level which is adjusted higher than the noise level. After the yield point is reached the Acoustic Emission (ringdown counting number and rms voltage) increases at high rate reaching a maximum value between 2 and 3% strain then decreases with lower rate till the fracture. Before fracture, the rate of ringdown counting decreases with higher rate than the vms voltage, this shows that the AE is of the burst type which gives low number and high rms voltage. Since it is proved [4,5,7] that Acoustic Emission is due to dislocation motion, the present work shows that during tension dislocation starts to move before the yield point with high number and low energy. After the yield point, the energy and number of mobile dislocations are increased to reach their maximum value, then due to the intersection of dislocation lines [8] the number of dislocation decreases, only dislocations of high energy can cross the barriers formed, these are low number.

CONCLUSION

The constructed machine is tested and proved to have very low noise. Tension test conducted on 7075-T6 Al alloy shows good coincidence between the rate of ringdown counts and the density of mobile dislocation. Comparison of the vms voltage and the rate of ringdown counts gives good idea about the movement and energy of dislocation during tension.

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