THE VALIDITY OF THE KAISER EFFECT IN ALUMINIUM ALLOYS

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ABSTRACT

The Kaiser effect was studied in the 2024-T3 Alclad aluminium alloy and found valid. During the load-hold-release cycle the acoustic emission root mean square voltage was monitored. No creep was detected at the constant load part as observed from the dilatation curve. At the beginning of the constant load part and during the release of load, some delayed acoustic emission was detected.

1. INTRODUCTION

Assurance of structural integrity requires extensive non destructive testing (N.D.T.) at various points in the fabrication process, up to and including a final proof test. Such N.D. inspection techniques as radiography, visual inspection, ultrasonics and eddy current measurement are generally time consuming and expensive, and often inadequate because of low resolution or operator error.

Catastrophic failure during proof tests has so many ramifications that nearly any technique of reducing the probability of such failure or of detecting or locating the critical defects during proof testing will be economically descriable. Acoustic Emission (AE) techniques offer this capability [1].

Great progress has been made in utilizing the A.E in assessment of structural integrity of pressure vessels, primarily in initial evaluation before they are put in service proof testing and continuous monitoring of a wide variety of structures can be visualized: structures such as pressure vessels for petroleum industries, pipe lines, aeroplanes, buildings, bridges and wooden beams [2,3].

During the initial testing it is reasonable to use one half of the design strength [5], the remaining cycles load-hold-release are scaled in regular increments from the maximum load as shown in Figure (1). During each cycle the acoustic emission is monitored. In the low stress cycles, no A.E. should be released. At higher stress level A.E. appears, but according to Kaiser [6] very little or no A.E. will occur until previously applied stress are exceeded. The Kaiser effect is the irreversible characteristic of dislocation motion and consequenty the A.E. phenomenon.

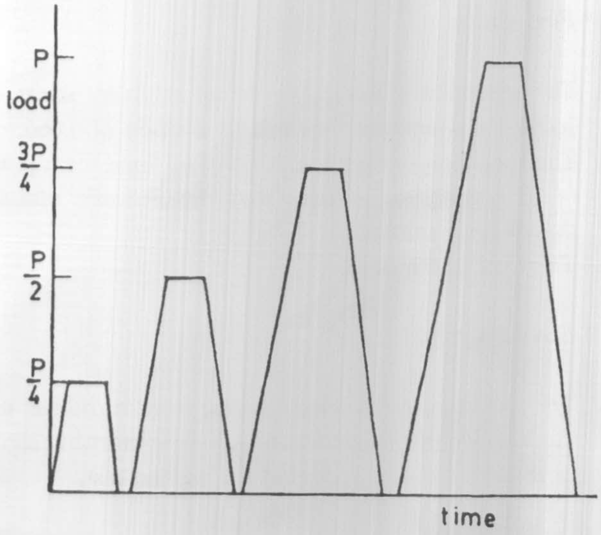

Figure 1. Load-hold-release cycles.

If the loading cycle is repeated with the same maximum load (stress), no A.E. Should be obtained if the Kaiser affect is valid for this material, otherwise there should be a crack growth in the material (or structure). The crack will cause A.E. during loading to the same previous load either due to decreasing the cross-sectional area or to the stress caused at the tip of the propagating crack.

Some investigators checked the validity of Kaiser effect, they found that it is not absolutely correct in some materials possessing stress relaxation or age hardening [6]. The aim of this work is to check the validity of Kaiser effect for 2024-T3 Alclad aluminium alloy due to its importance in industry, especially in aeronautical engineering.

2. EXPERIMENTAL TECHNIQUE

The machine used for tests, specimen preparation, as well as the measuring instruments are detailed elsewhere [7]

2.1 Test Procedure

Two tests were performed to check the validity of Kaiser effect on claded 2024-T3 aluminium alloy. Parts of these tests were designed to check constant load emission. The following gives the procedure for each test.

Test No. 1

This test is performed is two cycles:

* *First Cycle:*

1. The specimen is loaded up to an arbitrary stress, say 360M Pa, which corresponds to a strain of 0.066.
2. The specimen is kept under constant load for a period of 35 second to be sure that the acoustic emission signals are vanished.
3. The load is removed.

* *Second Cycle:*

4. The specimen is reloaded starting from zero level until the fracture of the specimen. Acoustic emission signals were detected and recorded during the test.

Test No. 2

This test is performed in three loading cycles:

* *First Cycle:*

1. The specimen is loaded up to on arbitrary strain, say 0.036
2. The load is kept constant for period of 50 seconds.
3. The load is removed.

* *Second Cycle:*

4. The specimen is reloaded again by the same loading rate, starting from zero level up to a strain higher than 0.036 (first cycle) and less than fracture, say 0.078.
5. The load is kept constant for a duration of 60 seconds.
6. The load is removed.

* *Third Cycle:*

7. The specimen is reloaded with the same loading rate till fracture.

Acoustic emission signals are recorded during the test.

3. RESULTS AND DISCUSSION:

The results obtained from test number 1 show that in part I of the first stress cycle, Figure (2), the acoustic emission follows the same form like in normal tensile tests which is due to dislocation motion [8].

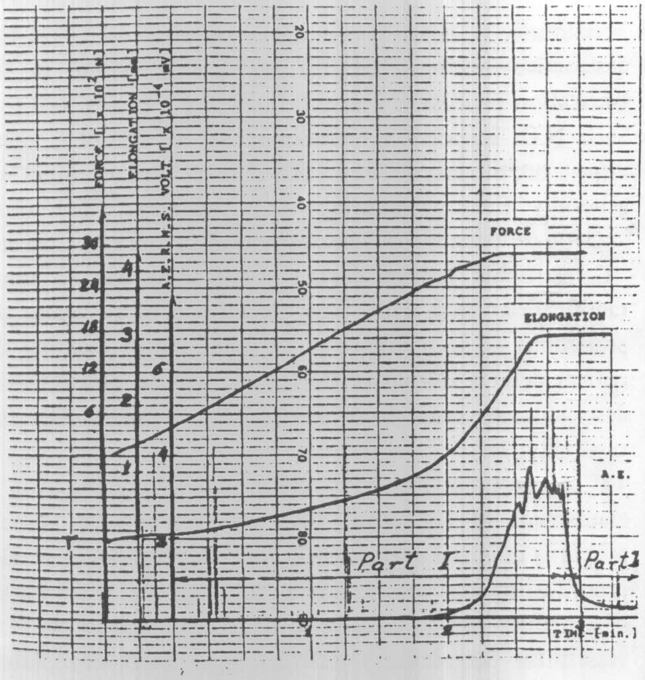

Figure 2.

In the second loading cycle Figure (3), section III, continuous acoustic emission starts to appear when the stress becomes higher than the maximum stress achieved in the first loading cycle which is 360 MPa, while the corresponding strain is 0.069. The difference between strain in the first cycle 0.066 and strain in second cycle 0.069, is probably due to strain hardening. Also it is reported [9] that stress strain curve is shifted to the right in the second loading cycle.

Test No. 2 was performed to verify the above remarks in addition to verifying the Kaiser effect. The applied loading procedure in this test was divided into three cycles. In the second loading cycle, no acoustic emission appeared till a strain level of 0.038 was reached. After that, continuous acoustic emission was detected. In the third loading cycle, no acoustic emission was recorded till a strain level of 0.08. After that, acoustic emission appears continuously till fracture. It should be noticed here that the strain level at which acoustic emission appears in the second and third loading cycles is greater than the maximum strains achieved in first cycle (0.036) and the second cycle (0.078) by about 0.002 which may be due to strain hardening.

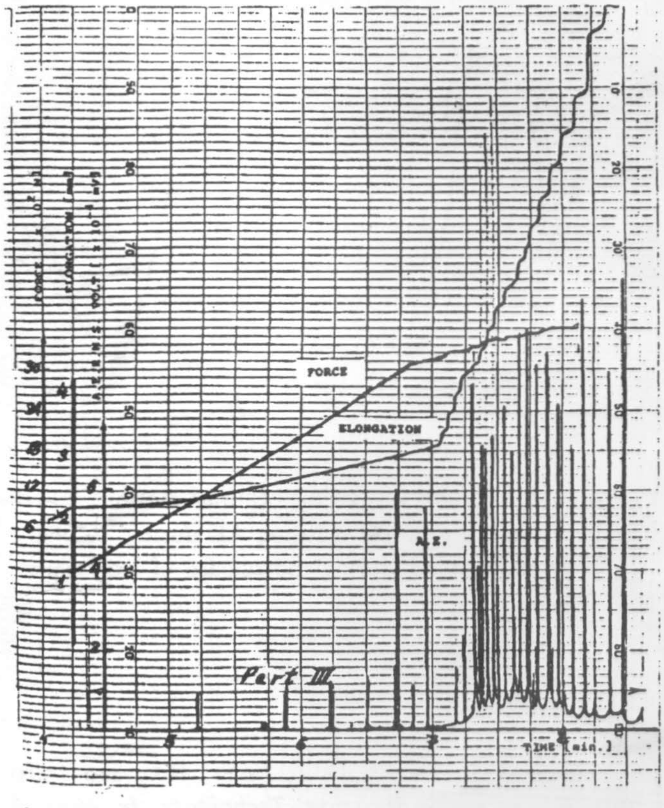

Figure 3.

The above observations support the argument that Kaiser effect exists in tests performed on 2024-T3 Alclad aluminium alloy.

Another important feature which was noticed from tests number 1 and 2 is that in the second and third loading cycles, the acoustic emission does not follow its known form [8]. Also, acoustic emission pulses were noticed after the first cycle.

Due to loading and unloading, the material is strain hardened [10]. As a result internal partial slips appear in the second and third loading cycles as seen from the delation curve, as seen from the delation curve. These slips produce pulses in acoustic emission. This is why, the recorded acoustic emission during tests number (1) and (2) is smaller than that registered in the test conducted on the same alloy under normal procedure of loading [8].

4. CONSTANT LOAD EMISSION:

Certain metals exhibit a prolonged decaying emission under the effect of uniform loading. Dunegan and Harris [11] observed this effect in beryllium and attributed it to room-temperature creep. This phenomenon was also observed in tests 1 and 2 as shown in Figures (2), (4) and (5).

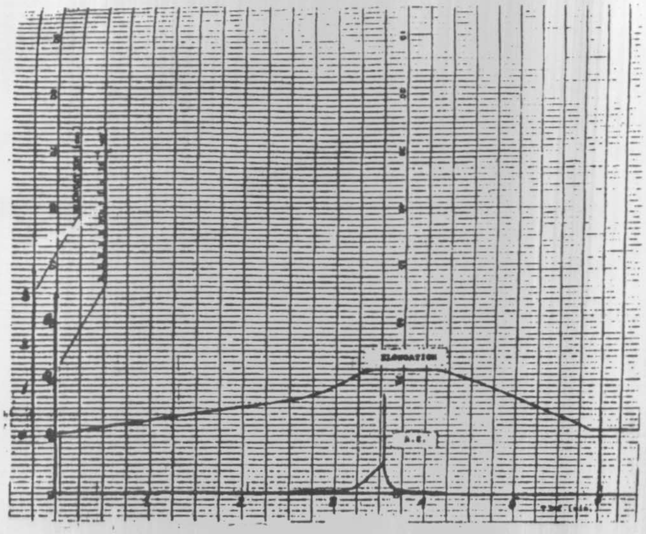

Figure 4.

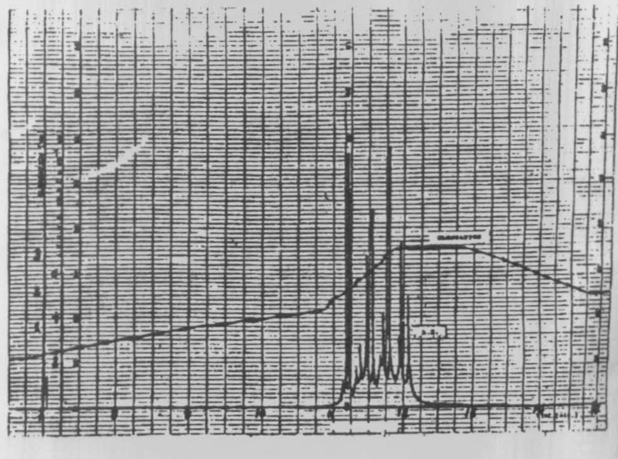

Figure 5.

K.H. Adams and others [12] found that the emission rate of beryllium decays exponentially. For 2024-T3 Alclad aluminium alloy, it was found that the emission decays with the same trend like beryllium. This might be due to the inertia of the accelarated dislocations which take time to rest in their new stable positions causing delayed AE.

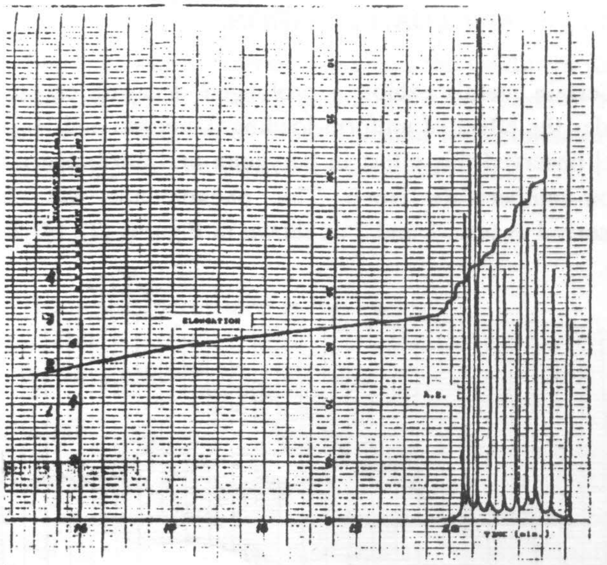

Figure 6.

5. CONCLUSION

Three types of AE were recognized during the lood-hold-release cycles carried on the 2024-T3 Alclad Al. alloy:

1- During the first loading cycle, continuous AE is released due to the motion of dislocations, this starts at the yield point.
2- At the beginning of the constant load part, the delayed AE is due to the inertia of dislocations which were accelarated at the end of the loading part.
3- Unloading emission: Dislocations gain energy during loading. If this energy is enough and the energy barriers are not so high, they will jump the barriers to reach their low energy stable positions, Figure (7-a). If the energy barriers are high enough, some dislocations cannot jump and are in the high energy levels. When the load is released they return back to their positions causing the unload emission, Figure (7-b).

Also it is concluded from the results represented in this paper that the Kaiser effect is valid for 2024-T3 Alclad Aluminium alloy.

The results can be made use of in many applications, for example:

(a) The acoustic emission characteristic of certain element, during its straining, as a function of strength is found first, then an acoustic emission detection system with comparator and alarm system is introduced to the element under consideration. Once the element subjects to a stress near certain limit the alarm system activates. An example for this situation is offshore plateform.

(b) It can be used to detect accurate values of previously applied loads on parts of certain system which is difficult to test under real situation. This is the case for some parts of aircrafts during flying or during emergency arrestments.

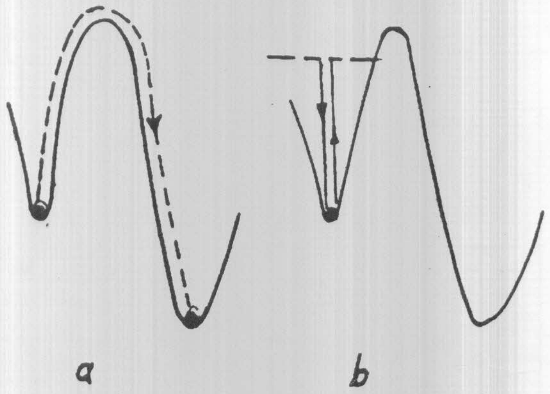

Figure 7. The probability of dislocations motion.
a- They jump the barrier causing AE during loading.
b- They return back during the release of load causing unload AE.

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