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An Experimental Study on Ratcheting Behavior of Polyacetal Tube Under Uniaxial Ioading and Internal Pressure

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ABSTRACT

In this study, the experimental tests are designed and carried out to analyze the behavior of polyacetal ratcheting under both uniaxial loading and internal pressure. Experimental tests are performed by an accurate servo-hydraulic machine, Instron 8802. Three group tests were presented in which two of the stress amplitude, mean stress or internal pressure was constant to observe the effect of another factor. The effect of stress amplitude, mean stress and internal pressure on ratcheting strain and softening behavior of the polyacetal tube are investigated. Graphs of ratcheting strain, ratcheting strain range, hysteresis loops of group tests were drawn. By using these graphs, some results such as softening behavior obtained. A suitable hardening factor was presented and its relation with the polyacetal fatigue life was examined. In a specific loading cycle for the specimen, whose hardening factor is more than the others, a lower fatigue life predicted. Softening behavior of the material, increases with increasing the loading cycles. The results show that the specimen with the high ratcheting strain value has lower fatigue life.

KEYWORDS

Ratcheting Strain, Polyacetal, Internal Pressure, Experimental Test.

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1- INTRODUCTION

Engineering structures are usually under cyclic loadings. Fatigue cracks can be initiates and propagate with cyclic loadings and then ends to failure. Ratcheting is a phenomena that the materials are under stress-control cyclic loadings with non zero mean stress. Ratcheting in a structure can create sooner failure. Because of the importance of ratcheting, many researchers studied about it. Xia in 1996, studied the effect of mean stress with ratcheting strain on the fatigue life[1]. Shariati and et. all studied the ratcheting behavior of polyacetal under axial loading experimentally[2,3]. They also carried out some researches on ratcheting of steels and their softening behavior numerically and experimentally[4]. In this study the effect of stress amplitude, mean stress and internal pressure on ratcheting strain and softening behavior of the polyacetal tube are investigated. A suitable hardening factor was presented and its relation with the polyacetal fatigue life was examined.

2- TECHNICAL WORK PREPARATION

For supplying the experimental specimens, the polyacetal bars with 40 mm diameter has been used. Specimen gauge length is 50 mm and its internal and external diameters are 25 mm and 20 mm respectively.

For experimental tests is used a servo hydraulic machine Instron 8802 is used. This device has the ability to apply 250 kN. Stored data are force and displacement with the accuracy of ±1N and 0.01 mm. For internal pressure a hand hydraulic pump was used. A pressure gauge and a hydraulic valve are used to reach the desired pressure. In order to maintain a constant internal pressure, an accumulator is used. Due to the continuous changing the load, the volume of specimen is also changed. The changes in specimen volume, changes the internal pressure. Then, an accumulator is used to overcome this problem.

According to the standard ASTM E8-03, the quantities of Young's module, yield stress and yield strain are evaluated. These values are as shown in table (1).

Table (1): Mechanical properties of Polyacetal

Mechanical properties	Tension
Young's module (E)	**MPa 3100**
Yield stress (σ_y)	**MPa 38.19**
Yield strain (ε_y)	**1.57 %**

All experiments are carried out under stress-control conditions and the constant temperature (room temperature). Ratcheting is related to the rate of loading. On the other hand, high rates of loading, raise the specimen temperature and then change the mechanical properties of specimens. So the loading rate is set to 8kN/sec to have a suitable condition and constant temperature.

To investigate the effect of mean stress, stress amplitude and internal pressure, experimental tests are divided into three groups: GT1, GT2 and GT3. In each of these groups, just one of mean stress, stress amplitude or internal pressure values is constant and other conditions are variable. The effects of these parameters can be seen in each experiment.

During each test, the forces and displacements data applied to specimens are recorded. On the basis of these quantities, the analysis for the mechanical parameters such as strain ratcheting, hardening factor, hysteresis loops, ranges of ratcheting strain are carried out.

Cyclic deformation led to the creation of a hysteresis loop for each cycle loadings. Stress - strain hysteresis cycle loops in specimen SP1 is shown in Fig.1. In experiments that ratcheting strain is existed, the hysteresis loop is not close. This shows the accumulation of strain by increasing the cycles and is the concept of ratcheting strain.

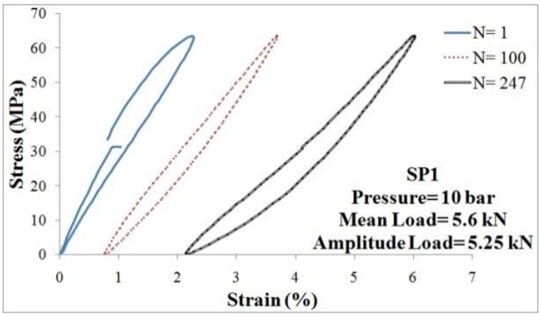

Fig.1: Stress-strain hysteresis loop of SP1 specimen.

It is observed that with increasing the number of cycles, more strain changes in each loop. Increasing strain range shows softening behavior of the material.

Ratcheting strain is the average of minimum and maximum strain such as:

$$\varepsilon_r = \frac{1}{2}\left(\varepsilon_{\max} + \varepsilon_{\min}\right) \qquad (1)$$

In a specific cycle, the specimen with greater ratcheting strain, has the less fatigue life.

Each hysteresis loop has a certain geometry that the width on horizontal axis is range of plastic strain $\Delta\varepsilon^p$ and the height on vertical axis is range of the stress $\Delta\sigma$ [5].

The stress amplitude is related to elastic strain by linear Hook's law. The hysteresis loop's shape can be expressed by the ratio of plastic strain range $\Delta\varepsilon^p$ to elastic strain range $\Delta\varepsilon^e$ that is called strain ratio (SR):

$$SR = \frac{\Delta\varepsilon^p}{\Delta\varepsilon^e} \qquad (2)$$

Total strain range $\Delta\varepsilon$ is the sum of plastic strain range and elastic strain range. So for a specific Young's module, stress range $\Delta\sigma$, total strain range $\Delta\sigma$ and strain ratio (SR) of a hysteresis loop are as below:

$$\Delta\varepsilon^p = \Delta\varepsilon - \Delta\varepsilon^e \qquad (3)$$

$$SR = \frac{E\Delta\varepsilon}{\Delta\sigma} - 1 \quad (4)$$

Hardening factor (H) is the ratio of strain ratio at the specific cycle SR_s to strain ratio at the first cycle SR_1 .That means:

$$H = \frac{SR_s}{SR_1} \quad (5)$$

For hardening material, H>1 and for softening material, H<1.

According to fig.2, it is clear that the specimen with larger value of hardening factor shows more softening behavior and less fatigue life. So at the definite cycle in some specimens, by calculating hardening factor, fatigue life is predictable if the value of hardening factor is greater than the others.

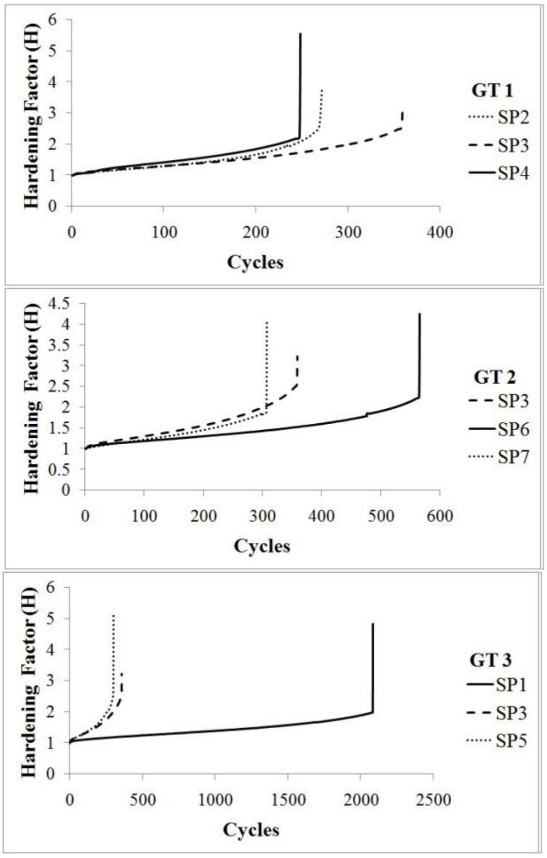

Fig.2: Hardening factor of GT1 to GT3

3- CONCLUSION

In this study, the stress controlled tests at the ambient temperature of the laboratory were carried out on specimens of tubular polyacetal. Tests have been done by Instron 8802 servo-hydraulic machine with different mean stress, amplitude stress and internal pressure. Behavior of ratcheting strain, the slope of hysteresis loop and hardening factor were studied. Some results are:

The specimen with more ratcheting strain has less fatigue life.

Increasing in mean stress and amplitude stress value, decrease the fatigue life.

The effect of the mean stress on ratcheting behavior is greater than the amplitude stress.

According to fig.2 the specimen with less loading value, has greater hardening factor, this means more softening behavior.

More softening behavior results in less fatigue life.

Softening becomes greater as the cycle numbers increases.

At any cycle, the specimen with 30 bar internal pressure has more ratcheting strain value and less fatigue life.

4- REFRENCES

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