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Geometric Optimization of Ultrasonic Fatigue Test Specimens Based on Thermo-Elastic Behavior

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ABSTRACT: Nowadays, the number of oscillations applied to some parts reaches the range of 107 and higher. Recently, researchers have used ultrasonic fatigue tests to study the fatigue behavior in these parts. This device is considered because of the high frequency of loading and as a result, achieving a higher number of oscillations in a shorter time. There is no universally accepted standard for this test, therefore, one of the geometries that are often used as a sample in this test is the geometry in the form of an hourglass In this research, while investigating this geometry in order to achieve optimal geometry or achieve maximum stress, the effect of geometric parameters on temperature increase during high-frequency vibration or the thermoelastic effect, which is known as one of the disadvantages of ultrasonic fatigue testing, has been investigated. This effect should also be minimized. For this purpose, the dimensions of the hourglass geometry were defined as parameters and its changes were investigated using the simulation. The results showed by decreasing the radius of curvature, along with the stability of the middle diameter and the diameter of the cylindrical part, the amount of stress increases and also the amount of temperature changes decreases. On the other hand, the diameter of the cylindrical part increases, while the middle diameter and the amount If the curvature is constant, it will increase the amount of stress and temperature. The above results were evaluated using the experimental arrangement and a good match was observed in them.

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1- Introduction

In addition to its advantages, the ultrasonic fatigue testing device also has disadvantages. One of the problems in the fatigue testing machine is the heat generated in the sample [1]. Among the measures taken to solve this problem is the use of the cooling system or the use of the device in an on-off cycle [2-6]. So far, in the search conducted by the authors of this article, no research has been done in the field of optimizing the geometry in order to reduce this generated heat. In this research, the geometry of the fatigue test sample is investigated with regard to the role of its geometric parameters in providing the desired stress, and on the other hand, the temperature behavior of the sample is investigated from the point of view of the thermoelastic behavior, so that the sample can be in the optimal state in terms of stress and heat.

2- Methodology

Fig. 1 shows the geometry of the hourglass-shaped sample and its geometrical parameters, so according to the flow chart presented in the figure, the design process is carried out to achieve the amount of stress and heat produced in the sample.

3- Results and Discussion

In Fig. 2., we can see the decreasing trend of stress for increasing *R* in *H* at constant *r*, on the other hand, it can be seen that increasing the diameter of the cylindrical part (*H*) while the middle diameter is constant causes an increase in stress. It can also be seen in Fig. 2, part b, that the trend of changes in *R* and temperature is parabolic, and the minimum values of temperature are obtained in minimum *R*. Also, by increasing the values of *H*, we will see an increase in temperature by increasing the values of *R*.

After examining about 200 cases resulting from permuting the parameters, two optimal states were obtained according to the amount of stress and heat for two middle diameters of 3 and 5 mm. These values are also seen in Table 1.

In order to create real test conditions to perform this test, the device developed at Kashan University [7] was used, thus first two optimal samples obtained from the simulation results were made, then by using a thermocouple connection, the temperature conditions and the amount of temperature increase in 10 microns of vibration was obtained during application. As shown in Fig. 3., the initial temperature for the samples is equal to 19°C and after applying vibration and reaching a stable temperature, the increase is 20°C and 29°C

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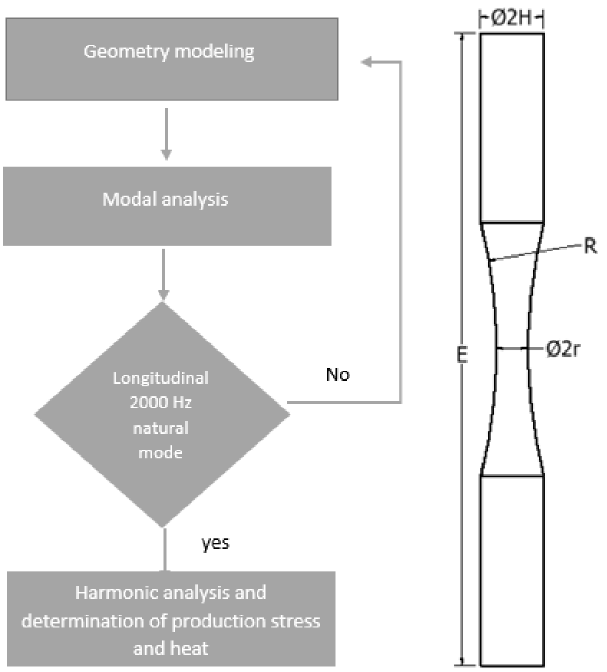
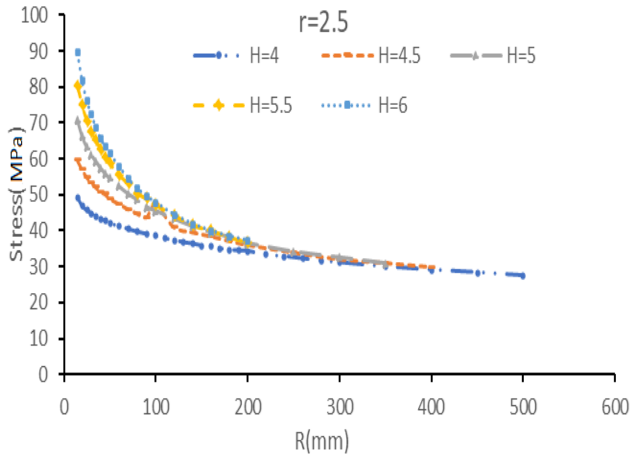


b a

Fig. 1. A- parameters considered in hourglass shape geometry. B - Flowchart of checking and selecting of stress and heat produced in the sample



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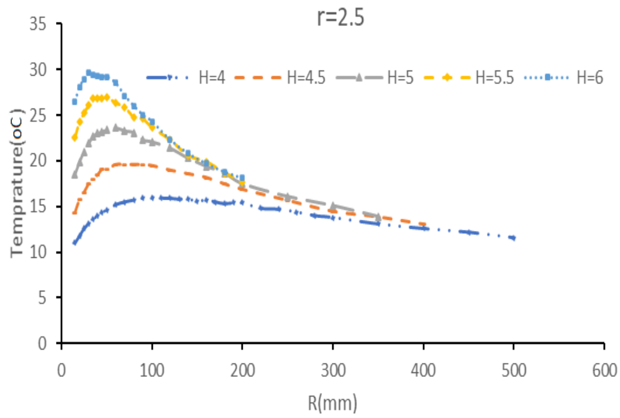

b

Fig. 2. Investigating changes in stress and temperature at constant r for different values of H compared to R

Table 1. Values of stress and heat production in two optimal samples and their geometrical parameters

T (°C)	*S*(MPa)	*E*(mm)	*R*(mm)	*r*(mm)	*H*(mm)
28.1	105.03	86	15	1.5	4
18.5	70.8	101	15	2.5	5

respectively, which is in good agreement with the obtained results that come from simulation.

4- Conclusions

In this research, the following results were obtained:

- The thermo-elastic behavior of the ultrasonic fatigue test sample was simulated.

- By reducing the radius of curvature (*R*) along with the constant middle diameter (*r*) and the diameter of the cylindrical part (*H*), the amount of stress increases, and also the amount of temperature changes decreases.

- By increasing the length of the sample (*E*) at constant R, the stress increases, and in general, with the decrease of *E* in all values of *R*, the effects of temperature increase will decrease.

- Increasing the diameter of the cylindrical part, while the middle diameter and the amount of curvature are constant, causes an increase in the amount of stress and temperature.

- The experimental results are in good agreement with the simulation.

The findings of this article can be used in designing the geometry of the ultrasonic fatigue test sample. In order to reduce the harmful effect of temperature increase, In the design phase, the geometry of the sample should be designed in such a way that, while having test conditions in the form of an ultrasonic fatigue test device, it also achieves the maximum stress while reducing the temperature increase.

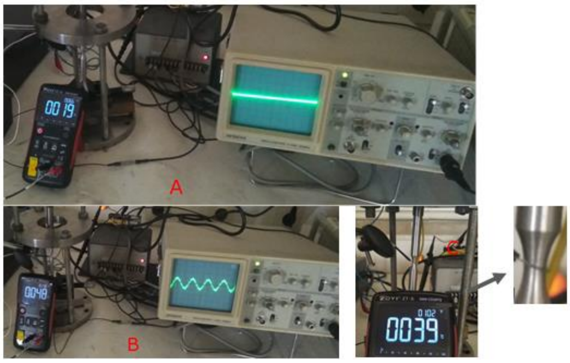

Fig. 3. A- The arrangement of the experimental test has been done in order to verify the simulation (the observed temperature is the temperature before the oscillation). B - The stable temperature of the smaller sample (middle diameter 3 mm) C - The stable temperature of the larger sample (middle diameter 5 mm)-Larger view and connection method of Thermocouple to sample-

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