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Fatigue Testing of Polymeric Hollow Fibre Heat Transfer Surfaces by Pulsating Pressure Loads

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Abstract: This article deals with the fatigue tests of polymeric hollow fibre heat transfer surfaces. Hollow fibres have an outer diameter around 0.5-0.8 mm and thickness of the wall is 10 % of the outer diameter. These heat transfer surfaces made from plastics have some limitations but also a lot of benefits. One of the limitations is durability of plastic under fatigue loading. The heat transfer surfaces were subjected to pulsating pressure loads under different conditions (level of pressure, ambient temperature, number of cycles). Firstly, just the pulsating load was applied and the behaviour of hollow fibres was observed paying special attention to the presence of a leaking, rupture, etc.

Then some other conditions of operations were added. The heat transfer surfaces were immersed in a hot bath and loaded by pulsating pressure and high temperature simultaneously. Testing under the different temperature is important because the temperature significantly affects the material properties. The presence of the leaking, rupture and other possible damage was monitored as for previous tests.

Introduction

Service life is a very debated topic nowadays. It is necessary to guarantee a lifetime of every technological device. The prototypes of polymer heat exchangers consisting of many polypropylene hollow fibres are under development for hot-water applications. The working conditions will be: temperature around 80 °C and gauge pressure 0.35 MPa. Prototypes of polymeric heat exchanger developed in our laboratory need such kind of tests too. For more details see [1,2].

Stress in the wall

The aim of fatigue tests is simulation of operation conditions. In this particular case the hollow fibres were loaded by the internal pressure p = 0.35 MPa and the period of the pulse was T = 1.4 s. The parameters of fibres were the outer diameter d = 0.5 mm (respectively 0.8 mm), and wall-thickness was 10 % of the outer diameter, thus w = 0.05 mm (respectively 0.08 mm).

The important factor is the strain inside the wall of the fibres. There are two types of strain in the fibre, the hoop stress, and the axial stress. The hoop stress is obtainable from the following relation $\sigma_\theta = \mathrm{pd}/2\mathrm{w}$. In the case when two ends of the fibre are constrained the axial stress is obtained as $\sigma_z = \mathrm{pd}/4\mathrm{w}$.

From the previous equations it is obvious that the stress depends on the internal pressure p and the ratio of the parameters of fibre d/w. The dependence of the ratio σ/p on the ratio d/w is possible to see in Fig. 1.

In the measured cases was the ratio always $\mathrm{d}/\mathrm{w} = 10$. Hence, the hoop stress was $\sigma_\theta = 1.75$ MPa and the axial stress was $\sigma_z = 0.875$ MPa under the corresponding pressure p = 0.35 MPa.

Fatigue tests

Tests with prototypes of heat exchangers were run for both outer diameters, 0.5 mm and 0.8 mm under the above specified conditions (p, T, w, d). The connection method was constructed as follows: the

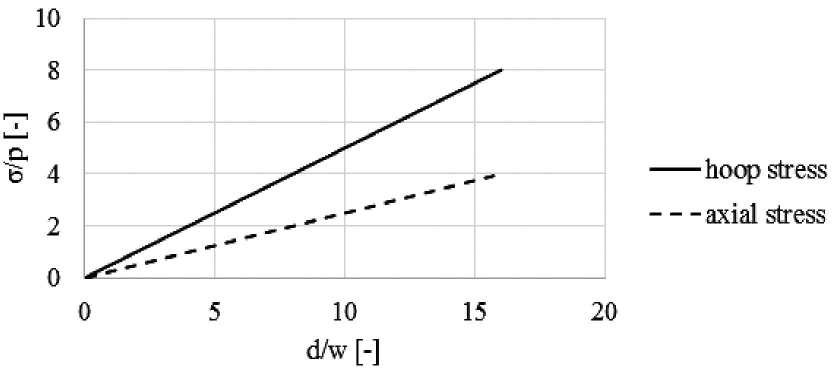

Fig. 1: The dependence of the ratio stress in the wall σ and pressure p on the ratio of the diameter d and wall thickness w of the fibre.

pressure reduction valve at the input, the water filter followed and then the system of two electromagnetic valves between which were the hollow fibres. Behind the second valve was the output to the drain. The test was done at room temperature. The system of valves was controlled in the following sequences: the input valve was open and the output valve was closed. The pressure inside the fibres reached the level of 0.35 MPa and the input valve was closed. When the pressure has stabilized, the output valve was opened and the pressure inside the system dropped. After that the output valve was closed and the input valve was again opened and then the whole process was repeated. Typical results are shown in Fig. 2. The test was stopped after more than 1.5 millions of successful cycles. Fibres showed no signs of damage. The next step are tests in a hot bath.

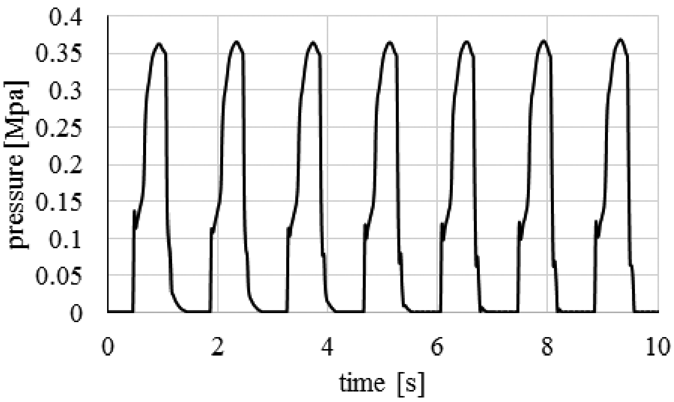

Fig. 2: The pressure profile during the test.

Conclusion

The tensile stress (yield) for the used material of hollow fibres is 35 MPa. The hoop stress reached in the wall of fibre is 1.75 MPa which is only 5 % of the yield stress. Hence, fibres are working in a safety zone but a creep can occur in a long time loading. This is why more tests has to be done.

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