EXPERIMENTAL ANALYSIS OF THERMALLY INDUCED MOTION OF U-TUBES

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Abstract. The present article focuses attention on the effect of thermal load on dynamic response of the thin U-tubes. Experimental studies are carried out on thermally induced vibration of internally heated cantilevered U-tube. The dynamic response of the tube is studied in lateral and transverse direction for varying heating rates and frequencies. The analysis showed that the rate of vibration is governed by the heating rate and natural frequency of the tube. Lower the heating rates larger are the time to attain steady state amplitude and vice versa, there exist a threshold heating rate to produce thermal induced motion for tube. Displacement response of the U-tube in the lateral direction, during the initial period of the tube motion, occurred in the first mode and with progress of time the displacement response changed to second mode with amplitude of vibrations being lower than that observed in first mode.

Keywords: thermally induced vibrations, internally heated U-tube, dynamic response, lateral and transverse displacement

1. Introduction

Thin walled small circular tubes are widely found in various structural engineering applications, for example boom type antennas used on satellites, heat exchangers etc. In the present study attention is focused on the effect of thermal load on the dynamic response of thin tubes. Thermal load is likely to arise due to heating of the structure by constant exposure to heat source, passage of electric current or sudden exposure to very large amount of heat, sudden temperature changes

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encountered by satellite structures at day-night or night-day transition in the orbit, etc. The first paper to address thermally induced vibrations was by Boley[1]. Beam[2] of NASA Ames demonstrated unstable thermally induced oscillations in the laboratory. The experiment was performed using a 3 ft long boom fixed at one end with an attached mass at the other end. Beam[2] demonstrated through experiments, thermally induced vibrations in beams due to radiant surface heating. The first published experimental data on thermally induced vibrations due to internal heating was by Baker and Mikina[3], in their article they mentioned that the thermal vibrations occur under so varied conditions that they cannot be normally controlled but can be prevented from building up by using some form of damping. Blandino and Thornton[4] have reviewed the contributions of various researchers to study thermally induced vibrations. They also carried out detailed theoretical and experimental studies on the thermally induced vibration of single tube caused by internal heating. The results from the theoretical model agreed very well with the experimental data. The authors have carried out theoretical study on thermally induced motion of internally heated tube with tip mass[5]. The main objective of present article is to carry out experimental investigations on the dynamic response of the internally heated vertical tube bent to a U shape. The ends of the two limbs of the U-tube are fixed. These two ends of the tube also serve the purpose of supplying power. The tubes were heated by means of current supplied by regulated DC power supply. The dynamic response of two different sizes of U-tubes in lateral and transverse directions was studied experimentally for different heating rates.

2. Experimental setup

The U-tube cantilever beam is shown in Fig. 1. The test specimens used for the experimental investigation were stainless steel SS304 tubes with 1.86 mm and 1.05 mm external diameter and 0.22 mm thick each bent to a U shape to form cantilever beam.

The test specimen was mounted inside a wooden test box of 300 mm wide, 300 mm long and 1100 mm high with three sides of the box covered with perspex glass. The test box performed several functions: (i) the walls of the box prevented cross currents from affecting the convection heat transfer from the surface of the tube, (ii) provided clamped support for holding the tube and (iii) allowed for the mounting of instrumentation. The ambient temperature inside the test box was measured before each experimental trial using the digital thermometer. Tube displacements were measured directly with a laser displacement sensor. The sensor head was located approximately 40 mm from the point where the displacement was measured. The sensor used had a ± 10 mm resolution with a response time of 1 ms. The output from the laser sensor was