THE INFLUENCE OF THE PRELIMINARY GARTER SPRING SPACER SIMULATOR CLAMPING FORCE IN THE PRESSURE TUBE SPACER – CALANDRIA TUBE HOOK-UP SIMULATOR AGING BEHAVIOUR

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ABSTRACT

The garter spring spacer is a specially constructed torsion spring used to fit-out the CANDU 6 fuel channel. The pressure tube ageing decreases the gap to the calandria tube. Continuous gap decrease directly affects the garter spring spacers behavior during fuel channel assembly operation. The preliminary clamping force value of the garter spring spacer assembly is important for its ageing behavior.
This paper briefly describes the experimental technological facilities used for conducted the experiments and highlights some of the important moments during an experiment carried out in laboratory conditions, without using pressurized boiled water and irradiation working conditions. The results analysis and some conclusions are outlined at the end, pointing out that a garter spring spacer preliminary clamping force increase reduces the vibration response signal amplitude, and does not lead to its relaxation.
The paper is dedicated to specialists working in research and technological engineering.

Key words: garter spring spacer, pressure tube, preliminary clamping, ageing

Introduction

The CANDU 6 fuel channel consists of two end fittings, a pressure tube, a calandria tube, bearings, fasteners, expansion takeovers and biological protection. The whole assembly is positioned between the end plates of the calandria vessel.

The pressure tube is the high pressure limit of the fuel channel assembly being part of the heat transport primary circuit; it is bulged at both ends in terminal fittings and is enveloped inside the calandria tube, its lower pressure limit. The annular space between the calandria and the pressure tubes is closed and traversed by CO_2.

The four garter springs spacers assembled on the pressure tube serve to impede the contact between the pressure and the calandria tubes that causes hydrogen accumulation inside the pressure tube material that can lead to wall weakening, and over time, to the loss of the fuel channel assembly pressure limit, [1].

The pressure tube's operating aging is marked by its diameter growth that has a direct influence over the garter spring spacers' behavior during the operation of the fuel channel assembly. Because the garter spring spacer is subjected to a series of complex stresses, its behavior is difficult to replicate through a calculation model.

The garter spring spacer is an elastic element known as a torsion spring. It receives the discharged effort on a number of coils that come into contact with the pressure tube and respectively on the calandria tube. The spacer's contact coils twist triggers: - the garter spring's contraction around the pressure tube preventing its movement from the initial assembly position; - the garter spring's tilt in one direction or the other in its upper side while trying to reduce the compression load over the loose coils.

The pressure tube's diameter growth reduces the gap in the contact area with the spring spacer and the calandria tube generating an overload upon the loose coils. This leads to a new state of instability. Because the coil diameter is much smaller than its length, during mechanical vibrations caused by the flow of the cooling agent, its deflection reaches a certain value causing it to seek to regain its stability by expanding in the contact area's opposite side.

In order to study the influence of aging on the elastic coupling made out of the pressure tube, the garter spring spacer and the calandria tube, and especially the garter spring spacer behavior, we constructed a device that simulates the load received by such a coupling in laboratory conditions, without using pressurized boiling water and irradiation working conditions.

The article briefly describes the devices used for conducting the experiments, and shows details from the tests, the results and finally some conclusions.

Brief description of the experimental assembly

The testing devices assembly is partially reproducing the geometrical similarity of the central intermediate bearing of the fuel channel assembly. In this case, the pressure tube simulator is simply supported on two garter spring spacer simulators, reproducing the conditions imposed by the central intermediate bearings geometry.

All of the coupling's components are geometrically and physically similar with the originals. The pairs of spacers were crafted from spring wire with a circular section. We took all the original spacer's geometrical characteristics as reference except the wire section shape, keeping its section surface (about ~ 16,4% larger that of the original spacer).

The physical characteristics of the spacer simulator pairs involved in the experiments differ from one another and differ from those of the original spacers. They are designed to facilitate understanding of their functional behavior under the influence of the pressure tube geometry modifications caused by aging and also the influence they have on it.

Figure 1 displays the vibration table (1), the stand framework (2), the pressure tube simulator (3), the downstream calandria tube simulator (4), the downstream electric heater coupling (5), the downstream bearing force cell (6) and the accelerometer (7). The device assembly structure consists of: the upstream calandria tube simulator, the upstream electric heater coupling, heating elements power supply, the temperature measurement and monitoring system, the reference accelerometer mounted on the vibration table and the spectrum analyzer.

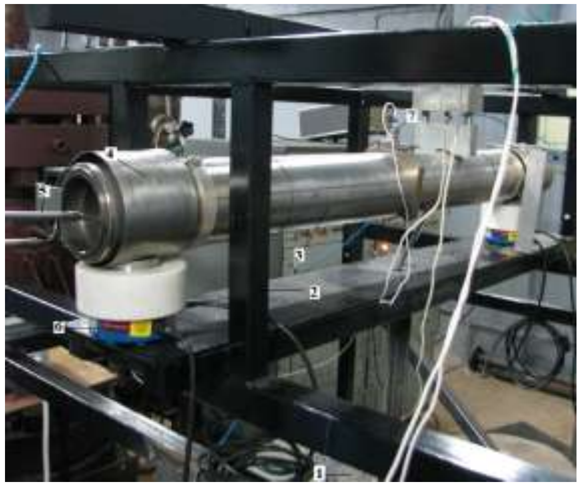

Fig. 1 *The devices assembly*

The experimental tests

To load the pressure tube simulator inside onto the two elastic bearings we took into account the values from previous tests carried out inside the high pressure hot loop at a temperature lower than 250˚C. The values resulted from measurements in hot tests: 59.5 kgf – at the upstream bearing; 32.5 kgf – at the downstream bearing.

The experiments were conducted with table vibration in the frequency range of 2 Hz÷33 Hz. The accelerometer A2 placed on the vibration table provided the control for the induced mechanical vibrations. The pressure tube simulator feedback according to the frequency (displacement signal - peak) was taken over by the A1 accelerometer and analyzed using a „Pulse" spectrum analyzer.

Tests were aimed to studying the spacer's behavior during the pressure tube simulator diameter change. This change is similar to those detected at the pressure tube after ten and sixteen years of operation and their influence on the simulator.

For the pair of garter springs GS-207, the pressure tube simulator feedback according to the frequency (simulated in laboratory conditions described above) is displayed in figure 2.

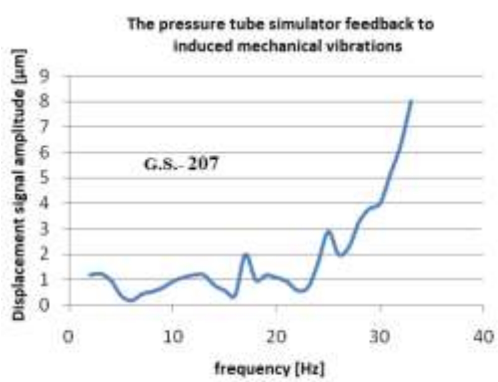

Fig. 2 *The pressure tube simulator feedback to induced mechanical vibrations*

For the same pair of spacer simulators, after reproducing the central bearings geometry according to a 10-year pressure tube aging, the pressure tube simulator feedback to frequency is displayed in figure 3.

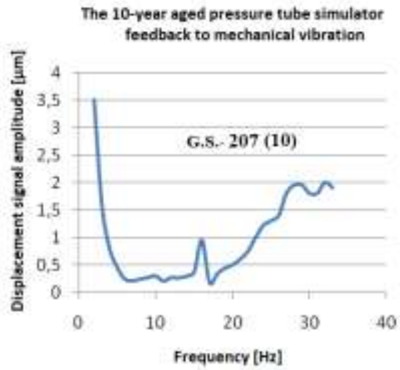

Fig. 3 *The 10-year aged pressure tube simulator feedback to mechanical vibration*

For the same pair of spacer simulators, after reproducing the central bearings geometry according to a 16-year pressure tube aging, the pressure tube simulator feedback to frequency is displayed in figure 4.

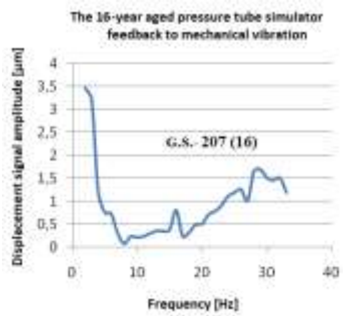

Fig. 4 *The 16-year aged pressure tube simulator feedback to mechanical vibration*

The 16-year aged pressure tube simulator feedback is much like that achieved by simulating a 10-year aging from 27 Hz up, hovering just below 1,65 µm, figure 5.

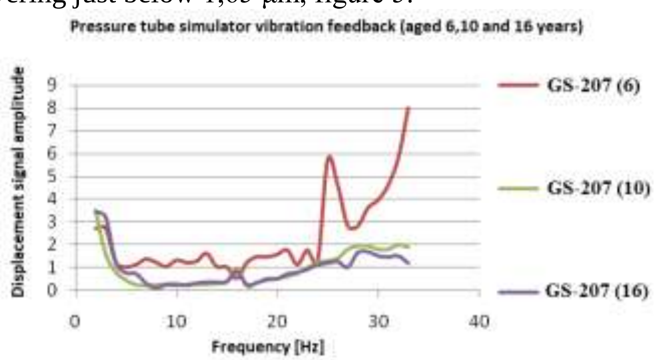

Fig. 5 *Pressure tube simulator vibration feedback (aged 6,10 and 16 years)*

The 6-year aged pressure tube simulator feedback showed that the signal amplitude is generally kept in narrow limits, except the points having 2 Hz, 3 Hz, and 25 Hz frequencies, figure 5.

The 10-year aged pressure tube simulator feedback showed that the signal amplitude generally dropped, with the exception of the point having a 2 Hz frequency. The response peak initially identified at 25 Hz even after 6-year aging disappeared from the response spectrum, and further on, the signal amplitude did not pass 2 µm, figure 5.

Spacer simulator displacements occurred around the assembly position, most often the spring spacer having a tilted motion on the pressure tube simulator. We generally noticed a reducing tendency for the spacer simulator's average tilting angle as it tightened around the pressure tube simulator while aging. We also notice a tendency for changing its tilting direction around the pressure tube. It became frequently unstable at the 10-year aging.

The second pair of garter springs GS-197 had a greater tightening around the 6-year aged pressure tube simulator. The pressure tube simulator feedback according to the frequency (simulated in the laboratory conditions described above) is displayed in figure 6. The difference between the two bracelets was made by the preliminary clamping force imposed by a 4.5% greater number of coils (the pitch remained the same).

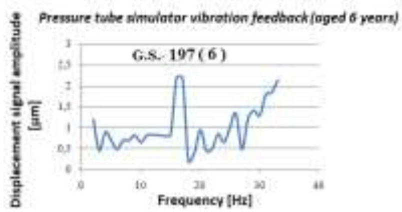

Fig. 6 *Pressure tube simulator vibration feedback (aged 6 years)*

For the new pair of spacer simulators, after reproducing the central bearings geometry according to a 10-year aging, the pressure tube simulator feedback according to the frequency is displayed in figure 7.

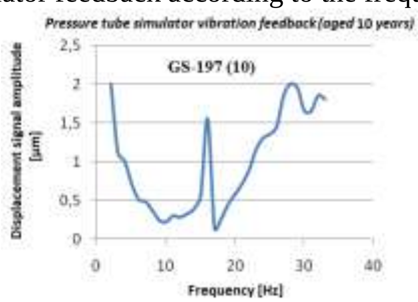

Fig. 7 *Pressure tube simulator vibration feedback (aged 10 years)*

For the new pair of spacer simulators, after reproducing the central bearings geometry according to a 16-year aging, the pressure tube simulator feedback according to the frequency is displayed in figure 8.

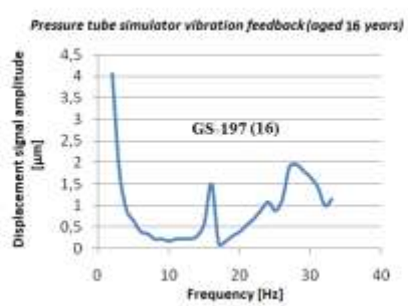

Fig. 8 *Pressure tube simulator vibration feedback (aged 16 years)*

The feedback given by the pressure tube simulator aged by 16 years is much like that achieved by simulating the 10-year aging, the difference is given by the 2Hz and 4 μm signal amplitude shown in figure 9.

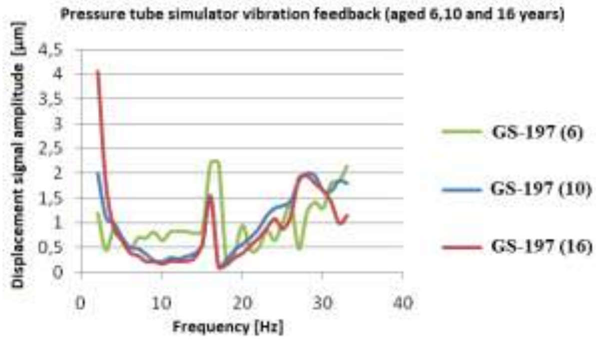

Fig. 9 Pressure tube simulator vibration feedback (aged 6,10 and 16 years)

We noticed that after 6 years, the pressure tube signal amplitude exceeds 2 µm at 16, 17 and 33 Hz. After 10 years, the signal amplitude reaches 2 µm only for 2 and 28 Hz, figure 9.

The displacement of the garter spring spacer simulators again took place around their assembling positions. The spacer simulator mostly moves tilted along the pressure tube towards downstream. We generally notice the reduction tendency for the medium garter spring bracelet tilting angle as it tightens around the pressure tube during aging. We also notice a tendency for changing its tilting direction around the pressure tube. It became frequently unstable for the upstream spacer and also for the downstream spacer after 16 years. Also after 16 years, we noticed that the downstream spacer simulator increased its state of instability and its medium tilting angle instead of decreasing it.

Results

Through these experiments, we searched for useful answers for in depth understanding the garter spring bracelets behavior after 6, 10 and 16 years when subjected to mechanical vibrations by applying a preliminary clamping force around the pressure tube.

All tests were conducted in laboratory conditions without using pressurized hot water as working agent on the pressure tube simulator supported by two spacer simulators reproducing as accurately as possible the conditions imposed by the fuel channel assembly's central intermediate bearing geometry.

The pressure tube simulator was previously modified in the bearing simulation areas so it dimensionally corresponds with an aged pressure tube section thus simulating the effect of six, eight and sixteen operating years.

We wanted to study the preliminary clamping force influence over the garter spring spacer after each simulated period of time. The experiments were conducted in the same laboratory conditions for each garter spring spacer. Each garter spring pair provided a different assembly tension onto the pressure tube simulator.

The pressure tube diameter's increase as a result of aging leads to a preliminary clamping force increase for the spacers. This situation was geometrically simulated during the laboratory experiments.

Comparing the feedbacks provided by the pressure tube simulators after six, ten and sixteen years of laboratory aging for the two types of garter spring spacer pairs we notice that the signal amplitude is generally similar for almost all of the spectrum except for the 2 and 16 Hz frequencies where the amplitude is markedly larger for the spacer simulator with a small number of coils which is considered more elastic, figure 10.

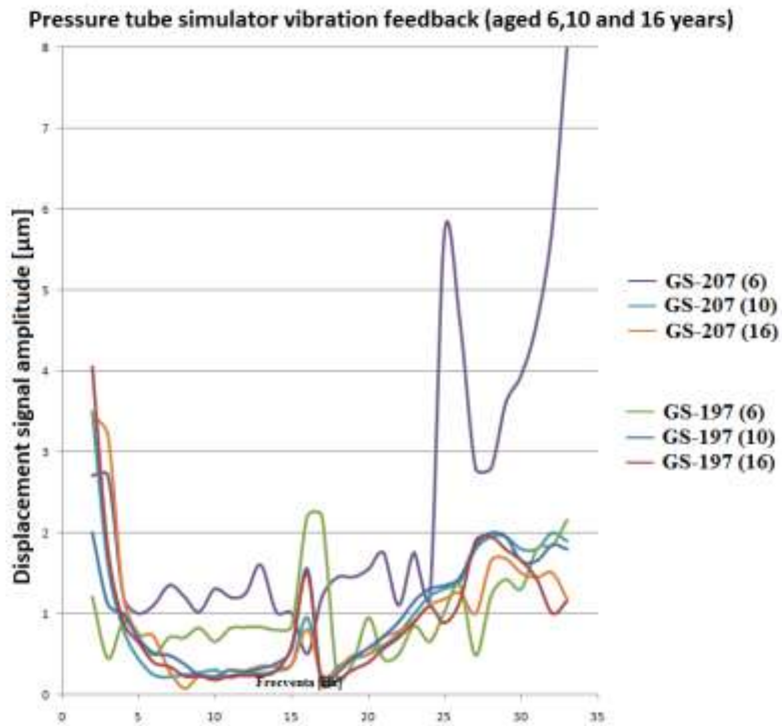

Fig. 10 *Aged pressure tube simulator vibration feedback (for the two spacer simulator pairs)*

Overloading the garter spring bracelet at assembly continued to reduce the pressure tube simulator's vibration amplitude response (displacement) throughout the two experiments.

In general, the experimental simulator highlights that operating the pressure tube simulator for up to ten years at reduced frequencies (2 and 3 Hz), its feedback is greater for a larger spacer simulator preliminary clamping.

In the case of the coupling aged 16 year of operation, we also noticed that the pressure tube simulator feedback was greater in the coupling with a lower spacer simulator clamping force. This happens because at a lower spacer simulator deflection, the spacer takes in less rigidly the stress caused by mechanical vibrations, because of a higher vibration amplitude.

Spring simulators displacements took place each time around their mounting positions around the pressure tube simulator.

We noticed that for the GS-207 spacer, simulating a 10-year pressure tube operating age resulted in displacements out of the ± 1 mm range compared to their initial assembly positions around the pressure tube simulator. We believe that this is due to a spacer simulators instability increase.

The GS-197 spacer simulator displacements on the pressure tube were reduced whatever the simulated aging.
We could not establish a causal relationship between the pressure tube simulator amplitude and the spring bracelets positions variations in their bearings.

Conclusions

- All tests were conducted in laboratory conditions without using pressurized hot water as working agent on the pressure tube simulator supported by two spacer simulators reproducing as accurately as possible the conditions imposed by the fuel channel assembly's central intermediate bearing geometry;
- The experiments are useful for in depth understanding the vibration behavior of the garter spring spacers mounted through preliminary clamping on the outside of the pressure tube, which is a CANDU 6 fuel channel component after 6, 10, and 16 years of operation;
- The pressure tube's diameter growth as a result of aging increases the spacers' preliminary clamping force and reduces the pressure tube's vibration amplitude throughout the experiments;
- From the experimental simulation we established that the pressure tube simulator's signal amplitude generally resembles almost all frequency spectrum except 2 and 16 Hz where the amplitude is visibly greater for the spacer simulator with a smaller coil that is considered to withstand less stress;
- The spacer's preliminary assembly clamping force increase due to aging of the pressure tube does not generate the spacer relaxation.

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