ASPECTS OF CAVITATION STUDIED ON THE HYDRODYNAMIC CAVITATION TRIBOMODELS

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ABSTRACT

In the first part of the work it will be presented the methodology of the cavitation wear tested on the industrial tribosystems as well as on the cavitation tribomodels. Afterwards, it will be presented the hydrodynamic cavitation tribomodels existing in the Research Laboratory of Machine Design Department: tribomodel with TC1 hydrodynamic tube and the tribomodel with TC2 rotation disk.

The tests have been realised on the tribomodels with TC2 rotation disk and have as purpose to establish the conditions of cavitation appearance and development, as well as to locate the positions of the cavitational stamps. Has been used an aluminium disk on it being fixed cavitation drivers, on different radiuses, under the form of 12 bolts having the variable dimensions – heights and diameters. As cavitation drivers, there have been used 6 circular holes/openings, placed on different radii. The work environment was water, temperature being constantly maintained at the level of the environment, using the open circuit, coupling the work room to the water network from the Research Laboratory.

The positions of the cavitational attack zones have been determined through the visual remarks by the help of the stroboscope and by studying the surface of the aluminium disk.

KEYWORDS: cavitation, cavitational germs, tensions, viscidity, temperature, pressure.

1. Considerations on testing methodology

The reference literature does not contain a methodology unanimous accepted, regarding the study of the behaviour of the different materials at destroying by cavitation. The tests are realised, generally, through 3 procedures:

a). Tests on elements from the actual tribosystems: this method is characterised by the long duration, difficulty in prospecting the destroyed zones and in the quantity appreciation of the destruction.

b). Tests on models of the actual triboelements, in cavitation tunnels, the disadvantages of this method are that they are alike with the ones mentioned above.

c). Tests on triboelements from cavitation tribomodels. By this method it is realised an intensity of destruction much bigger than that of the prior cases, the exposing timers are relatively low, the handling of the tribomodels is easier because of the small dimensions and the simple geometrical shapes of those and the work parameters are changing easily as required by the experiment necessities.

A special attention must be given to the experimental installations, these having to be in a direct relation with the desired purpose, generating of cavitational states in the same conditions of work with those of the actual triboelements [3], [4], [8], [9], [11], [12], [13], [18], [19], [20], [21], [22], [23], [24], [26], [27], [31], [34], [35], [38], [39]. A special attention must be given to the method of reproducing the phenomenon that is more alike with the ones met in the practice of exploiting the hydrodynamic systems functioning in cavitational regime.

Establishing of the testing methodology has begun from the proposal made by Kostetki [15], enlarged and developed afterwards within the researches made by Machine Design Department of Galati University, by the application of tribomodelling method. It is wanted the realisation of cavitation wear in laboratory conditions, using installations where there are placed typical cavitation tribomodels, namely: hydrodynamic cavitation tribomodels, cavitation tribomodels with impact liquid jet, vibration cavitation tribomodels [10].
2. Cavitation tribomodel with hydrodynamic tube TC1

The tribomodel is designated to the research of the cavitation phenomenon in the conditions of a hydrodynamic current. The installation is compound of the following:

1 – electro pump: electric engine with the power of 7.5 kW and the revolutional speed of 2900 rot/min; centrifugal pump with the flow of Q-200 l/min. and the maximum pressure of 80 meters of water column,
2 – main tank with the capacity of 1200 l. of water and the pressure of 2.5 daN/cm²,
3 – buffer tank with capacity of 130 l (having openings and sight),
4 – workroom, with a rectangle section 10x25mm. having the forms presented in figures 2 and 3,
5 – Venturi tube with the characteristic section ratio of 0.3,
6, 7, 8, 9, 10, 11, 12, 13 – straight – way valve (with spigot, valve and sluice),
14, 15, 16 – work piping,
17 – buffer container piping,
18 – air piping.

The electro pump vacuums the water from tank 2 through pipe 14 and represses it in the workroom via pipe 16. The workroom 4 (figures 2 and 3), of a rectangle section, has transparent lids. On one of the lids is applied the triboelement that is studied, just like the obstacle that creates the cavitation (the cavitation driver). Passing a liquid quantity straight into the tank 2 via tap 9 and pipe 15 it can modify the speed of the liquid in the workroom. The testing regime can be also modified and by changing the pressure from the installation. The compressed air is introduced in tank 2 via tap 11 and pipe 18. For times when it is working with bigger pressures, the atmospherically pressure in the main tank 2 is endowed with a safety valve 10 that is regulated according to the test conditions. For changing the triboelements in the workroom it is necessary to modify the level of the installation liquid. It was endowed, for this purpose, the buffer tank 3 that through tap 7 and pipe 17, takes a part of the work liquid, so that its level is inferior to the testing room 4 level. So, with the electro pump functioning, it is opened the tap 7 and there are partially closed taps 8 and 9, the liquid passing into the buffer tank 3.

The hydrodynamic cavitation tribomodel realised has also a differential pressure gauge (to the Venturi tube), thermometer and pressure gauge (figure 4).

3. Cavitational tribomodel with rotation disk TC2

The installation in which functions the cavitational tribomodel with TC2 rotation disk is presented in figures 5 and 6. In the tight (figure 5) a disk is rotated on it there are placed a number of triboelements. In the front of them are mounted the cavitation drivers (figure 7 and 8) made of stiffed oval holes or cylindrical bolts fixed on the disk.

The making tight of the workroom at the shaft ending on which is mounted the work disk is made with a rings system maintained in contact through a spiral spring of compression.

The tight rings are manufactured out of antifriction material and the spring is manufactured out of brass. The driving of the main shaft is made through a narrow trapezoidal driving belt. The electrical engine which equips this tribomodel has a power of 13 kW and a revolution of 2900 rot/min in order to minimise the electrical shocks when starting the installation it is used a rectangle – star switch. The revolution of the disk can be variable in a narrow domain of (0.9…..1.0)n_{nom} by using an electronically system with thyristor which modifies the efficient value of the tension on the three phases. The peripherical speed of the triboelements is modified by their emplacement to different radiuses. In order to
stop the moving of the work liquid in the rotation of the disk there were used six deviational elements on both sides of the rotation disk. To see the phenomenon from the workroom it is used a sight. The visual contact can be made using a stroboscope. The tribomodel functions with water in open circuit, allowing the maintaining of a constant temperature in the workroom, the pressure modification in the workroom it is made by partial closing of the taps on the supplying and evacuation way; for controlling the pressure there were endowed two liquid column pressure gauges.

4. Tests on hydrodynamic cavitation tribomodels

The tests have been made on tribomodels with TC2 rotation disk with the purpose of establishing the conditions of cavitation appearance and development, and also to locate the cavitational marks. It was used an aluminium disk on which were fixed 12 bolts at different radiuses, with the variable dimensions – heights and diameters. As cavitation drivers there were used a number of 6 circular holes placed at different radii. The work environment was the tap water, its temperature being constantly maintained at the environmental level using the open circuit, meaning the coupling of the workroom to the water pipes of the research laboratory. The positions of the cavitational attacks have been determined by visual observations with the stroboscope and by researching the surface of the used aluminium disk. The angle speed $\omega_2$ of the disk was constant, equal with $\frac{\omega_2}{i_{12}}$ where $\omega_1$ is the angle speed of the electric engine and $i_{12}$ is the rapport of belts driving. The tests have been made at an angle speed of $\omega_2 = 210 \text{ rad/sec}$.

The cavitation drivers will have peripheral different speeds because of the emplacement of those to different radiuses.
Keeping the same speed and the diameter of the driver to constant values it can be seen the dependency between height \( h \) of the driver and the distance \( l \) until the cavitational mark (figure 9).

Analysing the position of the experimental points obtained in figure 10, it can be noticed that for \( d = \text{constant} \), it can be found the equation of a regression line that approximates the link between \( l \) and \( h \) under the form:

\[
\overline{l} = a_0 + a_1 \cdot h
\]  

(1)

Marking with \( l_i \) the values determined experimentally and with \( L_i \), the values approximated through the equation (1), it is calculated the sum of the square differences, under the form:

\[
S = \sum_{i=1}^{n} (l_i - \overline{l})^2 = \sum_{i=1}^{n} (l_i - a_0 h_i - a_1)\]

(2)

According to the boundary condition, for \( S \) to be minimum, the partial derivatives of the first order have to be cancelled:

\[
\frac{\partial S}{\partial a_{0_i}} = ma_0 + \left( \sum h_i \right) a_1 - \sum l_i = 0
\]

\[
\frac{\partial S}{\partial a_{1_i}} = \left( \sum h_i \right) a_0 + \left( \sum h_i^2 \right) a_1 - \sum l_i h_i = 0
\]

(3)

From the equation system (3) is determined:

\[
a_0 = \frac{\sum l_i \sum h_i^2 - \sum h_i \sum h_i l_i}{m \sum h_i^2 - \left( \sum h_i \right)^2} \quad \text{and} \quad a_1 = \frac{m \sum h_i l_i - \sum h_i \sum l_i}{m \sum h_i^2 - \left( \sum h_i \right)^2}
\]

(4)

Replacing \( a_0 \) and \( a_1 \) obtained in the equation (1), it is got the values given in the table 1, for \( d = 6, 7, 8 \text{mm} \), respectively and \( v = 31.5 \text{m/s} \), the dependency \( l = f(h) \) is presented in figure 11. For the disk arrangement like in figure 12, it is obtained the dependency between distance \( l \) and speed, for constant diameters of the cavitation drivers (figures 13 and 14). It is noticed that for this case, it can be found a regression line that approximates the relation between \( l \) and \( v \) (table 2).

Figure 15 represents the variation of \( l \) in the same time with the increase of the driver bolt diameter for a constant peripheral speed. Table 3 presents the equations of regressions for this case. It is noticed that the influence of the diameter variation is small against the height influence. Analysing the surface of the tested disk it can be concluded that the increase of the diameter and the height of cavitation driver means the increase the surface of cavitational mark. In the hydrodynamic cavitation tribomodel case, the cognition of the dependency between \( l \) and the work parameters is important in the establishing exactly the positions of the tribomodels in the laboratory tests.

\[
<table>
<thead>
<tr>
<th>\text{Element}</th>
<th>d = 6\text{mm}</th>
<th>d = 7\text{mm}</th>
<th>d = 8\text{mm}</th>
</tr>
</thead>
<tbody>
<tr>
<td>( h_i ) [mm]</td>
<td>3</td>
<td>5</td>
<td>7</td>
</tr>
<tr>
<td>( l_i ) [mm]</td>
<td>12</td>
<td>21</td>
<td>29</td>
</tr>
<tr>
<td>( \overline{l} )</td>
<td>12.7</td>
<td>20.4</td>
<td>28.1</td>
</tr>
<tr>
<td>Eq.</td>
<td>( \overline{l} = 3.85 \cdot h + 1.15 )</td>
<td>( \overline{l} = 4.1 \cdot h + 3.40 )</td>
<td>( \overline{l} = 3.75 \cdot h + 8.75 )</td>
</tr>
<tr>
<td>( \sigma_m )</td>
<td>0.7582 ; ( \sigma_m = 0.8755 )</td>
<td>( \sigma_m = 1.024 ; \sigma_m = 1.035 )</td>
<td>( \sigma_m = 0.6123 ; \sigma_m = 0.7071 )</td>
</tr>
</tbody>
</table>
Table 2

<table>
<thead>
<tr>
<th>Element</th>
<th>d = 7mm</th>
<th>d = 9mm</th>
<th>d = 12mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>( t ) [m/s]</td>
<td>20</td>
<td>24</td>
<td>28</td>
</tr>
<tr>
<td>( l ) [mm]</td>
<td>5</td>
<td>10</td>
<td>16</td>
</tr>
</tbody>
</table>

Eq. \( \sigma = 0.4358 \cdot \sigma = 0.5032 \) \( \sigma = 0.252 \cdot \sigma = 0.291 \) \( \sigma = 0.665 \cdot \sigma = 0.768 \)

Table 3

<table>
<thead>
<tr>
<th>Element</th>
<th>h = 3mm</th>
<th>h = 7mm</th>
<th>h = 9mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>( d ) [mm]</td>
<td>6</td>
<td>7</td>
<td>8</td>
</tr>
<tr>
<td>( l ) [mm]</td>
<td>12</td>
<td>15</td>
<td>16</td>
</tr>
<tr>
<td>( \sigma ) [mm]</td>
<td>12.4</td>
<td>15.4</td>
<td>18.51</td>
</tr>
</tbody>
</table>

Eq. \( \sigma = 0.861 \cdot \sigma = 0.995 \) \( \sigma = 0.801 \cdot \sigma = 0.925 \) \( \sigma = 0.8863 \cdot \sigma = 1.02 \)

Fig. 15

REFERENCES