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SCHOCK ABSORBER IN IGNALINA NPP

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Abstract -Theoretical calculation and experimental analysis of models of schock absorber in Ignalina NPP is presented. The results obtained from the investigation with the model of schock absorber coinside with the theoretical calculation.

Keywords: nuclear reactor, schock absorber, pool, covering, kinetic energy, plactic deformation, water pillow.

1. Introduction

How safe is a nuclear power plant depends not only on the safety of the reactor, but also on many other factors. One of such factors is the storage of the nuclear fuel waste. This waste is transported, cooled and kept in special castors (containers). The mass of such a castor, filled with the waste might be of abaout hundred tons. The containers with the waste are transported to deep cooling pools, kept here for a while, and after that transported to the long storage place. The castors are being transported both in vertical and horizontal positions with a high capacity crane. During the transportation the possibility of an accident is very high. The container might fall down from a certain height. If this happened in a cooling pool or a lifting shaft, the covering of the bottom of the cooling pool or lifting shaft might be destroyed. Then the radioactive water may run out from the cooling pool. Such an accident might cause an ecological catastrophe.

These accidents may be prevented by the help of a shock absorber, arranged at the bottom of a lifting shaft. The materials and the constructions of shock absorbers may be various. The proposed contruction the shock absorber is shown in figure 1. The shock absorber is constructed of vertical pipes, that are connected by the upper and lower plates, and it is put down on a "water pillow". The lower plate must be of high rigidity, while the lower ought to be flexible. The distribution of dynamic load on the coverings depends on the rigidity of the lower plate. But it is very difficult and complicated to produce a plate of a very high rigidity (shock-absorber's weight is getting bigger, more materials are to be used et ctr.) Therefore a "water pillow" is proposed to be equipped under the shock absorber. The "water pillow" distributes load uniformly on the coverings of the pool and shaft.

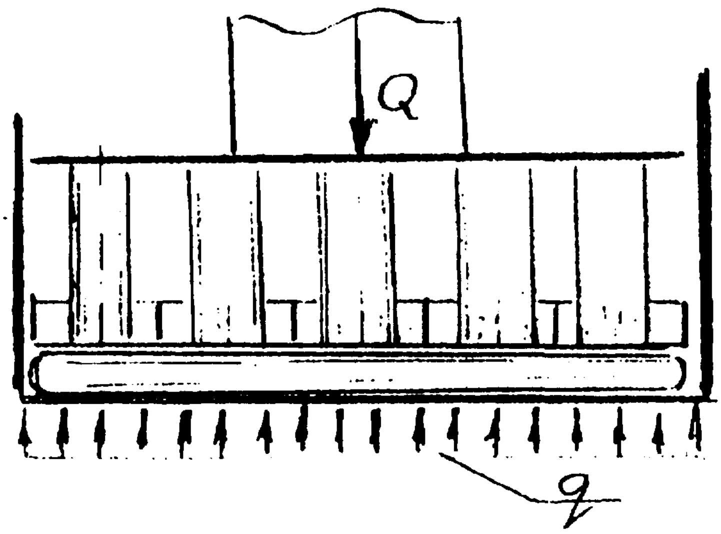

Fig. 1 The scheme of a shock absorber.

The main principle of the work of the shock absorber is suppression of container's kinetic energy by the help of plastic deformation of vertical pipes. Having in mind plastic deformation of the pipes as well as the permitted loads on the coverings, it is possible to calculate the geometrical parameters of the pipes. As the area of the container's bottom is smaller than the one of the shock absorber's upper plate, the shock-absorbers pipes cannot be deformed equally. The pipes under container will be deformed by axial compression, while the other pipes will be deformed by eccentrically applied loads and bendings. Besides, the container may fall not on the center of the shock-absorber.

The theoretical calculations were verified by the help of the experiments with the container's model. These investigations proofed that all the possible cases of the container's falling (centric, non-centric) are not equally dangerous. If the container falls on the edge or the corner of the shock absorber, the lower plate may touch the covering. In this case the part of the "damped" dynamic load will be passed to the covering through the edge of the lower plate, While the remaining part- through the "pilow". In the case of the centric fall the bending moments in the lower plate were bigger then in the case of non-centric fall, therefore here we give the estimation of the centric fall.

2. Calculation of the pipes

When the load on the model of the shock absorber's pipe was centric (the modell was made of plastice steel), the fallowing diagram has been got (fig. 2).

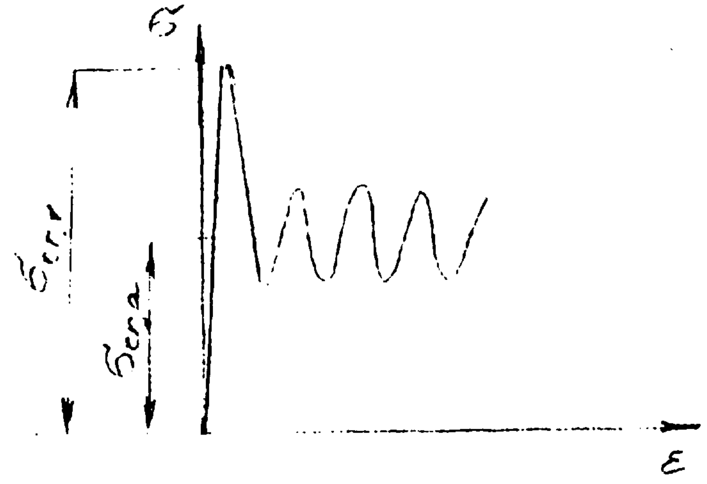

Fig. 2 Diagram compression of pipe

When the upper critical limit $\sigma_{cr,v}$ is reached, the wall of the pipe loses regional stability. The pipes wall curves inward, wrinkles, the stresses decrease, till the lower critical limitt $\sigma_{cr,a}$ is reached. Further the pipe's wall is being deformed by constant stresses till the absolute deformation of the pipe. In this way very big plastic deformation as well as, the energy of the plastical deformation energy is achieved. If the permitted load on the covering is known, the permitted dynamic load will be

$$F_{adm} = q_{adm} A$$

A- the aerea of the pool bottom.

This dynamic load may be expressed by the allowable load of the pipes.

$$F_{adm} = A_c n \sigma_{cr,v}$$

A_c - the area of cross section of one pipe, d -the diameter of the pipe, t -pipe wall's thickness, n -the number of centrically compressed pipes.
In this way

$$F_{adm} = \pi d t n \sigma_{cr,v}$$

From this, the tickness of the pipe's wall

$$t = \frac{F_{adm}}{\pi d n \sigma_{cr,v}} = \frac{q_{adm} A}{\pi d n \sigma_{cr,v}}$$

The kinetic energy of the falling body

$$E_k = Q(h + \Delta_{dyn})$$

Q - forse of falling body, h - height of falling, Δ_{dyn} - dynamical deformation of the pipe.
The energy of the plastic deformation

$$E_{pl} = F_{cr,z} \Lambda_{cr,a}$$

Because $Fa_{cr,a} = A_c \sigma_{cr,a}$, $E_{pl} = A_c \sigma_{cr,a} n \Delta_{dyn}$
Both energies must be equal.
Then

$$Q(h + \Lambda_{dyn}) = A_c \sigma_{cr,a} n \Delta_{dyn}$$

and

$$\Lambda_{dyn} = \frac{Qh}{A_c \sigma_{cr,a} n - Q}$$

The height of the schock-absorbers pipes is limited and depends on the building's construction and technology. Because of this, when the pipes dynamical deformation is calculated, if might be necessary to repeat the colculations changing the tickness of the pipes' walls. When thickness is increased, the deformation will be smaller, but the pipes rigidity and shock's load will be bigger.

3. Calculation of the lower plate

When the container falls down aproximately are to appear 4-6 pipes are to appear under its bottom. And the load on coverning will be passed through relatively small surface.

The maximum bending moment in the cross-section of the lower plate, when $F_{cr,v} = F_{adm}$ ir $q = q_{adm}$ is:

$$M_d = q_{adm}\, a \frac{c^2}{2}$$

Later, when the pipes are plasticly deformated, the forces as well as the distributed loads are getting smoller. The plate's W:

$$W = \frac{M_d}{\sigma_{adm}}$$

Using the W, the geometrical parameters of rigidity wall on the lower plate may be calculated. The height of the rigiding wall must be smoller than 1/4 of the pipe's height, because there must be enough place for a deformed pipe between plates rigiding walls.

4. The calculation of the upper plate

The upper plate of the shock-absorber joins all the pipes. This plate must be maximum flexible and work only on tension. In the case of an accident, the pipes, loated on the schock-absorber's fringes will be acted by forces, passed through the upper plate. The shear force Q_s, which activates the fringe pipe's plastical bending moment is calculated as following:

$$Q_s h = M_{pl} = \frac{D^3 - d^3}{6}\sigma_y, \quad Q_s = \frac{(D^3 - d^3)\sigma_y}{6h}$$

σ_y - yield point of the steel, D - external diameter of the pipe, d- internal diameter of the pipe, h - height of the pipe.

The necessary area of the cross section of the plate:

$$A = bt = \frac{Q_s}{\sigma_{adm}}$$

and necessary thickness of the upper plate

$$t = \frac{Q_s b}{\sigma_{adm}} = \frac{(D^3 - d^3)\sigma_y b}{6h\ \sigma_{adm}}$$

5. Colculation of „water pillow"

Water „pillow" or distributer of pressure on the bottom of the pool is at hin-wall vessel. Its deformation is limited by bottom and walls of pool and as well as the lower plate of the shock-absorber. The maximum stresses will ocur in the cylindrical part of the „pillow". They may be calculated from the equation:

$$\sigma_t = \frac{p}{t} r$$

There p - internal pressure, t - thicknes of wall, r - radius of cylindrical part.
Then necessary thickness of the wall of the „pillow":

$$t = \frac{pr}{\sigma_{adm}}$$

The results, obtained from the investigations with the model of the shock-absorber coinside with the theoretical calculations.

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