THEORETICAL AND EXPERIMENTAL CONSIDERATIONS ON THE INFLUENCE OF THE AXIAL FORCE TO THE CRITICAL ROTATIONAL SPEED OF THE SHAFTS FOR MIXING DEVICES

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Abstract: The methods for theoretical analysis and for experimental analysis, separately used, are insufficiently to study the behavior under vibrations of the shafts of the mixing devices, because the computation in the fields of this kind of shafts, doesn't only partially take into account the real static of loading.
The paper shows some numerical values for the coefficient k, which introduces the effect of the axial force on the computation of the own real rotational speed, in the case of the propeller impellers and standard open type turbine impellers.

Keywords: correction coefficients, real own frequency, theoretical own frequency.

1. INTRODUCTION

It has been one of the consequences of introduction of ever higher speeds of rotation in mechanical engineering that problems concerning stability of running of revolving machine elements, for instance, have increased in importance on the side of questions relating to strength. One has to be able, already at the designing stage, to determine with reliable and sufficient accruing the critical speeds of shafts in order to avoid exceedingly high weight of structures resulting from high safety and other detrimental effects.

Considering the effects of all the factors which were enumerated in abstract, in determining of the critical speed, is absolutely necessary, as the formula (1) i shows us. It is recommended to examine the magnitude of the effect exercised by each partial factor on critical speed of the shaft of mixing device. Subsequently, it is possible to decide which factors may be neglected in each case.

2. THEORETICAL CONSIDERATIONS ON THE INFLUENCE OF THE AXIAL FORCE TO THE CRITICAL ROTATIONAL SPEED OF THE AHFTS FOR MIXING DEVICES

The own frequencies which were theoretically computed don't take into account the effect of rigidity of the scaling device, the damping effect of the liquids which arc mixed, the elasticity of the bearings.

So. the value of the real own frequency will be obtained through the correction of the theoretical own frequency using some coefficients which show the influence of the factors which were previously specified .

Based on experimental researches, it is possible to conclude that the real own frequency or critical rotational speed having "j" degree, of the shaft for a mixing device, has the general formula [4]:

$$\omega_{cr,\,j} = (k_a\, k_\mu\, k_\rho\, k_b\, k_s\, k_g)\, \rho_j \tag{1}$$

where: p_j - own pulsating of the mixing devices, which is considered in vacuum
k_a, k_g, - coefficients which introduce the effect of the axial force and of the gyroscopic moment
k_b, k_s , - coefficients which show the influence of the bearings and of the sealing of the shaft

The axial force, which loads the mixing device, may lead on decreasing of the static deflection of the shaft or on increasing of it depending if this force contribute to elongate or to contract of the shaft.
The effect which is produced by axial loading is considered in formula (1), through the coefficient k_a, which can be computed as the formula from [4]:

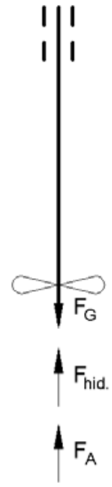
$$k_a = \sqrt{1 +/- \frac{F_a}{j^2 F_{crj}}} \tag{2}$$

where F_a - axial force which has sign"+" if it leads to elongate, or sign"-" if it leads to comprise

$$F_{crj} = \frac{\pi^2 \beta_j^2 EI_{min}}{l_f^2}$$ - critical buckling force having "j" degree

β = 1....2, depending on the number of the harmonic vibration "j"

For the computation of the axial force it must to consider the following stresses: the weight of the shaft and of the impeller (F_g), uplift force (F_A), axial force because of the stream of Liquid (F_{hd}) - figure 1



The mass of the impeller is considered to be concentrated in a point and so it results the force

$$F_g = m_a g$$

where : m_a - the mass of impeller
g - gravitational acceleration

It is considered a uniform distribution of the mass and so result a uniform distribution of the loadings.

Because a part of shaft and the impeller are under liquid, there is a lifting force (Archimedean force) which is equal and on counter direction as the weight of the volume of the swiped fluid. Lifting force F_A, which loads the impeller has the point of application in the centre of mass and has the form:

where : p - fluid density
V_{im} - the volume of the impeller g - gravitational acceleration

The lifting force $F_{A,ar}$ which is loading the part of the shaft which is under liquid it is uniformly distributed considered

$$A_{A,ar} = \frac{\pi}{4} d^2 pg \tag{5}$$

where : $F_{A,ar}$ - the lifting force related to the unit of length
d - diameter of the shaft
p - density of liquid
g - gravitational acceleration

Ail the impeller having the vertical suction (ex : propeller impellers and turbine impellers) create an axial force, having counter direction by the direction of flowing, it overlaps on the axe of the impeller. Hydrodynamical axial force continuously modifies its orientation in space, because it depends on particular conditions of mixing.

On computing of the hydrodynamical axial force, Burger **[2], [3],** presents the following formula:

$$F_{hd} = KRe^m pvn\, d_a^{\,2} \tag{6}$$

where . Re - Reynolds criterion
K, m - coefficients which were experimentally established
p - density of the fluid
n - rotational speed of the impeller
v - kynematic viscosity of the fluid

In specialty papers there are also known other formulas for computation of the axial forces.
It will be presented two cases: first, when axial force elongates the shaft and the second, when it comprimates the shaft.

1. When axial force (sign "+" in formula (2)) elongates the shaft, the deflection decreases and so, ω_{cr} increases. So, in formula (1) $k_a > 1$ and from formula (2) results:

$$k_a = \sqrt{1 + \frac{F_a}{j^2 F_{crj}}} > 1 \tag{7}$$

Raising the formula at the second power and reducing the same members it results

$$\frac{F_a}{j^2 F_{crj}} > 0 \tag{8}$$

To have a elongating effect from equilibrium of the forces (figure 1) and using the formula (8), it results:

$$F_a = F_g - F_A - F_{hd} > 0 \tag{9}$$

Using also, formula no (6), it results:

$$F_a = F_g - F_A - KRe_m\, pvnd_a^2 \; > \tag{10}$$

It is easy to observe from previous formula, that this case corresponds to the impellers having big mass, with law rotational speed and laminar flow

2. When the axial force (sign "-" m formula no.2), compress the shaft, the deflection increases and so, $\omega_{cr,}$ decreases. Thus, in formula (1), $k_a< l$. So, from formula (2) it results:

$$k_a = \sqrt{1 - \frac{F_a}{j^2 F_{crj}}} < 1 \tag{11}$$

Raising the formula (2) at the second power and reducing the same members it results:

$$k_a = \frac{F_a}{j^2 F_{crj}} > 0 \tag{12}$$

From formula (12), it results:

$$F_a < 0 \tag{13}$$

Producing the effect of comprimation, from the equilibrium of the forces (figure 1) and using the formula (12), it results :

$$F_a = F_g + F_A - F_{hd} < 0 \tag{14}$$

$$F_a = F_A + F_{hd} - F_g > 0 \tag{15}$$

Using formula (6). too, it results:

$$F_A - KRe^m pvnd_a^2 \; + F_A \sim F_g > 0 \tag{16}$$

It is observing that this case corresponds to the impellers which have a small mass, a big rotational speed and a turbulent spectrum of fluid flow.

3. EXPERIMENTAL RESULTS

The experiments with propeller impellers and with standard open type turbine impeller were performed for the sense of rotational producing a downward flow, and so a positive axial force.

We investigated water (specific weight y_m = 9ooo N/m^3 viscosity μ - 2.3 10^{-2} Ns/m^2) and glycerin (y_m - 12 500 N/m^3).

The viscosity of glycerin was varied by heating it to different temperatures. For measuring of the axial force, the tank was placed on the pan of a lower balance.

The other part which contained the balancing weight was connected with a steel plate to tensometric data units. These data units transmitted signals to an amplifier and a millimeter with a calibrate scale. In determination of the value of F_a we took into account weight of impellers, the Archimedean force, which is considerable in mixing where a central eddy develops. Experiments show that the magnitude and direction of axial force depend

on the type, dimensions, weight, and the angular velocity of impeller and on the characteristics of the agitated medium; -with a change in the sense of rotation of propeller impellers, the axial force changes its remains unchanged (a change in the direction and magnitude of the axial force for any of the other investigated impellers).
It is evident that the axial force is larger for a propeller impeller than a turbine impeller. The thrust coefficient k_a is larger than unit in the laminar region and smaller than unit in the turbulent region.

3. CONCLUSIONS

Theoretical computation of the own frequency doesn't take into account the damping effect of the mixed liquids, the effect of the axial load, the elasticity of the bearings, etc.

So, the real own frequency will be obtained through the correction of the theoretical own frequency by the aid of some correctional coefficients which depend on the influences of the effects of the factors which were previously shown. The paper is presenting theoretical and experimental views about k_n , which introduces in theoretical formula of real own rotational speed, the influence of axial force.

It is necessary to lay emphasis that there isn't a unitary method for computation the behavior, under vibrations, of this kind of shafts.

The models for loading which are presented in specialty papers are more simplified, but in this way it may appear a lot of errors.

The author consider that the axial forces in the operation of standard Wade and paddle impellers are insignificant and can be neglected in calculation of the drive and the mixer shafts.
In theoretical and experimental considerations, the authors took into account only the effect of the action of the axial force, taking no care of all another toads.

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