SOMMERFELD-EFFECT IN AUTOMATIC BALANCING

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Automatic balancing devices, comprising several balls in circular tracks, can efficiently compensate rigid rotor unbalance within certain ranges of rotational speed. However, near critical speeds the vibration level can be comparatively high due to the phenomenon, which is similar, but not identical to the well-known Sommerfeld-effect in unbalanced rotors with a limited driving moment. The presented paper generalizes the investigations of the Sommerfeld-effect in automatic balancing.

INTRODUCTION

The automatic balancing device of considered type with one track and two balls was first introduced by Thearle [1] in 1932. Since then the automatic balancing becomes a well-known phenomenon. Nevertheless, the interest in autobalancing and the number of publications on this subject have been noticeably increasing nowadays [2-5]. Some principal aspects of automatic balancing were investigated in publications by Sperling et al [6-9]. Autobalancing is particularly advantageous for rotors with a variable unbalance, such as washing machines, centrifuges, grinding machines and CD-ROM drives.

The main attention of researchers is focused on the possibility and stability of unbalance compensation by means of autobalancing devices. Therefore, investigations usually concentrate on synchronous motions, where the balls and the rotor have equal speeds. Meanwhile, experimental data confirmed by simulation results revealed that a different type of motion may take place in the regions near rotor system critical speeds. Under specific conditions during the run-up, the balls exhibit non-synchronous motions, continuing to move with the speed close to the rotor eigenfrequency, whereas the rotor gains in speed and passes the critical speed area. This phenomenon is similar (but not completely identical) to the well-known Sommerfeld-effect in unbalanced rotor systems with a limited driving moment.

The non-synchronous motion of the balls is an undesirable phenomenon in automatic balancing as it may cause high vibrations near critical speeds. If parameters are not properly chosen, such vibrations may significantly exceed the magnitude of vibrations of the rotor system without autobalancing device.

The display of non-synchronous motions in automatic balancing was first revealed in [6,7]. The systematic analysis of the important particular cases was performed in [10,11,12]. In the present publication the authors generalize the investigation considering statically and dynamically unbalanced rigid rotors with two-plane autobalancing devices. The paper includes an analytical study, detailed simulation results and experimental data, as well as an analysis of different measures for diminishing negative influence of the Sommerfeld-type ball motions on the vibrations near critical speeds.

INVESTIGATIONS OF THE SOMMERFELD-EFFECT

The analytical study and simulations are based on the solution of equations of motion of the rigid rotor with autobalancing device derived in [7,8]. In the analytical part the possible quasi-stationary motions are investigated by the method of direct separation of motions. The non-linear algebraic equations for determining the ball speeds in dependence on the driving moment are obtained and analyzed. The borders of the Sommerfeld-type motion are estimated and the influence of device parameters on the display of the Sommerfeld-effect and on the level of vibrations near critical speeds is depicted.

Simulations, performed employing the Advanced Continuous Simulation Language (ACSL), model the transient processes of the rotor run-up to the speed higher than critical speeds. The results of simulations are used for the optimization of the device vibration performance.

The “theoretical” results are confirmed by experimental data obtained at the specialized stand at the Otto-von-Guericke-Universitaet Magdeburg and during the test runs of the centrifuge rotor system.

The investigated effect is illustrated in Fig.1,2 presenting typical simulations results. We intentionally selected the “inauspicious” parameter values, so the Sommerfeld-effect can be clearly observed. These figures demonstrate the rotor and ball speeds and difference between them during the run up. From the start the balls fall behind the rotor. Near the critical speeds the difference between the rotor and the ball speeds becomes especially noticeable as the balls display Sommerfeld-type motion: they move with a speed close to the eigenfrequency of the rotor system, whereas the rotor gains in speed and leaves the critical speed area. After the rotor speed has reached the border value of the region of non-synchronous motions, the balls accelerate and drift to the rotor speed. In the post-critical area the balls synchronize with the rotor.

In the system of coordinates connected with the rotor the balls “behavior” looks as follows. On the initial stage of the run-up the balls slowly drift along the track in the direction, opposite to rotation. Near critical speeds the difference between the rotor and the ball speeds increase. In dependence on the device parameters, the balls can make some rounds along the track, or simply turn from one position to another. In the post-critical region the balls synchronize with the rotor and move with constant phases providing compensation of unbalance and diminishing vibrations. As it is shown in [7-9], a two-plane autobalancing device can completely compensate inherent unbalance and eliminate rotor vibrations,
whereas a one-plane device provides a partial unbalance compensation making vibrations equal to zero only in the plane of the device.

The comparison of vibration amplitudes for the rotor system with and without autobalancing device demonstrates that autobalancing device successfully compensate vibrations in the post-critical area, but, at least for the inauspicious parameters selection, bring in additional vibrations near critical speeds.

MEASURES FOR DIMINISHING VIBRATIONS

The first step in diminishing vibrations near critical speeds consists in a reasonable choice of the device parameters. The procedure of parameters selection includes the choice of the number of planes and balls in each plane, determination of the ball masses and optimization of damping. However, the possibilities of parameter selection for improving vibration performance near the critical speeds are limited. Even for the optimal choice of parameters vibrations can still be considerably high. From this point of view more promising way to diminish vibrations consists in the active control of the driving moment and/or some other rotor system parameters, for instance, the elastic coefficients of supports.

The paper considers the efficiency of different measures for improving the vibration performance of autobalancing devices.

References