Durability Increasing of Rotary Equipment Based on Monitoring and Reducing Dynamic Loads

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Abstract. The Paper is devoted to reliability of industrial rotary equipment. It is known that industrial equipment creates dynamic loads that reduces its durability, reliability and also harmfully affect on human. Increasing durability allows reducing investment costs, reducing cost for repair and maintenance, and generally improves finance indicators of industry. Monitoring of work of rotary equipment allows controlling actual technical condition and forecast defects and failures. Monitoring also allows optimization of life cycle parameters of process equipment. Reducing dynamic loads is also a very actual problem. There are several ways of reducing dynamic loads. It this Paper application of high quality vibration isolation systems and dynamic absorber is studied. Authors create and study complex systems of durability increasing of rotary equipment, which consists of monitoring systems of actual state of equipment, methodology of for determining the probability of a defect in equipment, vibration isolating systems with low dynamic stiffness and dynamic absorber.

1. Introduction
Reliability of equipment is one of the most important tasks in many industries. For example, in oil industry reliability influences on stability of gathering, transportation and refining of oil and oil products. Low reliability causes failures and even accidents that may lead to great economical and ecological problems.

For oil transportation powerful centrifugal pump are usually used. Power of such machines reaches value 10 MWt (for oil pumps NM-10000-210), so they require careful attention. Repair of such a pump requires great costs. Hence providing high reliability and durability are very important problems for the industry.

Authors suggest a complex method for providing high reliability and durability of equipment. It consists of the following parts:
- Real-time monitoring of actual technical condition of a machine;
- Reduction of dynamic loads in a machine;
- Monitoring of life cycle parameters of a machine.

2. Real-time monitoring of actual technical condition of a machine
Nowadays technical condition of a machine is usually controlled in a certain period of time, i.e. so called maintenance according to plan is used. Such way doesn't provide actual information about a
technical condition of a machine [1]. For example, some defects may occur rapidly and cause either problems in work of a machine or reduce its efficiency.

The authors are developing real-time monitoring system of actual technical condition with elements of frequency analysis. This system use permanent vibration monitoring and processing of vibration signals. It allows identification of defects in real time. General scheme of this system is shown on the Fig. 1.

**Figure 1.** Scheme of the system for real-time monitoring of actual technical condition of a machine.

Figure 2. Prototype of system for real-time monitoring of actual technical condition.

Figure 3. Window of the program for spectrum analysis.
At this moment prototype of the electric block has been made. Also a alpha-version of computer program also is ready. On the Fig. 2 process of testing the monitoring system is shown. On the Fig. 3 window of the program is shown [2].

3. Reduction of dynamic loads in a machine via vibration isolators with quasi-zero stiffness

If a defect or imbalance already exists in a equipment, aftermath of it should be maximum reduced. One way is application of vibration isolation system. Isolation between equipment (e.g. centrifugal pump) and foundation allows reduce transmitting force and hence reduce negative effect of vibration on other equipment and machines.

Nowadays one of the most perspective ways to provide high-quality vibration isolation is application vibration isolators with quasi-zero stiffness. It is such a vibration isolator that has special non-liner force characteristics providing low natural frequency and low dynamic stiffness. These parameters allows to avoid transfer dynamic force from a machine to foundation [3].

The authors develop compact polymer vibration isolators with quasi-zero stiffness [4]. Prototypes of the isolators are shown on the Fig. 4. Typical experimental force characteristics is presented on the Fig. 5. As it follows from the graph, the isolators have an area with low stiffness that provide low natural frequency, so high vibration isolating properties may be obtained [5].

![Figure 4. Prototypes of vibration isolators with quasi-zero stiffness.](image)

![Figure 5. Typical force characteristic of vibration isolator with quasi-zero stiffness.](image)

The installation scheme is represented on Fig. 3. The steel rings are assembled to the frame of the unit by welding. These rings allows vibration isolators to hold stable position. A support frame is jointed to the foundation. The supporting frame is a steel sheet, the length and width of which is equal to the dimensions of the unit frame. Steel rings for the vibration isolators are welded to the sheet. The support frame is installed by anchor bolts embedded in the foundation.

Note any hard links of machine with technological pipelines should be removed. Otherwise, machine continues to be rigidly connected to the foundation of the building and the efficiency of the use of vibration isolation system will be low. So, elastics joint in pipes and elastic supports should be used.
4. Reduction of dynamic loads in a machine via dynamic absorbers
Despite advantages vibration isolation has one general problem. It doesn't reduce oscillation in a machine, it only reduce transmission of vibration to other objects. Reducing of transmission of vibration is very important, but it is necessary to reduce oscillation of a machine. One of the best ways to do it is to use dynamic absorber. Dynamic absorber is quite simple but effective facility. It consists of a weighting agent connected to a machine with a help of spring. Mass of the weighting agent and stiffness of the spring has certain calculated value that provide the same natural frequency that frequency of the rotor of the machine. It allows the dynamic absorber oscillate in a resonance and consume energy of oscillation of the machine. Simultaneous application of vibration isolator with quasi-zero stiffness and dynamic absorber allows reducing oscillations of the machine up to zero.

5. Monitoring of life cycle parameters of a machine
Analysis of life cycle parameters allows identifying hidden defects in details and identifying manufacturers that produce equipment and detail with high probability of defects. It is possible via careful analysis of statistics of failures of accidents. Usually intensity of accidents are distributed due to classical low like on the Fig. 7. Here I - period of running-in and failure of substandard details; II - period of normal operation; III - the period of aging (failures are caused by wear of parts or aging of materials).

Analysis of statistics of failures in whole industry of an enterprise allows get general distribution of failures of a certain detail. Compare of failure distribution of a certain pump and distribution of an enterprise can show various deviations. For example at the Fig. 8 statistics of different failure in centrifugal pump. There are two peaks that greatly deviate from general trend. Detailed analysis shows that in both cases most of failures appear after almost the same duration of exploitation, and the corresponded equipment are produced by the same manufacturers. So, it should be concluded that this manufacturer has a problem in manufacturing process and he has to fix it. Moreover the other equipment that may have the same defect should be changed in advance.
I - period of running-in and failure of substandard details; II - period of normal operation; III - the period of aging

Figure 7. Classical distribution of failures.

Figure 8. Amount of failures relative to duration of exploitation.

6. Conclusion

Complex method of maintenance of machine, for example oil main pump, is presented. It consists of the following parts: real-time monitoring of actual technical condition of a machine, application of vibration isolating systems, reduction of dynamic loads via dynamic absorber and monitoring of life cycle parameters of a machine. It allows to take after a machine at every step of it life cycle. Due to monitoring of actual technical condition probability of defect occurrence is decreased to minimum. If it finally occur, its aftermath is decreased via vibration isolating system and dynamic absorber. Monitoring of life cycle parameters of a machine allows to prevent defects in future. Due to this complex method durability of rotary equipment may be greatly increased.

7. References

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