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MACHINERY DATA INPUT OPTIMIZATION IN BEARINGS RATING LIFE

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ABSTRACT
The aim of the present work is to study and optimize the weakest elements that limit bearing efficiency, thus leading to bearing failure. Software was developed to determine the performance of the bearings according to the machinery design input data and correct the main failure causes by inappropriate lubrication selection (VG), lubricant contamination (ec), filter size (β), operating temperature (T), speed spectrum (VS) and load spectrum (LS). The results of the lubricant influences into bearings rating life, along with contamination factor, speed and operating temperature are presented as diagrams.
Keywords: bearing rating life, optimal working conditions, software

1. INTRODUCTION

The rolling-contact bearing is a machinery element with a very important role, since it dominates the machine's performance. The main purpose is to perform relative positioning and rotational freedom while transmitting a load between two bodies, usually a shaft and housing. Bearing failure has great impact on industry and economy. When designing a machine, all the parts are taking in consideration to achieve high performance and durability. Nowadays, all efforts are concentrated in finding new solutions that involves minimum production costs, maintenance-free, weight, dimension and material reduction that can negatively influence the final product safety and quality. If one of the bearings breaks, the efforts were worthless. But even if the machinery design and bearings selection were properly made, there are still a lot of other elements that can dramatically influence the proper operation of the assembly. Generally, the main characteristics that can influence the rotating machineries are rotating speed, torque, load, lubricant and operating temperature. Even if all these factors are considered, the life time of a single bearing is impossible to be accurately predicted. Also, bearings selected from the same manufacturer, which may appear to be identical, operated under identical conditions, can perform a different amount of time. Bearing materials are very complex and they are not homogeneous in all points, meaning that fatigue process will occur different in apparently identical bearings, operating under the same conditions. For this reason the fatigue process became a statistically determination. In order to be able to determine the amount of time in which a bearing will perform under certain working conditions a stipulated number of stress cycles or revolutions without testing a sufficient number of bearings for the particular application, a reliable life calculation at a given survival rate is considered to be a substitution for accuracy. On modern machinery design, costs and maintenance free efficiency represents the most important criteria that must follow the performance.

By eliminating the adjacent maintenance costs, the machinery is often subjected to failure due to uncommon running practice generated by a wrong running procedure disregarding the application technical specification. To eliminate this inconvenient, software has been developed to assure the desired designer expectations and to assist the applications parameters.

2. SOFTWARE

The main task of the software is to determine the performance of the bearings according to the machinery design input data and correct the main failure causes by inappropriate use of the application. Frequently, to increase the activity the operators abuse the machinery, using speeds and loads higher then designed ones, resulting in damaging the weakest components like lubrication, bearings, seals and finaly the application. The software was developed in LabVIEW (Laboratory Virtual Instrumentation Engineering Workbench) for a continuous monitoring of the application. The software use a data acquisition external chassis type SCXI-1000 and use two channels to acquire the temperature and the speed directly from the bearing position. When installed, the software is configured with data`s regarding the application functionality (load spectrum (LS), speed spectrum (VS), operating temperature (T), lubricant type (VG), filter size (β)). Then the operator selects the bearing type from the internal data base and, inserted as input data, the software performs an initial calculation, establishing the static [1] and dynamic load rating [2]. These calculations are made following the ISO 76 - Third edition 2006-05-01 and ISO 281 - Second edition 2007-02-15.

$$C_r = b_m \cdot fc \cdot \left(i \cdot L_{we} \cdot \cos(\alpha)\right)^{7/9} \cdot Z^{3/4} \cdot D_{we}^{\;29/27}. \quad \text{... (1)}$$

$$C_{0r} = 44 \cdot \left(1 - \frac{D_{we} \cdot \cos(\alpha)}{D_{pw}}\right) \cdot i \cdot Z \cdot L_{we} \cdot D_{we} \cdot \cos(\alpha). \quad \text{... (2)}$$

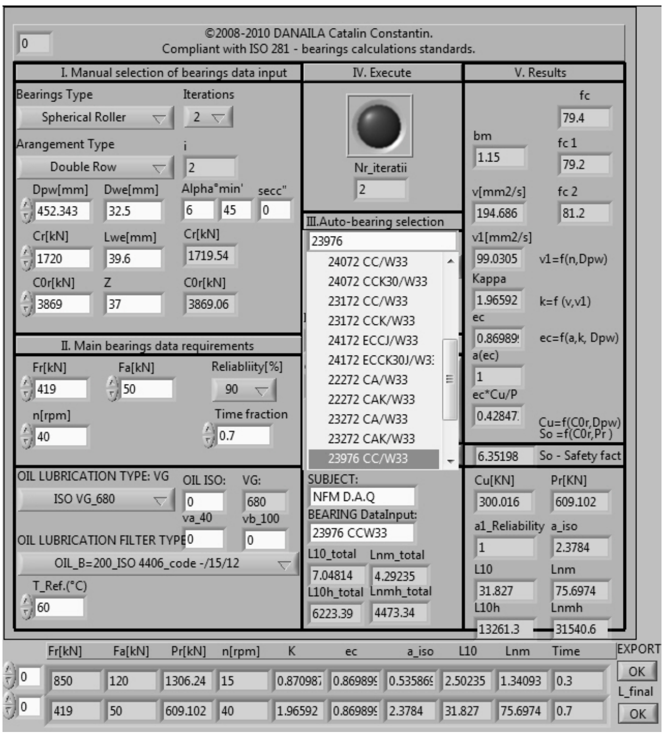

Figure 1. Software data interface.

If the bearings designation is not in the software internal data base, the operator can insert the main characteristics of the bearing (pitch diameter of ball or roller set, in millimeters (Dpw), roller diameter applicable in the calculation of load ratings, in millimeters (Dwe), number of rows of rolling elements (i), effective roller length applicable in the calculation of load ratings, in millimeters (Lwe), nominal contact angle, in degrees (α), number of rolling elements (Z)). When the machinery start to operate and the application have reached its speed (VS) and operating temperature (T), the lubricant must have a given minimum viscosity described by the viscosity ratio (k) in order to form an adequate lubricant separation film. Taking in account this information and the condition of the oil before it passes the filter (VG) the software calculates the contamination factor (ec) and plots it on the screen in order to be evaluated. With all these data sets, the software establishes certain limits to protect the applications performance if parameters are to be changed by the operator. An increasing value in the operating speed will change the temperature and the software recalculates the contamination factor (ec) and compare-it with the initial value. If the value decreases drastically under the projected value, the software will give warnings and after an amount of time, will send a signal (5 Volt) thru the data acquisition card and stop the application.

$$k = f(T, VG, VS)\,. \qquad \text{... (3)}$$

$$e_C = f(k, \beta, D_{pw})\,. \qquad \text{... (4)}$$

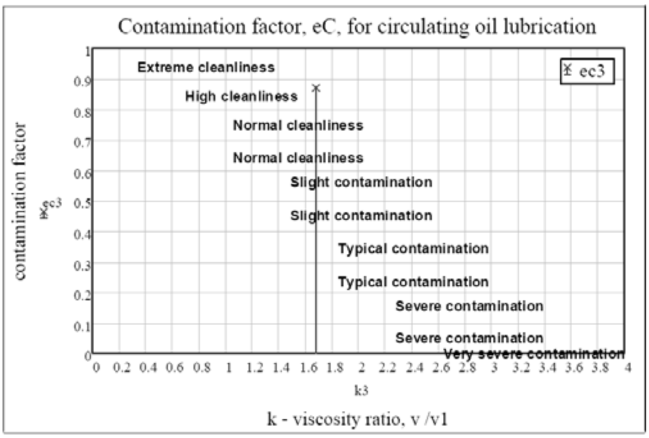

Figure 2. Software evaluation for contamination factor (ec).

Table 1.Operating conditions.

Time	[%]	30	70
n	[rpm]	15	40
Fr	[kN]	850	419
Fa	[kN]	120	50
T	[°C]	60	60
Oil	[VG]	680	680

When the application is designed, the bearings are selected to sustain multiple operating conditions in order to satisfy the requested life time. Operating conditions myght change during the running time due to several causes (shocks, accelerations, variable loads, temperature fluctuation, etc…). After the contamination factor (ec) was determinate, the software calculates the life modification factor, [1] based on a systems approach of life calculation (a iso) applied to the bearing modified rating life in hours (Lnmh), by splitting the total working time in fraction.

$$a_{ISO} = f\left(\frac{e_C \cdot Cu}{P}, k\right). \qquad \text{... (5)}$$

$$L_{nm} = a_1 \cdot a_{ISO} \cdot L_{10}\,. \qquad \text{... (6)}$$

$$L_{nmh} = \frac{1}{\sum_{j=1}^{time} \frac{T_j \cdot 60 \cdot n_j}{10^6 \cdot L_{10m}}}\,. \qquad \text{... (7)}$$

The test was performed on a MDU (main drive unit) of the tunnel boring machine based on a multiple conditions diagram (Table1), where 30% of total working time, the application was subjected to heavily forces, but limited speed in order to maintain a constant temperature of 60 degrees Celsius. In the second part, 70% of total working time, the speed was increased but the forces applied on the bearings were diminished, to maintain the operating temperature. The total modified life time is then plotted and compared with the requested life time. If the difference is considerable, the software will alert the user of the application about the calculated conditions and provide important information. After running the mathematical module by applying the application parameters, the software evaluate the life time considering large spectrum of temperatures and speeds, informing the user with the potential life fluctuation if the data input are not followed. If the bearings must be changed due the fatigue process, even with other manufacturer class, the software can be reset to initial position and the operator can perform again the steps to assure the machine stability and maxim performance during the exploitation. Mounting, dismounting and lubrication must be followed according to the application technical specification. If the lubrication type and filter are to be change, the software must be updated with information regarding lubrication selection (VG) and filter size (β).

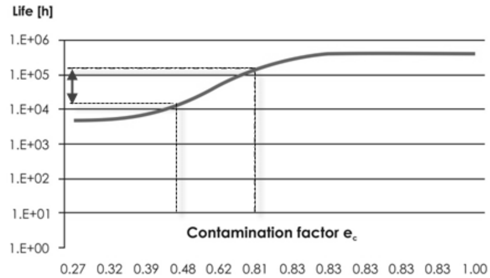

Figure 3. Life time evaluation for (ec).

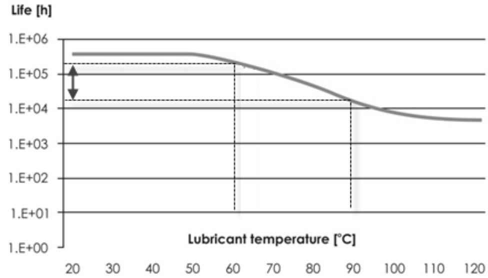

Figure 4. Life time evaluation for (T).

3. CONCLUSIONS

The software assists the application and optimizes the correct selection of these key elements in order to increase the reliability of the machinery and allows the bearings to operate in optimal conditions. As the figure 3 and figure 4 are showing, a proper selection of the lubricant, a good filtration and a proper speed-temperature ratio, will protect the application and will allow a proper running of the bearings. If new operating demands are to be covered, the software is able to study and propose the lubricant types and filters, speeds and temperatures, indicating continually the important numbers. When selecting the bearing, taking account of its internal geometry, the software compare the safety factor with the forces applied by the operator and alert if the parameters are overloaded. By optimizing the load spectrum, the lubrication conditions, the cleanliness and other operating conditions, a modern high quality bearing can attain an infinite life that will positively influence the life of the entire system.

4. REFERENCES

[1] ISO 76:2006(E): Rolling bearings - Static load ratings, Third edition 2006.,
[2] ISO 281:2007(E): Rolling bearings - Dynamic load ratings and rating life, Second edition 2007.,
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