Analysis of Shaft Alignment Fault of Asynchronous Motors by Current Signature Method

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***Abstract*— The aim of the paper is the prediction and analysis of shaft alignment fault of asynchronous motors by current signature analysis. The aim of the paper is the prediction and analysis of shaft alignment errors of asynchronous motors by current signature analysis. Mechanical fault prediction plays an important role in the detection of engine faults. Nearly 50% of machine [1-24] downtime is due to a mechanical error, so it is necessary to develop a predictive measurement method. The dissertation presents a method that analyzes the shaft alignment signals of a four-pole asynchronous motor and gives an fault map from it.**

***Keywords*— asynchronous motor, motor current signature analysis, shaft alignment insert, fault frequency**

I. Introduction

Nowadays, the role of condition monitoring of electrical machines has reportedly changed the simple analog measurement procedures developed for rotating machines, the rapid development of computer [1-24] technology and combined with measurement technology allows the processing of “unlimited” amounts of information. It is a process of processing and an information-gathering process that defines the current physical state of the machine and can form a learning system. The process, the electrical machine, and the measurement processing unit built around it can also be thought of as a rich set of numbers, including all the descriptive functions and phenomena that accompany a machine’s life cycle. Information carrier, for example: the spectrum formed from the current signal, its amplitude and frequency components, and then the analyzes performed on it. Electrical machines (asynchronous motors in this dissertation) are part of an integrated system (frequency converter, sensors, software, etc.) and already work with it. In this process, it is possible to set up an operational map of the machine, be it a continuous, intermittent, transient operating condition. Many rotary machines are present in the industry, cooperation and control is required, continuous condition monitoring. Here, the goal is no longer just to detect fault signals, but to manage and develop this beyond the source of information, moving towards the field of self-learning electric drives. Joint work of machines and systems, analysis and correction of each other's operating characteristics, drawing conclusions from it. Diagnostic testing of asynchronous motors was started in areas where the condition testing of machines played an important role due to operational safety. When coupling rotary machines, the adjustment of the shafts is one of the most important mechanical requirements. During operation of the machines, the shafts may move in other directions, causing additional noise and vibration. Shaft adjustment significantly affects the power and speed of the electric rotary machine. Previously, these were determined by vibration measurement to determine what vibration speed is acceptable for a given type of engine. A significant part of the machine failure is due to the shaft alignment fault, which also depends on the mode of operation of the motor.

II. Search for an Fault Signal Based on the Current Spectrum

A.) Shaft alignment fault analysis

The first step is to calculate the basic harmonic of the shaft misalignment fault.

There is basic formula:

$$f_{load} = f_s \pm m \cdot f_r$$

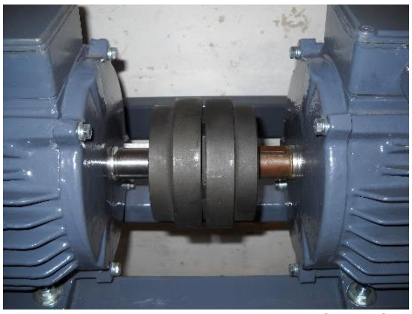
where

f_{load} is load frequency

$f_s =$ is electrical supply frequency

$m = 1, 2, 3, \ldots$

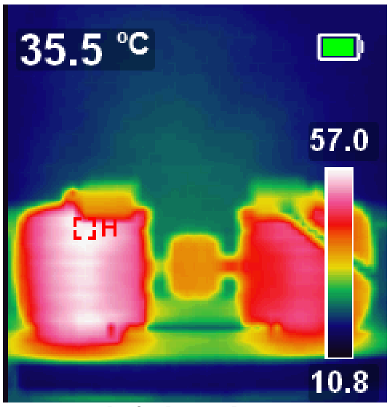
f_r is rotational frequency



1. Figure. Coupling the shafts of asynchronous motors.

The clutches of the asynchronous motors are provided by a clutch with a claw rubber insert.

A thermal image of the shaft connection of the asynchronous motors was taken continuously during the measurement.



2. Figure. Shaft thermal imaging. Examination of the temperature distribution on the coupling.

No significant temperature asymmetry is yet visible in this first thermal image (2. Figure).

B. *Measurement Concepts*

The target area of the paper is the diagnostic measurements of electric rotary machines, be it industrial or industrial research applications. The theoretical and practical experience of recent years has provided a significant basis for the birth of the work.

Assessing the diagnostic procedure and applicability of electric rotary machines, which means considering and combining currently known measurement methods to identify a machine-specific fault.

Phase current measurement and spectrum generation from it.

• Temperature measurement and calculation

• Thermographic measurements

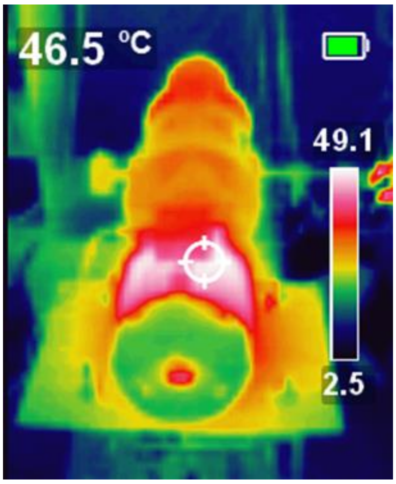
The procedures listed above provide a basis for starting work. When measuring rotating machines, the question of accessibility, how to carry out the work, must be borne in mind, which means that the measurement methods I have carried out and thought through can be divided into two parts.

• Measurements that can be performed under laboratory conditions.

• Measurements can be made under industrial conditions.

III. Shaft Coupling Fault Monitoring First Using a Thermal Imager

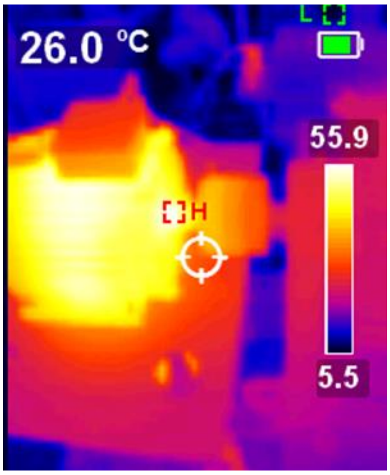
The pictures will show the continuous shaft coupling heating.



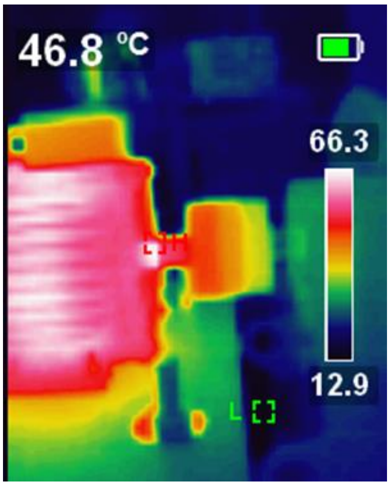
3. Figure. Asynchronous motor connected to a load machine (rear view).

The temperature distribution of the shaft coupling was checked using the thermal imager.

The temperature increase can be seen in the following pictures.



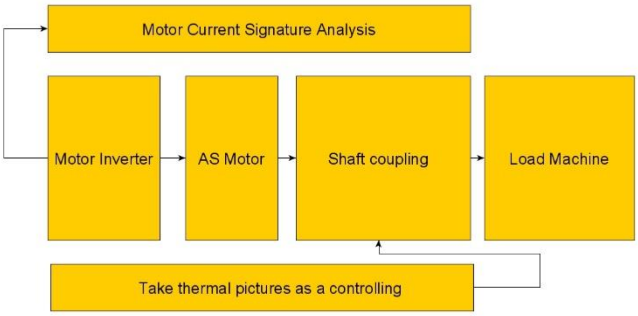
4. Figure. Asynchronous motor connected to a load machine (side view).



5. Figure. Asynchronous motor connected to a load machine (side view, warm condition).

A. *Structure of the machine group*

The load machine follows two types, there were asynchronous machine as generator and direct current generator. Machine group layout:



6. Figure. Machine group layout.

Working with other motors is a significant problem when placing machines.

This means that vibration transmissions make it difficult to clearly identify fault signals. Several shaft coupling are used for the measurement.

7. Figure. Machine group layout.

B. Fault frequency identification based on current signal

Measurement preparation: In this measurement cycle, a 3 kW four-pole asynchronous motor from the VZ motor series, once manufactured by EVIG, was used. In axial connection with a balance dynamo once manufactured by Siemens. The machine group has been specially designed for this series of measurements, which means that all "industrial faults" can be modeled on it, such as: shaft alignment error and vibration transmission phenomena, shaft height adjustability.

Measurement program: Lifetime estimation procedures require a longer time, depending on how we want to search for the error to be caused, i.e., the runtime and conditions had to be chosen so that a detectable error signal could be obtained correctly and evaluably. How can this be done? Of course, in recent decades, there have been (and are present) a number of test methods in factories related to lifetime testing, which cannot be mentioned in detail in this dissertation, but it should be noted that a longer cycle of up to a thousand hours is required. order of magnitude. The series of measurements, which began with a warm-up test in 2017, was then commissioned by the machine group. In that year, three to four hour warm-up measurements were performed on a weekly basis. The measurement cycle has changed, it has become more frequent, it has accelerated in the last one year, so by the end of the period we managed to reach the order of a thousand hours. Compared to the life cycle of the engine, this is not considered much either, so I used an acceleration process. The test was measured on the selected asynchronous motor with several axis alignment errors (angle, parallelism, perpendicularity error). This was one way for me to urge a malfunction and another for heating. The time constraint included a framework for conducting the study, but all important factors that affect effectiveness must be considered, which is why it is essential to apply operations research both before and during work.

The planning of the measurement cycle was preceded (accompanied throughout) by the formulation of an activity process. The duration of the warm-up test and the issues of re-measurements in terms of achieving thermal heat balance for different ambient temperatures required all experience to date. The thermal conditions are greatly influenced by the ambient temperature and the cooling system of the engine, in my case this is simpler due to the machine with external cooling. This was one aspect in determining activity times and the other was the length of time that could be maintained. My target was to reach a thousand hours, let there be a longer cycle. During the measurements, switching problems can also occur, which gave me the impetus to use the algorithm presented here for preparation.

C. Application of operations research in diagnostic measurement of electric rotary machines

- performed an optimal calculation to review measurement and time cycles. For algorithm design, PERT (PERT = Program Evaluation and Review Technique) and (CPM = Critical Path Method).
- Measurement cycle design using PERT-CPM algorithm, taking into account the activity times of random dependent probability variables, based on statistical estimates. Let the optimistic estimate of activity time be a-marked, the pessimistic estimate b-marked, and the most probable estimate μ-marked. It is worth considering the activity time as a probability variable, the density function of which takes its maximum only between non-zero and μ between a and b. It has a density function of the so-called for β-distribution:
- $f_{(x)} = \{C\,(x-\alpha)^{\alpha-1}\,(b-x)^{\beta-1}, \text{if satisfied}: a \leq x \leq b\}$

  α and β are positive divergent numbers, and the constant C is chosen such that,

$$\int_{-\infty}^{+\infty} f(x)\,dx = 1 \text{ be fulfilled.}$$

The density function is the maximum:

$$\mu = \frac{\alpha \cdot (\beta - \alpha) + b \cdot (\alpha - 1)}{\alpha + \beta - 2}$$

Pick it up at this place.

In practical applications, it is customary to assume that the probability variable of the duration of activities is β-distributed, with two parameters:

$$\alpha = 3 - \sqrt{2} \text{ and } \beta = 3 + \sqrt{2}$$

IV. Stator Phase Current Spectrum

Engine data used: Bearing data origin: Based on a search of the 6206 Z bearing series.

The calculation process presented in the previous section precedes the signal processing steps. This data can be stored in databases and reused.

Rotary machine diagnostics is a diverse field of expertise, so for now I will focus only on the asynchronous machine type. Current waveform analysis is an extremely widely used method, with a set of instruments and measurement procedures already developed today, the possibilities of which I examine in this chapter.

A. Motor current analysis

The motor current contains a lot of information about the current operating status of the motor. There are known methods for their determination. The series of measurements I performed was aimed at having as much information as possible about the behavior of the motor when using different power modes.

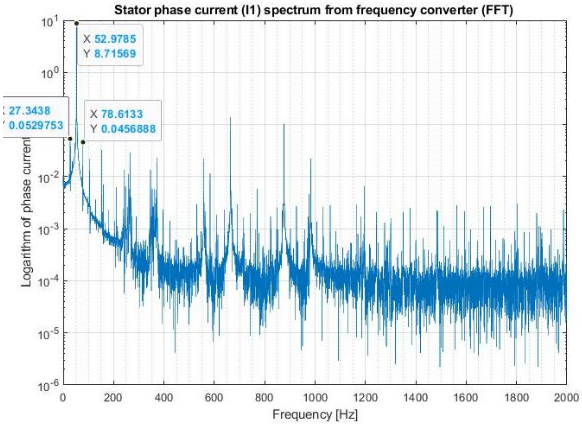
a) . For example, bearing fault frequency *b) Broken bar fault frequency*

c) Imbalance fault frequency

In this one article, I will examine the part caused by shaft alignment.

B. *Multiple fault analysis for shaft misalignment*

Spectral calculation was performed by fast Fourier analysis.



8. Figure. Motor current signature analysis with fast Fourier transform.

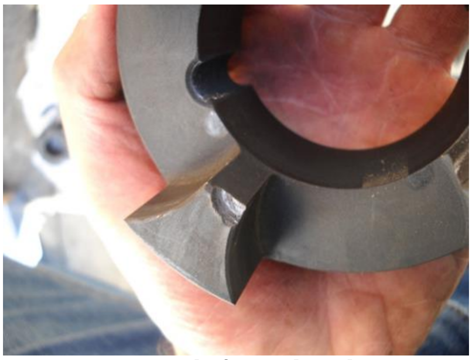
The next task is to set up a machine-specific data system that gives the most optimal state of the motor. The basic interpretation procedure is according to the spectra formed from the current signal.

Test criteria:

- Sampling time
- Speed range
- Pattern length
- Number of samples to be stored
- Number of repeated measurements
- Need for re-measurements
- Variable signal length
- Frequent sampling frequency
- Search default method
- Engine operating type
- Temperature conditions
- Power supply voltage stability
- Shaft coupling type
- Motor operating time

The current supply frequency of the motor is 52.97 Hz

The two extreme values indicate the shaft alignment fault (27.34 Hz and 78.61 Hz). The motor is at full load with a shaft torque of 20 Nm. This fault was demonstrated using a thermal image. The error signals appeared several times, which caused an unexpected (9. figure) phenomenon.



9. Figure. Shaft coupling damage.

The calculation, if we know the data of the machine, then the characteristic frequencies can be calculated from the geometrical data of the bearing, these are derived from mechanical rotation, which can be used in the case of vibration measurement, but only in the current spectrum. The other method is true in the absence of information about machine bearings, we are not sure exactly what error frequencies to look for. In this case, the spectrum analysis is possible with the help of a model or models, which may only apply to the bearing and rotor, other components.

The values marked in the spectrum refer to the rotational frequency.

ACKNOWLEDGMENT

Predicting a shaft misalignment will help prevent major damage. In the work we managed to get acquainted with the modern application of signal analysis and its possibilities. The role of the interaction of faults was omitted from the detailed analyzes. The machine can be examined for signals from itself, signals from the network, and their interaction. The results showed the effect of the excitation frequency caused by the shaft alignment on the faults produced by the bearing. When writing the search function, the question arose to develop an analysis method that not only counts multiples of the frequencies that can occur in a bearing, but also compares them statistically with different excitation [1-24] frequencies. This makes the use of a separate math set critical.

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