Study of DC Motor Diagnosis Based on the Vibration Spectrum and Current Analysis

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Abstract— **In this paper fault detection of permanent magnet dc motor is described. In past, Current Signature Analysis (CSA) has become an established tool for online fault analysis of AC induction motors. Presently, very little research has been performed using current signature analysis on DC motors. This paper is a brief introduction to fault diagnosis of DC motors using vibration and current signature analysis. In order to do the diagnostics there are analyzed vibration from the piezoelectric accelerometer. The accelerometer is mounted on the frame's motor. Also, for the current measurement it's used ampere sensor. Initially the measurements were realized by using "healthy" DC motor. Then we made successive measurements for the same type of motor with provoked faults. The many faults of DC motors are regarding collectors motor, the commutator short circuit and displaced permanent magnet out of poles in polar axe. We observe significant vibration and also current spectrum differences between "healthy" motors and faulty electrical motor. The spectral analysis of current and vibration provides a method to detect DC motors faults. Using these methods, diagnostic of commutator short circuit and displaced permanent magnet out of poles in polar axe, would be detected even if the motor operated unload.**

I. Introduction

Low power permanent magnet dc motors are widely used in automotive industry. DC motors are, also widely used in industrial systems, such as robotic manipulators, because their control is relatively simple and they are reliable for a wide range of operating conditions. Fault diagnosis of DC motors are quality control have received growing in the attention of engineers [1].

The possibility to give a prognosis for the eventually fault of a system is synonymous to detecting conditions that lead to reduced performance and eventual damage of the equipment. With this prognosis, attention can be brought to any problems a system may know before they cause the system to fail. The presence of small transient signals or larger, perhaps noisy signals always present in the electric system may indicate lack of health and a more or less imminent fault. [2]

The electric motor is a prime example of a electrical system, where failure occurring at an inopportune time can be inconvenient, expensive and dangerous. [3]

In the automotive industry the reason why there is a growing need for the development of the procedures for fault detection and diagnosis, in order to increase reliability and the availability of the electric motors part's of the automobile with the purpose of reducing the maintenance costs for the car.[4], [5]

Also, an early detection and diagnosis can help avoid car's system breakdown and material damage,[6],[7]

II. Vibration and Current Electrical Equipment Diagnostics

Basically, vibration is oscillating motion of a particle or body about a fixed reference point. Such motion may be simple sinusoidal or non-sinusoidal. Vibration can cause damage to structures and machine sub-assemblies, resulting in disoperation, excessive wear, or even fatigue failure.

Most vibration measurements usually use sensors of vibration-acceleration that work based on the piezoelectric effect. For this type of sensors the output electric charge is proportional to the force applied to the sensor.

The vibration signal is converted in electric signals. It is necessary to analyze this signal without loosing the diagnostic information. There are very strict requirements for the analyzing instruments. The operations that the vibration analyzing instruments must perform are the following:

- Measurement of overall vibration level in a standard frequency range and using the units required by these standards;
- Spectral analysis of the vibration, by using FFT.
- Analysis of the oscillation power of separate vibration components extracted preliminary from the vibration signal;
- Vibration spectra are generated from collected data by the accelerometer using FFT.

Experimental methods focus on vibration and DC motor current diagnosis. The tested methods are according to standard procedure of product and measurement's sizes. A specialised system was used for measure vibration with regard to electric equipment diagnosis. The measurement was realised in a noise and vibration studies laboratory. After completing the measurements, we should adapt the method to monitoring of supply current of DC motor.

The experiment has focused on DC motor diagnosis, more precisely the commutator short circuit and displaced permanent magnet out of poles in polar axe, using vibration and DC current analysis. This is why the sensors used for measurements were:

- the piezoelectric accelerometer for the vibration measurement ;
- ampere sensor for the current measurement.

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Initially the measurements were realised by using electric motor with a "healthy" motor. Then we did the same measurements for the same motor but with different faults.

III. The Vibration and Current Signature a DC Motor

The motor tested in this paper is a type of permanent magnet DC motor. The nominal operating conditions of the motor are as follows:

- rated voltage 12V,
- rated power 0.4kW,
- speed 4000rpm.

Initially the measurements were realised by using "healthy" DC motor. Then we made successive measurements for the same type of motor with provoked faults.

Based on experience the many faults are regarding collectors motor, the commutator short circuit and displaced permanent magnet out of poles in polar axe.

IV. DC Motor Vibration Signature

The harmonic vibrations spectra from figures are generated from data obtained by the piezoelectric accelerometer mounted on the DC motor's frame.

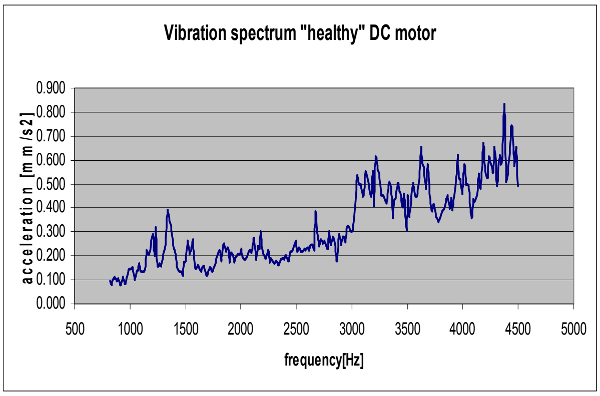

Fig. 1. Vibration spectrum for DC motor without fault

In fig. 1 is presented harmonic vibration spectrum for the DC motor without fault. The higher acceleration level is around 0.8 mm/s^2.

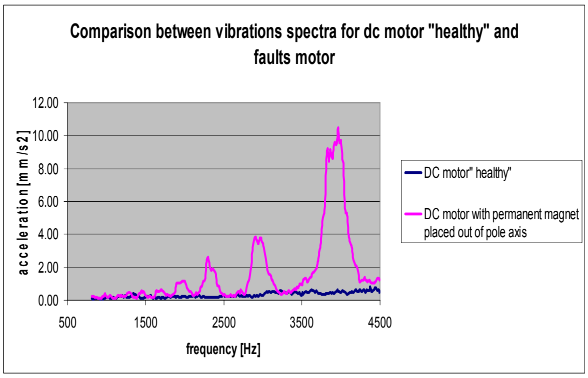

Fig. 2. Vibration spectrum for DC motor with permanent magnet placed out of pole axis

Then, we have placed one of permanent magnet in DC motor frame out of pole axis. There is a large difference between vibrations of the fault motor than "healthy" motor at 4000 Hz frequency, is around 10 mm/s^2.

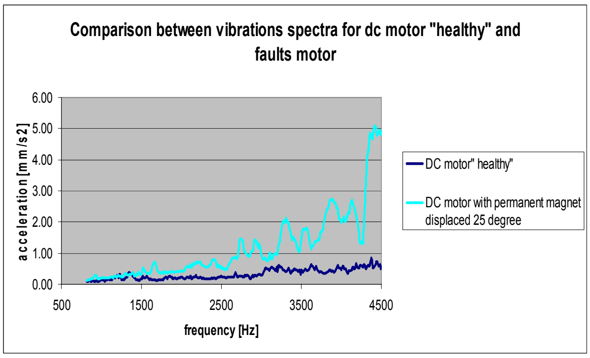

Fig. 3. Vibration spectrum for DC motor with permanent magnet displaced 25 degree out pole of axis

Similarly we have placed one of permanent magnet in DC motor frame 25 degree out of pole axis. The vibrations in smaller than the complete out of pole axe but, the bigger than the "healthy" motor at 4000 Hz frequency, is around 4mm/s^2.

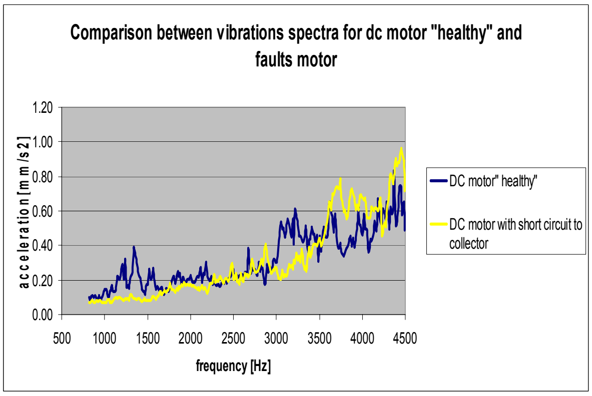

Fig. 4. Vibration spectra for DC motor with short-circuit to commutator

In fig.4 the harmonic vibration spectrum gives us information about the acceleration level in case of short circuit between two coopers bars, the vibration level is 0.7 mm/s^2.

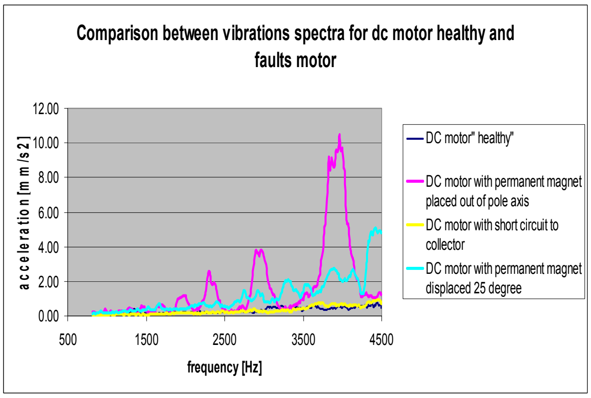

Fig. 5. Comparison between vibrations spectra for DC motor "healthy" and with faults

We make this analysis comparing the vibration spectrum obtained by the "healthy" motor - faults motors, and observe an increase of the vibration level in the motors faults.

For the relevant conclusions it is need to make a zoom in for the 2000-4500 Hz and 500-2000Hz frequency range. So we are obtained the spectra presented in the following figures.

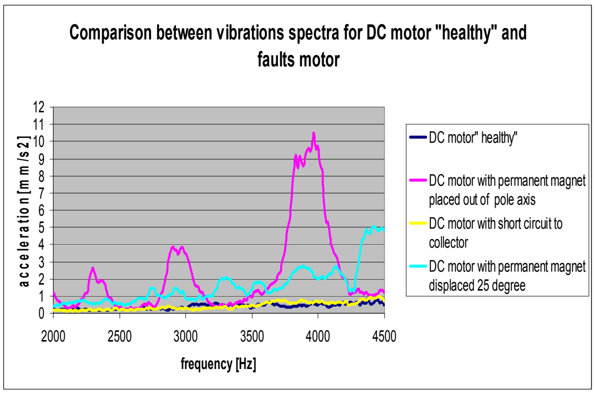

Fig. 6. Comparison between vibrations spectra for DC motor healthy and with faults for frequencies range 2000-4500 Hz

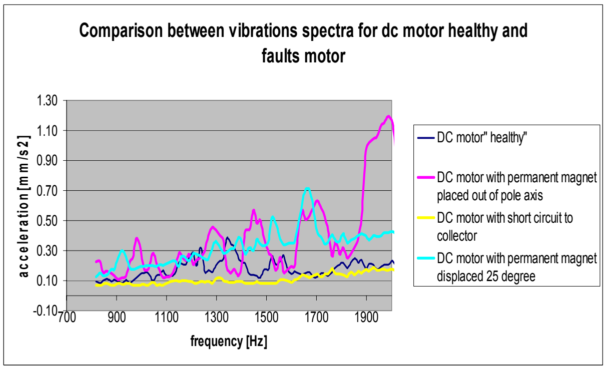

Fig. 7. Comparison between vibrations spectra for DC motor healthy and with faults for frequencies range 700-2000 Hz

The analyses of vibration spectra are focused on the frequency range 2000 – 4500 Hz and we observe that for the 4000 Hz the acceleration has been increase progressive depending on the type of fault.

For the smaller frequencies of motor the vibration has a unobvious evolution from the "healthy" to fault.

We observe that the acceleration corresponding to the motor with short-circuit it is smaller than motor without faults. The explication of this fact is that moving of the brush on the commutator with short circuit is easier (the current commutation is different), so the vibration level decreased.

V. DC Motor Current Signature

The current analysis is very useful for DC manufactures in faults diagnosis.

In figures 8,9,10,11 we present the harmonic current spectrums for the DC motor "healthy" and with diferents fault.

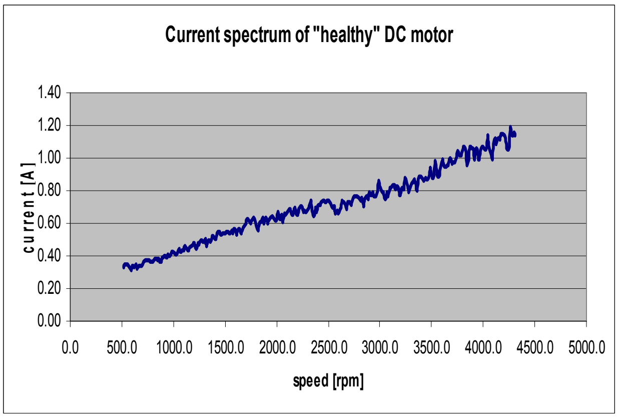

Fig. 8. Current spectrum for DC motor without fault

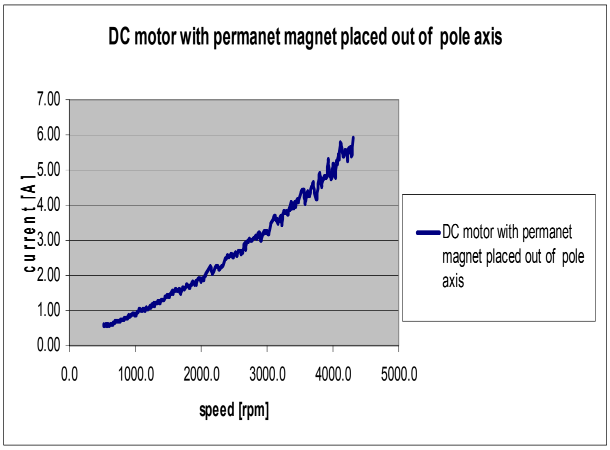

Fig. 9. Current spectrum for DC motor with permanent magnet placed out of pole axis

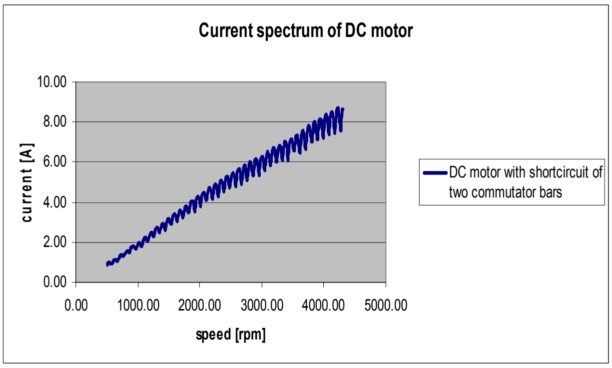

Fig. 10. Current spectrum for DC motor with short-circuit to commutator

In figure 12 and we present the DC current spectrums comparative analysis for DC motor "healthy" and with different faults.

For the relevant conclusions it is need to make a zoom in for the speed range 500-2000 rpm. So it is obtained the comparison that in figure 13.

We observe in the speed range 500-2000 rpm the amplitude current beginning with DC motor with permanent magnet placed out of pole axe and finally with the bigger amplitude for the DC motor with short circuit to commutator bars.

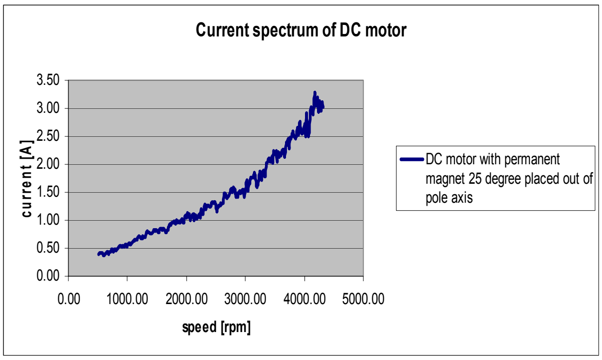

Fig. 11. Current spectrum for DC motor with permanent magnet displaced 25 degree out pole of axis

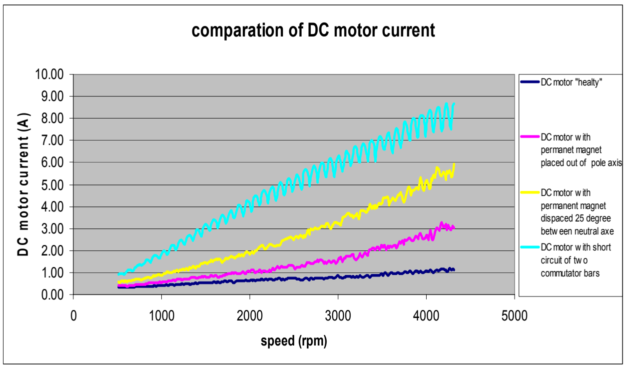

Fig. 12. Comparison between current spectra for DC motor “healthy” and with faults

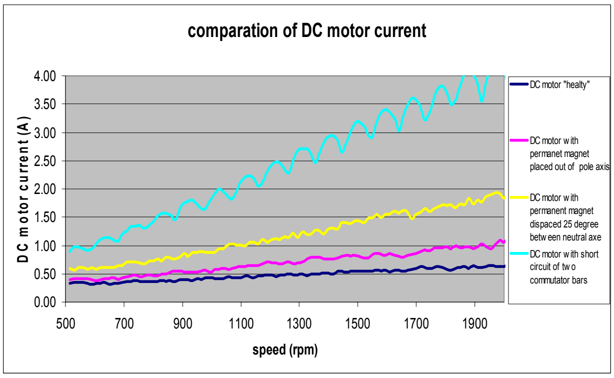

Fig. 13. Comparison between current spectra for DC motor healthy and with faults for speed range 500-2000 rpm

It is demonstrated that the method of DC motor current signature is very efficient to make DC motor diagnosis,

Also, it is known the fact that the short circuit to commutator provoked damage of the DC motor. Using the current signature these kinds of faults can be detect in the incipient stage.

VI. Conclusions

The technique of evaluating the motor condition by performing a FFT of the DC motor vibration and current has been verified by the experimental results. In this case electric motor vibration and current monitoring is very useful to detect the commutator short circuit and displaced permanent magnet out of poles in polar axe faults.

By the corresponding zoom we can observe that vibration and DC current it is different at the “healthy” motor related fault motor.

Having these measurements in the future we want to design a neural network which will help us to build an expert system. This way we decide if the motor is healthy or fault.

Thanks to these methods, the diagnosis the commutator short circuit and displaced permanent magnet out of poles in polar axe could be detected even if the motor operated unload.

So, the plant maintenance can easily and successfully detect mechanical fault that lead to unexpected downtime.

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