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Study of a Low-Cost Piezoelectric Sensor for Three Phase Induction Motor Load Estimation

Authors: Guilherme B. Lucas, Bruno A. de Castro, Marco Rocha and André L. Andreoli

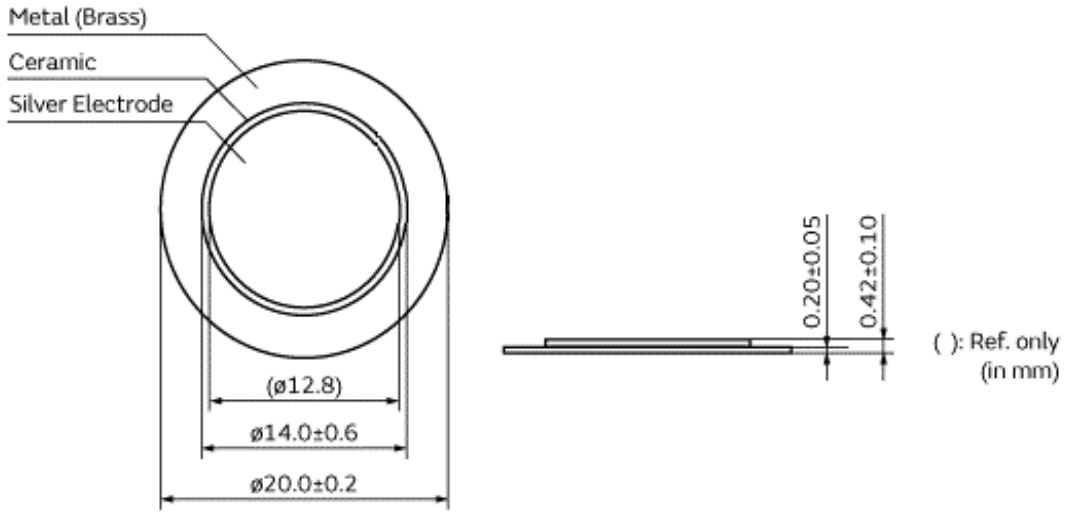
Presenter: Dr. André Luiz Andreoli

Introduction

- Nowadays, the development of several types of sensors have been increasingly the focus of several studies aiming to accomplish the correct feature extraction about the three phase induction motor (TIM) operation;
- The most of the currently NDT-based systems can only be employed for failure diagnosis in TIMs by using accelerometers or acoustic emission (AE) sensors, which have high financial costs. For this reason, this type of sensors is still an obstacle for dissemination of NDT in industries.

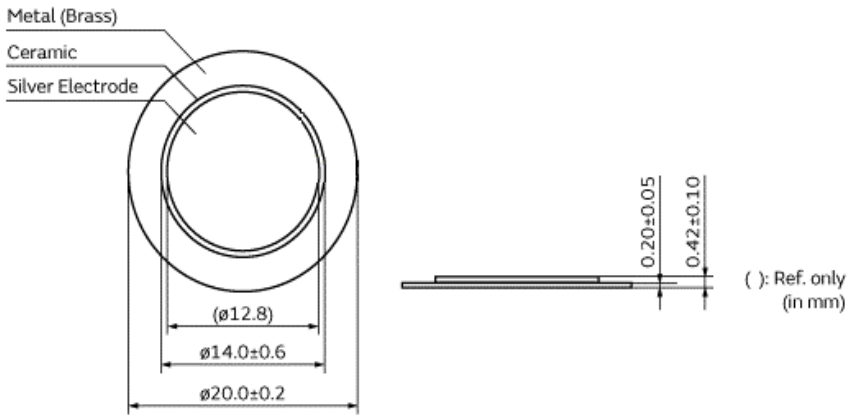
Objective

- This works aims to validate the low-cost piezoelectric sensors for vibration analysis and TIM;
- The specific transducers used in this work were the piezoelectric diaphragms, which have similar characteristics to conventional PZT ceramics. The diaphragms have a circular brass plate whose dimensions are 20 mm x 0.2 mm that houses a circular piezoelectric ceramic with dimensions of 14 mm x 0.42 mm, which is coated by a metallic film.



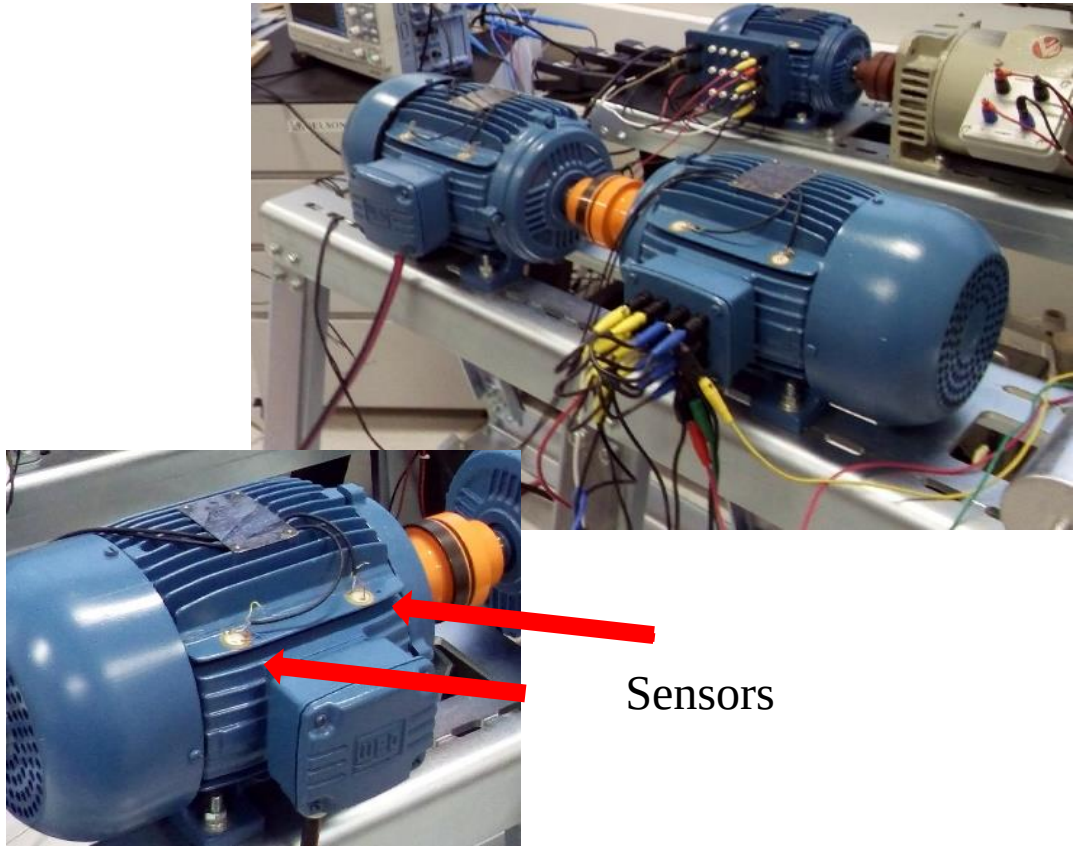
Piezoelectricity and NDT in TIM

- The piezoelectricity can be defined as a bidirectional electromechanical phenomenon perceived in some specific materials known as piezoelectric crystals;
- If a mechanical force is applied to a capsule, containing piezoelectric crystals, an electric charge will be induced on its terminals, otherwise, if an electric charge is applied to its terminals, a mechanical deformation will be perceived on this capsule;
- Piezoelectric transducers can be sensitive to the TIM pattern vibration, performing a NDT.



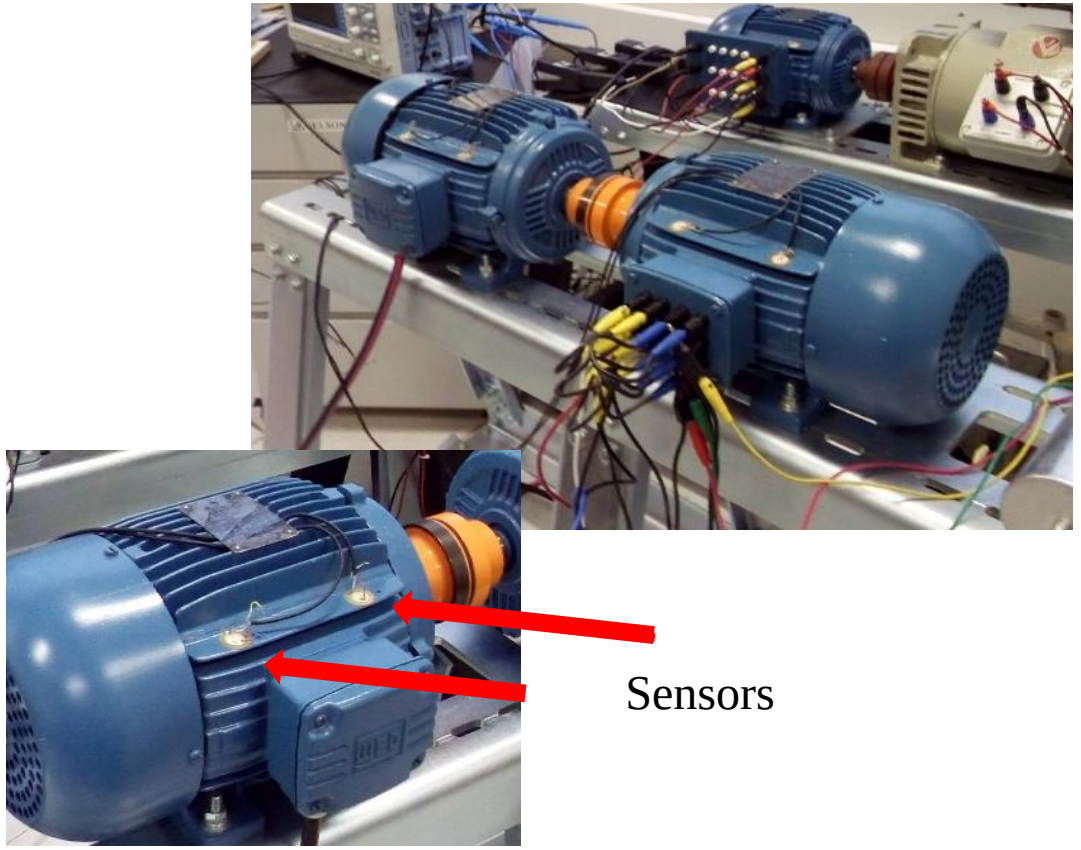
Experimental Setup

- Two electrical machines were used to perform the tests:
- TIM and an Induction Generator (IG) as a mechanical load.
- Both machines were fixed firmly on a bench and their shafts were coupled using a metal joint. The piezoelectric were attached in TIM.



Experimental Setup

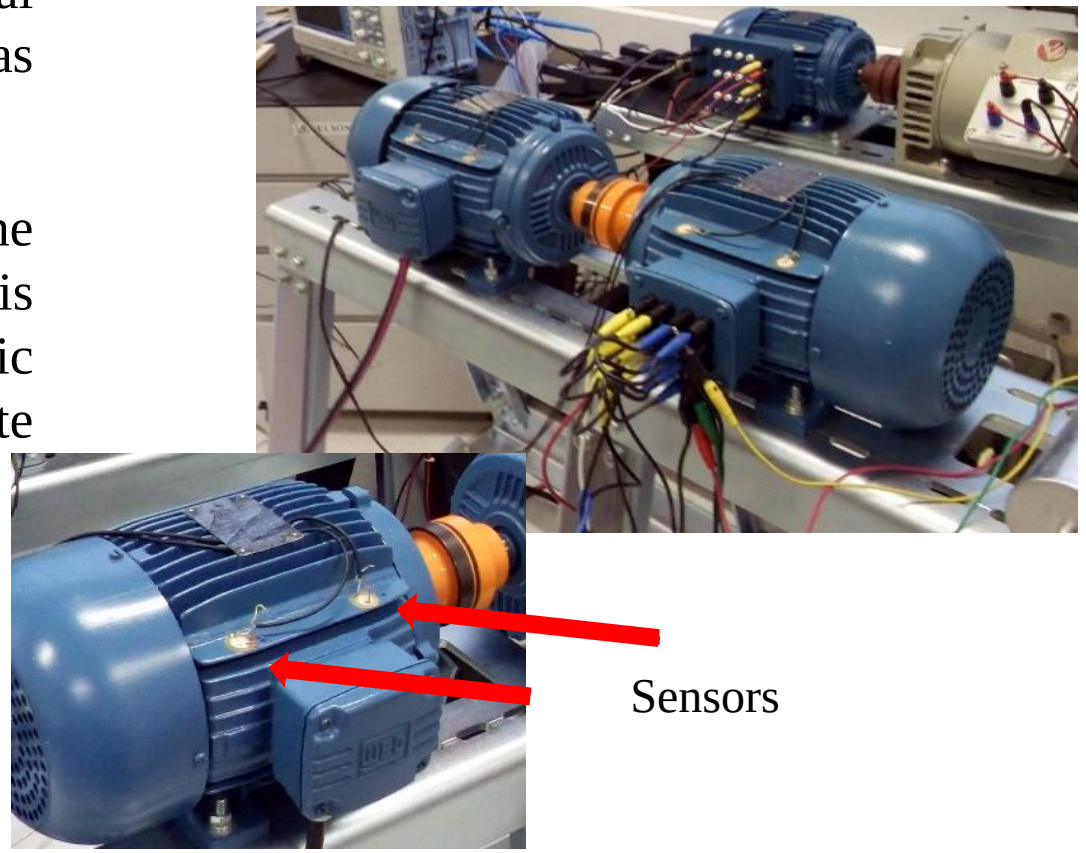
- The signals from the sensor were acquired by the oscilloscope with a sample rate of 1MS/s, which satisfies the Nyquist theorem, since the cutoff frequency for this sensors is about 117 kHz according to PLB test.
- In order to avoid high-frequency interferences, the resulting signals from the piezoelectric sensors were subjected to a 20 kHz low-pass filter and processed using MATLAB® software.
- To avoid temperature fluctuations, the TIM was taken to steady state before any measurement and, for loads greater than 100%, the tests were performed quickly.



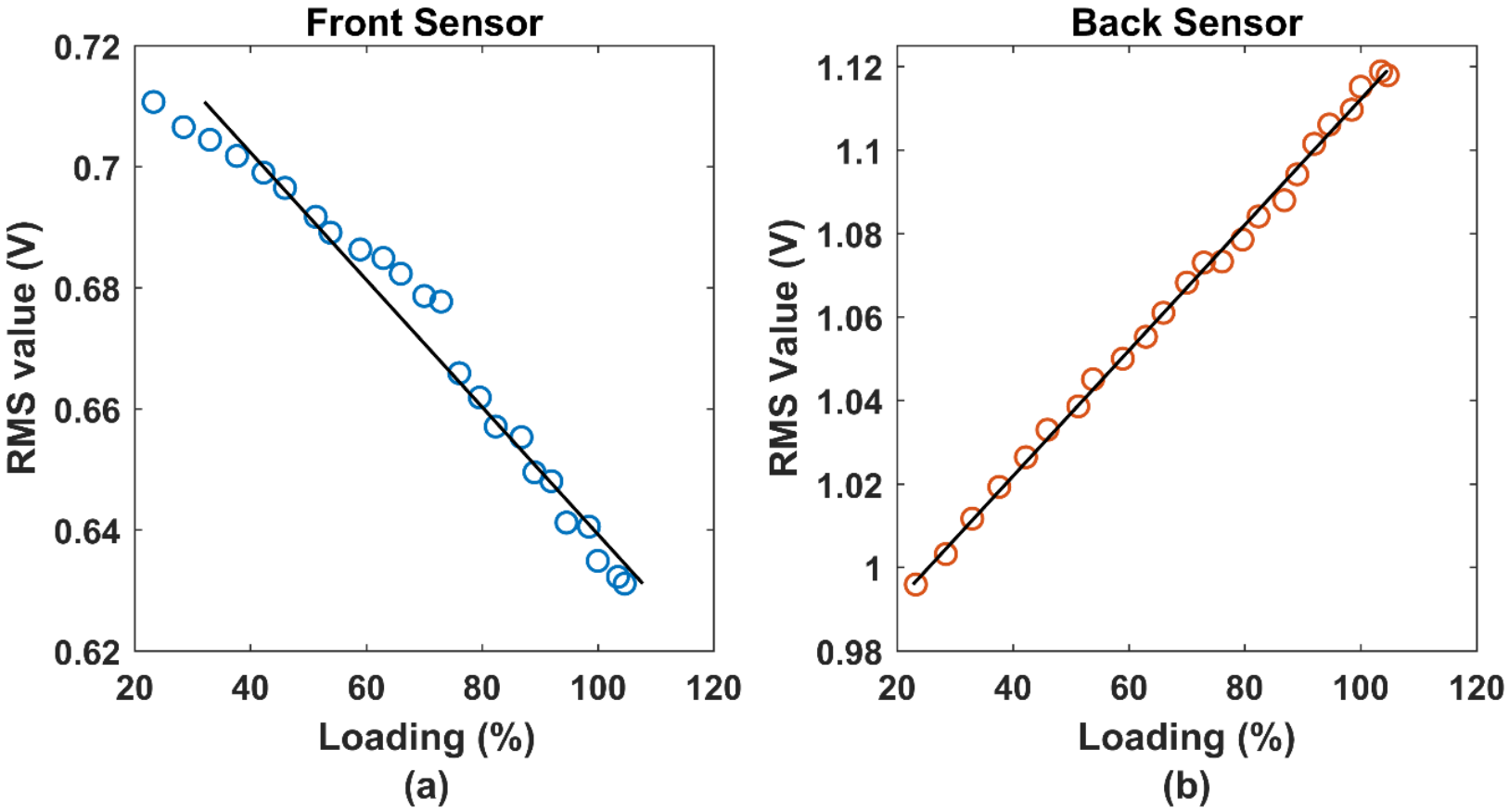
Experimental Setup

- The load was varied and, for each vibration signal collected, the root mean square (RMS) value was calculated;
- RMS can be an effective alternative to perform the vibration and acoustics signal characterization. This approach is directly related to the vibrational or acoustic load applied to the sensor and is an attractive attribute for any monitoring application

$$V_{RMS} = \sqrt{\frac{1}{T}\int_0^T \left(V(t)\right)^2 dt} = \sqrt{\frac{1}{n}\sum_{n=1}^{n} v_n^2}$$



Results

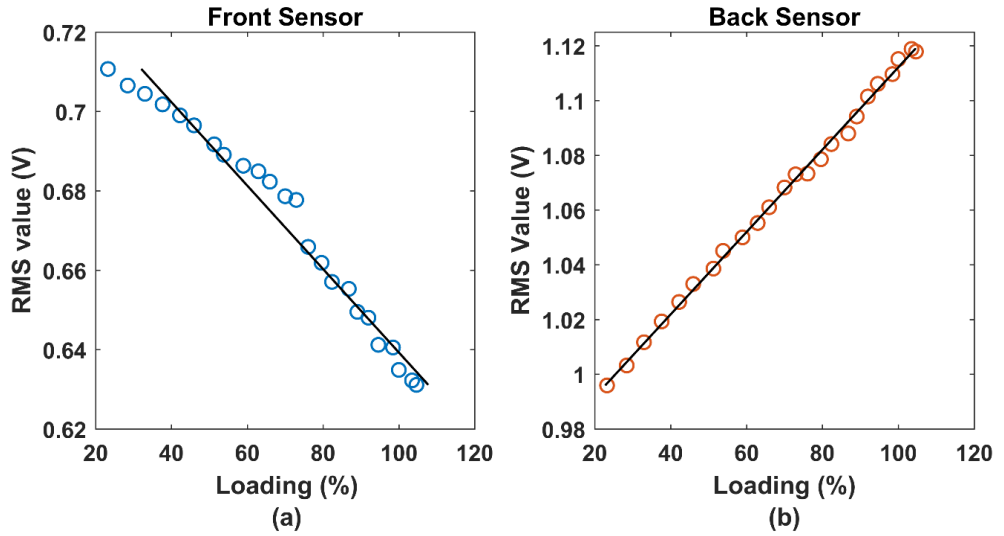


RMS values for the: (a) front piezoelectric; (b) back piezoelectric sensor.

Results

Linear regression equations

Sensor	Slope	y-intercept
Front side	-0.0010161	0.74196
Back side	0.0015009	0.9619



Conclusion

- Based on the results presented by this work, the RMS curves, attest that the piezoelectric sensors are capable to estimate the TIM loading through a linear regression of these curves. Additionally, they indicated that oversized motors may present mechanical wear in their front side components due to the higher vibratory oscillations, caused by the freedom observed in the coupling between the TIM and the load for lower loading values.
- The first experimental results demonstrated that low-cost sensors have the potential to act as transducers in vibration analysis, therefore, for future studies, it is feasible that these sensors could be able to identify electrical and mechanical failures in TIM.
- This is an initial experiment and more tests must be applied to the sensors for future validation.

Thank you!