Efeitos de tensão na eficiência de compressores alternativos herméticos.

Voltage effects on the efficiency of hermetically sealed reciprocating compressors.

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Abstract: A technique for the fast and accurate evaluation of the effects of power supply voltage variations on hermetic compressors for domestic refrigerators is being proposed. This technique involves the procedures for the fast and accurate determination of the revolution of the compressors, without contact with the rotating parts, using a vibration transducer and FFT numerical analysis. It was concluded that if domestic refrigerators are fed with lower voltages than 127 volts, not above, a national economy would be realized in the energy supply of 140 GWh/month, avoiding a waste of more than R$ 60 million per month, at March 2015.

Keywords: Compressor; motor; hermetic; revolution; test; measurement.

1 INTRODUCTION

This experimental technical investigation originated through a demonstration of interest by PROCEL - National Program for the Conservation of Electric Energy, Eletrobras - Centrais Elétricas Brasileiras, in evaluating the so-called "Electric Energy Economizers" widely available in popular markets, especially the Internet. In order to do so, a vast study was prepared and "Truths and Myths" about the energy economizers were identified [4]. Also, in the mentioned studies, the effects of voltage on the performance of single-phase motors and the economic impacts at the national level of such effects were identified [5]. However, not everything can be published in one, two or three technical articles, as a result of the results and experimental techniques adopted in a great experimental investigation. The studies conducted for Procel were condensed into 83 pages of a technical report [7] and 6304 digital files were produced in 474 separate technical file folders, totaling 3.5 GB. In this way, in the present work will be approached two unpublished themes, not explored in the other previous publications and little explored in the literature.

The present publication will deal with an experimental technique to evaluate the efficiency of hermetic compressors used in refrigerators, but in a fast and precise way, involving an equally accurate evaluation of their revolution, which will certainly be very useful for other researchers involved in Energy efficiency.

In the hermetically sealed compressor, here called motor-compressor, or only compressor, the compressor, and the motor are enclosed in the welded steel casing and the two are connected by a common shaft. This makes the whole compressor and the motor a single compact and portable unit that can be handled easily. The hermetically sealed compressor is very different from the traditional open type of compressors in which the compressor and the motor are different entities and the compressor is connected to the motor by coupling or belt. It is widely used for the refrigeration and air conditioning applications. In all the household refrigerators, deep freezers, window air conditioners, split air conditioners, most of the packaged air conditioners, the most popular types of the hermetically sealed compressors are the reciprocating compressors, on 115 or 220 V [2].

2 EFFICIENCY ASSESSMENT

Standardized techniques for evaluating refrigerator efficiency involve long-term tests, usually one week, or at least 50 hours of testing, not counting efforts to evaluate experimental results. Even so, the results are highly influenced by a number of out-of-control variables, including the external temperature oscillations; moving the ambient air around the object under analysis; Air and heat leaks from the door seals and fluctuations in the refrigerator power supply voltage.

For the studies on electrical energy saving, however, so many variables without control would not allow the identification of the effects of the voltage or of the Power Saving Devices in the energetic consumption. In this way, the successful technique was used.

Current refrigerators incorporate a number of devices that consume some electrical energy. In the evaluation of the compressors, such devices must be excluded from the measurement of consumption because they belong to the refrigerator and not to the compressor. That is, the refrigerators usually contain some of the following auxiliary devices, or systems: Permanent heater of the system of sealing of the doors; the intermittent heater for defrosting; Electronic control and timing system; and still, temperature and status control systems.

In order to evaluate the relative consumption of the compressor, under different controllable conditions, the measuring system must measure only the electrical motor, excluding the others, according to the circuit shown in Figure 1.

As the magnitude of interest constitutes only the relative energy consumption, or the relative efficiency, taken instantaneously, for a given specified, controlled condition, of electric voltage and frequency of the power supply, was used the energy consumption by revolution of the compressor, or consumption for a thousand full revolutions. This has been established considering that the mechanical work of gas compression must be maintained as a reference and, within small variations, 1000 revolutions should produce the same cooling work and, not necessarily imply the same energy consumption, since the revolutions by units of time vary with the applied electrical voltage and, likewise, the energy consumed, in reasons not necessarily similar. Precisely these differences are sought to determine either the variations in the performance of the motor-compressor with the voltage or even the energy variations with the use of so-called energy-saving.

The refrigerators were evaluated in the instantaneous mode, i.e., the power required for the compressor to complete 1000 revolutions was measured. Since the mechanical work of compressing the refrigerant depends on the number of revolutions of the compressor, the relative consumption has been evaluated in this way, that is, by the power consumed for a thousand complete revolutions of the compressor. Thus, the following equation is suggested for the expression of the relative consumption of the same motor-compressor system, under different operating conditions under control.

$$\text{Power Consumption} = \frac{\text{Electrical Power}\left[\text{watts}\right]}{\text{Rotation}\left[\frac{r}{s}\right] \bullet 3600\left[\frac{s}{h}\right]} \bullet 1000\left[\frac{Wh}{1000\,r}\right]$$

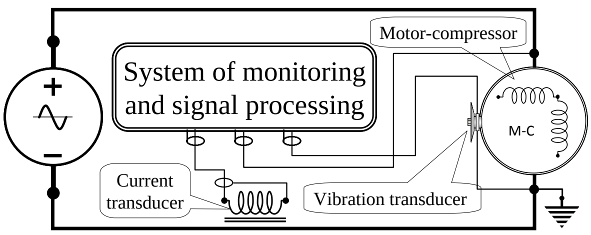

Figure 1 - Efficiency measurement diagram.

3 REVOLUTION MEASUREMENT OF HERMETIC MOTOR-COMPRESSORS

In dealing with hermetic motor-compressors, obviously there is no possibility of introducing probes or revolution sensors to establish mechanical contact with the rotating shaft. In this way, the revolution determination necessarily needs to be without any contact with the rotating parts internal to the compressor shell. Then, an improvised vibration or displacement sensor formed by a scrap microcomputer speaker was used. The small speaker was turned into a vibration transducer by the addition of a metal mass in the moving part thereof, as shown in Figure 2. The mass consisted of a non-magnetic stainless steel nut. In order to lightly raise the mass and gain more amplitude in the electrical signals generated, a non-metallic mass - ceramic in the center of the steel nut was also added, as also shown in Figure 2.

A small, unshielded speaker was selected so that the dispersion magnetism could also be used as the transducer fixation system to the steel casing of the motor-compressor. This mode would not require the use of glue or staple of the revolution sensor on the object being evaluated, it was sufficient to approximate it on the outside of the compressor. Figure 2 shows the mode of attachment of the vibration transducer at the motor-compressor.

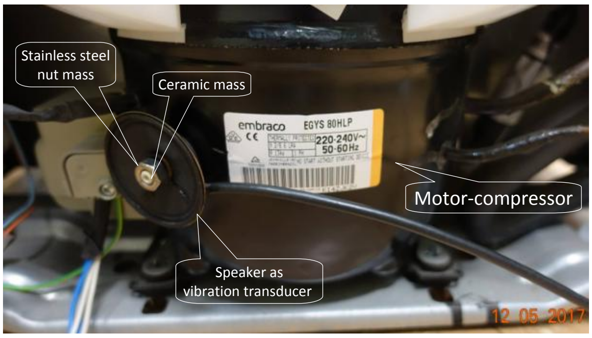

Figure 2 – System of revolution measuring.

With the temporal electrical signal generated by the mechanical vibrations of the compressor, it became possible to identify the frequencies associated to revolution of its internal parts.

Initially, the pick up electrical signal was time integrated. Then, the numerical signal was transformed by Fast Fourier Transformation-FFT, into the frequency domain, on another continuous signal. On this same generated signal, still on the same digital oscilloscope, it was possible to identify very sharp and significant peaks of dynamic oscillations, as shown in Figure 3.

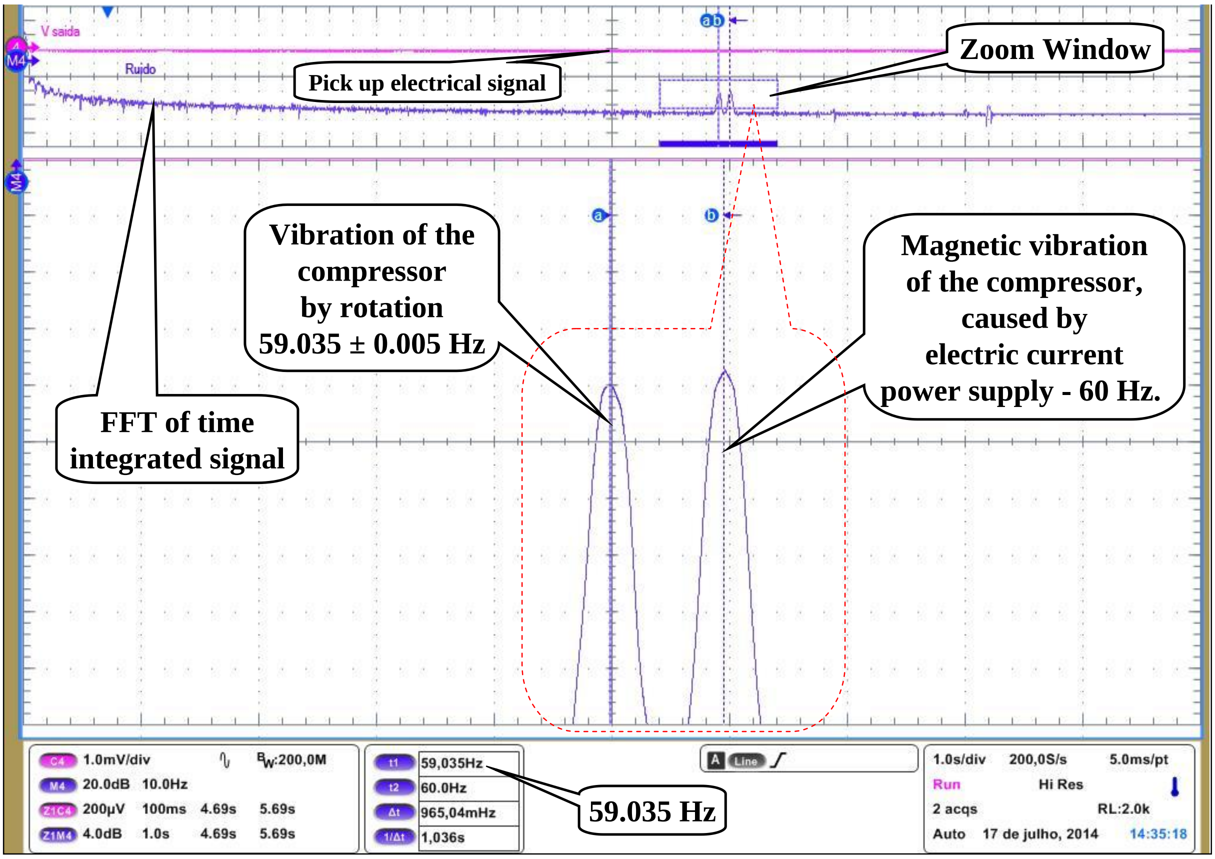

Figure 3 – Identification of very sharp and significant peaks of dynamic compressor oscillations.

The peak on the right in all measurements was the result of the magnetic vibration of the hermetic electric motor at the frequency of 60 Hz. The second peak, further to the left, was the result of the mechanical vibrations or the revolution of the compressor to be determined.

In the oscilloscope itself, it was possible to obtain the digital reading of the revolution of the object tested, as shown in Figure 3, in revolutions per second, or in Hz, with the resolution of up to five significant figures. The system waits for calibration because it has the reference peak next to it, constantly being compared and with the reading of 60.000 Hz from the power supply, or from the local power grid line.

4 EXPERIMENTAL RESULTS

By using the suggested measurement and analysis systems, it was possible to identify the effects of the mains voltage on the consumption of the compressors, as well as energy waste, as shown in Figure 4 and Figure 5 [6].

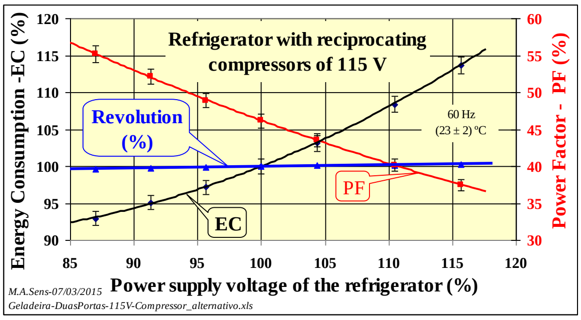

Figure 4 – Consumption of compressors

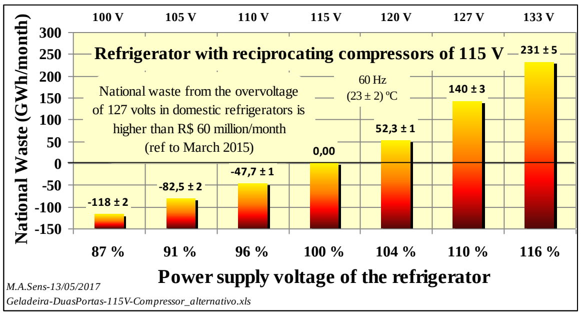

Figure 5 – Energy waste of compressors

5 CONCLUSIONS

It was concluded as practical and efficient to compute the energy consumed by hermetic refrigeration reciprocating compressors, by a thousand revolutions and, likewise, practical way of measuring the revolution. The procedures apply, possibly, to the centrifugal pumps.

Considering only the 10 % overvoltage in the 35.5 million (54.4 %) households fed by the rated voltage of 127 V [1], [3], [8], still in the range considered normal by Aneel, the 115 volts motor compressors represent a waste of electric energy of 140 GWh/month, or R$ 60 million monthly.

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