COBEM-2017-0178
ELECTRIC VEHICLE FAN BALANCING VARIATION ACCORDING TO SPEED

Moraes, R.S.A.
Rolim, T.L.
Universidade Federal de Pernambuco, Department of Mechanical Engineering, Pernambuco, Brazil
tlr@ufpe.br

Abstract. Fan blades undergo deformation during their operation due to aerodynamic loads, resulting in the modification of the mass distribution of the system, which directly influences the rotor balancing. Therefore, if a rotor is balanced at specific speed, the unbalance during operation may change if the speed is different. In automotive vehicles, the electric fan responsible for the cooling of the power train is susceptible to operation at different speeds. If the balancing is not done correctly, the vibration in the steering wheel can reach unacceptable levels by the customer, causing quality problems. Through experimental tests, we used the influence coefficient balancing methodology to measure the influence of speed on the operational unbalance of electric vehicle fans. The results showed that the speed of rotation have a strong influence on the balancing of the fans and, if neglected, may turn it impossible to respect the design's unbalance limits. If the behavior of the unbalance variation is studied, it is possible to adjust the balancing methodology by modifying both the position and the value of the balance mass to guarantee the level of operational unbalance.

Keywords: Flexible Rotor Balancing, Balance of Electric Fans, Operational Balancing.

1. INTRODUCTION

The fan is one of the rotary machines most used by man. In addition to being used to generate thermal comfort, it is also used for equipment cooling. In automotive vehicles, the electric fan is crucial to keep the engine temperature within the design limit, and if it is poorly balanced, high levels of vibration can be felt on the steering wheel and driver's seat.

Good balancing quality ensures minimal vibrations from moving parts, especially rotors. This implies lower levels of dynamic stresses, especially on bearings (Brito, 2002).

As a general result, in addition to superior performance, balanced machines require fewer maintenance stops. This fact, from all points of view, is a great economic advantage, fully justifying the investments necessary for the balancing of the machines (Góz, 1994).

According to (Hartog, 1985) the design phase of a machine design, its balancing should be considered, significantly reducing its sources of unbalance. This way, we try to determine the location of the balancing points, facilitating the corrections within minimum time. Despite all precautions, there will always be some residual unbalance. It will cause vibrations, which tend to deteriorate bearing structures, rotors, bearings and so on (Correia, 2007).

2. EXPERIMENTAL PROCEDURE

The tests were performed on workbench, which can be seen in Figure 1. Additionally, a voltage source was used to control the electric fan speed during the experiment, an accelerometer to acquire the vibration level, an optical tachometer for speed and an data acquisition and processing equipment.
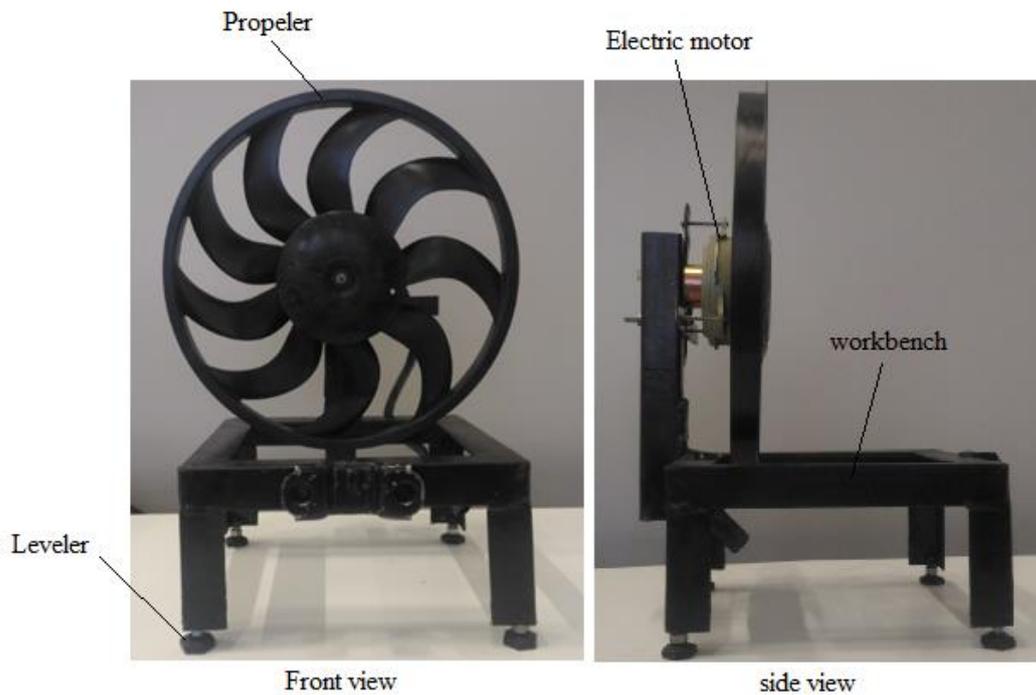
Figure 1. Rotor balancing workbench

Different from the balancing method by the classical coefficient of influence that evaluates the balance with the rotor at constant speed, the data were acquisitive with the rotor subjected to an acceleration ramp.

On the ramp, the rotation of the electric fan varied from 1500 to 3400 with a growth rate of approximately 6 RPM / s, with the aid of a controllable voltage source. During the test, every 10 RPM, the vibration and the rotation were acquired generating a point of the vibration and phase curves.

As can be seen in Figures 2 and 3, across the acquisition range, the unbalance amplitude value and the phase value vary linearly with the rotation, with determination coefficient, R^2, greater than 0.92. In Table 1, are the equations that were used as the functions of the unbalance amplitude and the phase of the electro-ventilator.

$y = -0,016x + 86,245$
$R^2 = 0,9251$
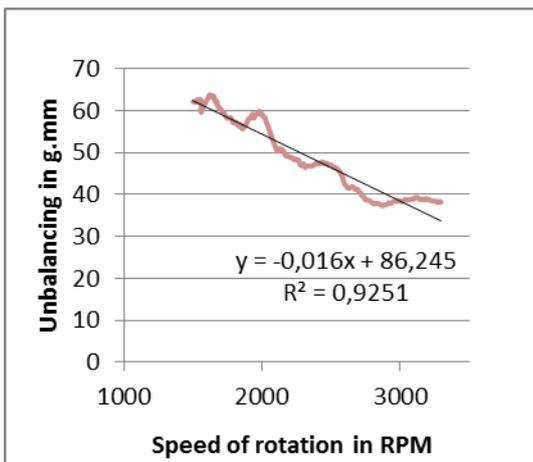

$\beta = -0,0267x + 362,95$
$R^2 = 0,9421$

Figure 2. Rotor unbalance amplitude as a function of the speed of rotation
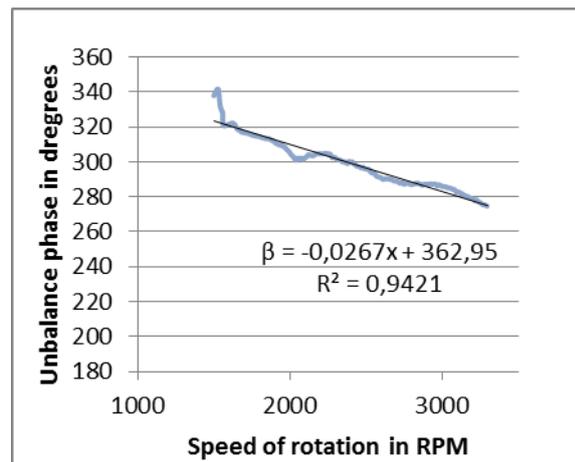
Figure 3. Rotor unbalance phase as a function of rotational speed

Table 1. Unbalance of the electric fan.

Unbalance (g.mm)	R^2	Phase (degree)	R^2
$U = 86,25 - 0,016\Omega$	0,925	$\beta = 362,95 - 0,027\Omega$	0,94

3. RESULTS

In order to measure the effect of the unbalance variation, it is necessary to calculate the effect of the mass added during the balancing process and then to calculate its effect with the electric fan running at the operating speed.

If the Electric Fan is balanced at the speed of 2100 RPM and operates at the speed of 2950 RPM, the operational unbalance will be 22.23 g.mm, considering that the project unbalance limit is 20 g.mm and that the production aims to deliver the rotor with Unbalance less than 10 g.mm, the balancing process was inefficient, so the speed chosen for balancing does not meet design requirements.

After testing 8 electric fans and arriving at a global formula for the behavior of the set, in Table 2 is the operational unbalance at 2950 RPM as a function of the speed chosen to perform the balancing.

Knowing the behavior of the unbalance as a function of the rotation, it is possible to balance the electro-fan at a speed lower than the recommended one, but the value and position of the mass should be modified considering this phenomenon. The mass added in the balancing process needs to be corrected by the difference between the mass found in the balancing speed and the speed of operation, as in Eq. (1).

$$\vec{W}_{cor} = U_c - 0,01236\cdot(S_o - S_n)\, gmm \angle(0,0273\cdot(S_o - S_n) - Pc)° \tag{1}$$

Where:
U_c = Calculated unbalance.
S_o = Operational speed of rotation.
S_n = Rotation speed of the balancing process.
Pc = Phase of calculated unbalance.
$\vec{W}_{cor}$ = Vector of balancing mass corrected.

Table 2. Global operational unbalance at 2950 RPM

Balancing speed (rpm)	Operational unbalance phase (degree)	Operational unbalance module (g.mm)
1000	13,09	49,79
1100	11,27	47,01
1200	9,46	44,24
1300	7,64	41,48
1400	5,83	38,74
1500	4,01	36,02
1600	2,20	33,33
1700	0,39	30,65
1800	-1,41	28,00
1900	-3,22	25,38
2000	-5,03	22,79
2100	-6,84	20,23
2200	-8,64	17,70
2300	-10,45	15,21
2400	-12,26	12,75
2500	-14,08	10,34
2600	-15,90	7,96

2700	-17,75	5,63
2800	-19,66	3,34
2900	-22,05	1,10
3000	157,94	1,10
3100	155,56	3,24
3200	153,65	5,34
3300	151,81	7,38
3400	149,99	9,37

4. CONCLUSIONS

In this work, it was shown that the rotation speed of the electric fan is an important variables in the calculation of the operational unbalance and that this phenomenon can be compensated to ensure a good balance.

For the studied electric fan, it was verified that considering only the effect of the rotation velocity variation, with the electric fan running at 2950 RPM, the minimum rotation speed suitable for balancing is 2500 RPM and ideally 2950 RPM.

It was verified that it is possible to correct the balancing method by influence coefficient, to make possible to balance the electric fan at a speed different from operational, provided that the overall behavior of the unbalance is known .

5. REFERENCES

CORREIA, F. A. G. "Determinação de Características de Desempenho de Mancais Radiais Elípticos Utilizando o Método de Elementos Finitos". 109p Dissertação (Mestrado em Engenharia Mecânica) - Programa de Pós-Graduação em Engenharia Mecânica, Universidade Federal de Minas Gerais, Minas Gerais, 2007.

GÓZ, R. D.; "Balanceamento de Rotores". s.l. : R&T Análise de Vibrações e Balanceamento, 49p., 2013.

HARTOG, J P. "Mechanical Vibrations" – New York: *Dover Publications,* Inc, 1985.

BRITO, J. N. "Desenvolvimento de um sistema inteligente hibrido para diagnóstico de falhas em motores de indução trifásico". Campinas: Universidade Estadual de Campinas, 214p. Tese de Doutorado, 2002.

6. RESPONSIBILITY NOTICE

The author are the only responsible for the printed material included in this paper.