Vibration Is Not The Only Method For Balancing

Byron Martin

University of Adelaide, Australia

ABSTRACT

Mechanical engineers for a long time have realized the advantages of balancing Fan impellors and other rotors; increased power efficiency, increased bearing life, reduced probability of unplanned failures and an increase in rotor and shaft life. Most Condition Monitoring practitioners, who use vibration as the primary monitoring tool, regularly balance rotors in-situ using single or two plane balancing techniques. This paper will present an alternative primary method to vibration measurements; it is particularly useful for drum impellors commonly found in cooling water systems and for medium size fans mounted on isolation mounts. The author is an experienced condition monitoring engineer with many, many year's field experience.

INTRODUCTION

In-situ balancing is the process of balancing a rotor in its own bearings and support structure, rather than in a balancing machine.

Unlike balancing in a specially designed balancing machine, in-situ balancing has the disadvantage of the rotor being installed in its working environment. Therefore the dynamic properties of its bearings and support structure, and the influence of other elements in the complete rotor train have an influence on the dynamic properties of the rotor.

STANDARDS FOR BALANCE

ISO Standards

ISO 1925, Mechanical Vibration – Balancing – Vocabulary

ISO 1940-1, Mechanical vibration – Balance quality requirements of rigid rotors – Part 1: Determination of permissible residual unbalance.

ISO 1940-2, Mechanical vibration – Balance quality requirements of rigid rotors – Part 2: Balancing errors.

ISO 2041, Vibration and shock – Vocabulary.

ISO 2954, Mechanical vibration of rotating and reciprocating machinery - Requirements for instruments for measuring vibration severity.

ISO 7919, Mechanical vibration of non-reciprocating machines – Measurements on rotating shafts and evaluation criteria.

ISO 10814, Mechanical Vibration – Susceptibility and sensitivity of machines to unbalance.

ISO 10816, Mechanical vibration – Evaluation of machine vibration by measurements on non-rotating parts.

ISO 11342, Mechanical vibration – Methods and criteria for the mechanical balancing of flexible rotors.

ISO 19499, Mechanical vibration – Introduction to balancing standards.

AS/NZ Standards

AS 3709-1989, Vibration and shock - Balance quality of rotating rigid bodies. (This is a re-write of ISO 1940-1)

This latter standard gives the Balance Quality Grade for fans as being G6.3 and this equates to the permissible imbalance mass for rotors at varying speeds as given in Table 1, where the *permissible unbalance relative to rotor mass,* e_{per} with units g.mm/kg is the defined as:-

$$e_{per} = \frac{U_{per}}{m} \qquad \text{eq. 1}$$

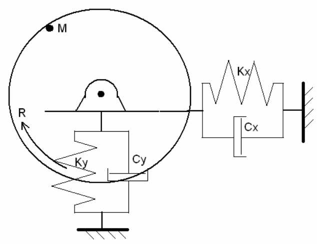
Where: m is the rotor mass in kg and

U_{per} has units g.mm

Table 1: Balance quality grade for Fans

RPM	e_{per}
1000	60
1500	50
3000	20

THEORY



In this simple model, the imbalance mass M rotating at R (RPM) will cause the axis of the rotor to move and therefore vibrate. The level of vibration is controlled by the vertical (Ky) and horizontal (Kx) stiffness. In most industrial machines the damping (Cx and Cy) can be ignored.

V = M x C

The resulting machine vibration vector is the product of the mass imbalance and the machine influence coefficients matrix.

Normally the bearings which support the shaft are solidly mounted to the fan frame and the fan frame mounted solidly onto the planet, as in Figure 1.

TRADITIONAL METHODS FOR BALANCING

The traditional method for in-situ balancing is to measure the vibration and phase, often called *magnitude and phase*. This is done at either one or two measuring planes for one or two plane balancing respectively. A trial weight is attached to the rotor and the vibration and phase re-measured. The balancing software calculates the balance mass and position.

An example of a single plane balance is shown in Table 2.

Table 2: Example of single plane balance

Condition	Vibration	Phase
Initial [mm/s, °]	15.4	256
Trial weight [gms]	10	0
Trial run [mm/s, °]	13.8	72
Balance weight [gms]	5.28	2
Check [mm/s, °]	3.4	48
Trim weight [gms]	1.66	-29
Final vibration	2.7	56

The vibration is measured directly at the shaft bearings, in the fan of Figure 1 the accelerometers are mounted on the motor case adjacent to the bearings (a).

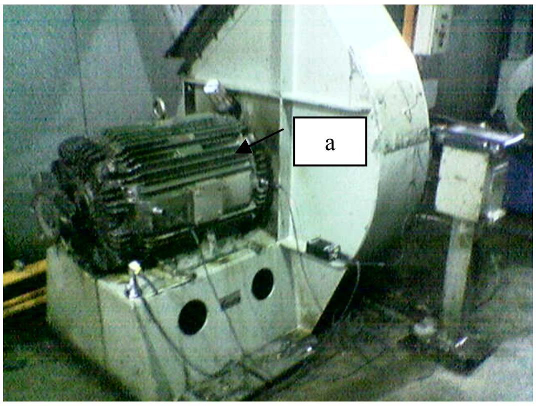


Figure 1: Example fan during balancing. The accelerometers (a) are mounted on the motor case adjacent the bearings

WHEN THE TRADITIONAL METHODS FAIL

Things start to come undone when the machine is not stiffly mounted, *eg* on isolation mounts. Under these circumstances the stiffness is a second order function with the machine as a spring mounted component within which is rotating imbalance mass.

Figure 2: Cooling tower fan

The most common examples of fans with soft mounting are cooling tower fans, see Figures 2 and 3. These fans have "flexible" bearing mounts, often onto a fibreglass housing and often with long shafts between two bearings. The shaft in the fan shown in Figure 2 was visibly flexing before balancing.

The initial vibration levels for two fans in Figures 2 and 3 were:-

Figure 2 – DE 16.4mm/s @ 126°, NDE 26.3mm/s @ 347°; with a run speed of 835RPM

Figure 3 – DE 23.3mm/s @ 144°, NDE 18.7mm/s @ 116°; with a run speed of 948RPM

Figure 3 : Fibreglass cooling tower and fan

When attempting a two plane balance under these conditions, our CSi FastBal II program will recommend balance weights and locations which have little or no effect on the vibration levels. And when going onto the next stage of "trim balancing" similar size weights are recommended at approximately 180° from the balance weights. We have concluded that the program cannot cope with the additional flexibility of the bearing mounts.

I have tried several stand-alone software programs (email me at byron.martin@adelaide.edu.au if you would like a copy) and obtained similar results.

BALANCING WITH FLEXIBLE MOUNTS

For the two fans described previously the impellors are driven by belts from the motor. In both cases (and others) I have achieved excellent results by removing the belts and balancing the rotors statically.

In the two fans described the impellors are as long as or longer than their diameter, circumstances which would normally indicate that two plane balancing was required. However, by adding the balance weights so that they are symmetrically distributed along the impellor or equally at each end I have balanced these fans.

In the case of Figure 2 where two impellors are suspended between two bearings with the drive pulley overhung at one end, a total of 1200 grams was added to statically balance the two impellors. The resulting vibration levels were 4.3 and 3.7mm/s at the two bearings.

In the case of Figure 3 with one impellor, approximately 80 grams was added to reduce the vibration levels to 0.8 and 0.6mm/s.

In both cases the balance weights were folded metal clamped onto the long narrow curved blades, see Figure 4.

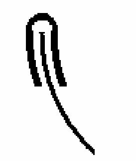


Figure 4: Attaching balance weights

CONCLUSION

If the fan is belt driven follow this procedure before attempting software driven balancing techniques:-

- Remove the drive belts, make sure that the impellor is free to turn,
- Inspect and clean the impellor, hollow blade impellors which "pump" dirty gas can have erosion holes, see Figure 5,
- Statically balance the impellor, either place all the weights on the back plate or end plates, or distribute them evenly along the blades.

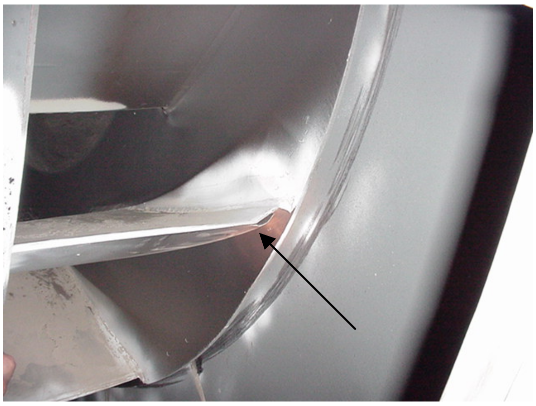


Figure 5: Impellor with eroded holes in fan blades

POST-SCRIPT

I now start all in-situ balancing jobs with a static balance.