DISTRIBUTION LAW OF RANDOM UNBALANCE RESPONSE OF MULTISTAGE BLOWER①

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ABSTRACT To study the distribution law of random unbalance response of multistage blower, a kind of random emulation experiment method was brought forward, of which the principle is using the simulated values of random unbalance variables generated by computer, through a large number of emulation experiments and statistical analyses, to draw a conclusion about the distribution law of the vibration type and amplitude. Using this method, the study result of D900 blower of a metallurgical factory showed that the vibration types of blower are mainly the first order vibration type, so it is practical to apply auto-balance technology; the figure of the distribution law of the blower's amplitude by statistics was also obtained, therefore a series of statistical parameters such as maximum amplitude, average amplitude were defined, which have reference value in some degree to guide the blower equipment's working condition diagnosis and service action management.

Key words unbalance distribution random experiment method vibration response centrifugal blower over-critical rotating speed auto-balance technology working condition diagnosis

1 INTRODUCTION

Unbalance is one of the main failures of blower rotors[1, 2], the vibration of rotors at the excitation of unbalance system of forces is called unbalance response. In the design of centrifugal compressor, foreigners have put forward and done calculations about the unbalance response (vibration type and amplitude) of rotor system to determine whether the system works safely since 1980s'. Such researches have also been done in our country[3-5], but the real field unbalance distributions are complex, random and even changing with time. So, the calculation of unbalance response is seldom applied to production practice. This paper takes D900 centrifugal blower with triple impellers of a metallurgy factory as an example and makes study on it, this blower can be simplified to a flexible rotor linear system with three rigid disks, the response of the rotor system under the affection of one unbalance force is calculated in literature[6], with these data and linear superposition principle, it is easy to know the vibration type and amplitude when all the three disks are effected by system of forces with fixed distribution.

To the response of the system under the affection of system of forces with random distribution, this paper adopts the method of random experiment: transform the system of forces with random distribution into a series of random system of forces with fixed distribution, do a large number of emulation experiments and then make statistical analysis and study on their results.

2 CALCULATION AND ANALYSIS OF ORDERS OF VIBRATION TYPE

D900 blower's working rotating speed is between the critical rotating speed of the first order and that of the second order. Its vibrations are mainly in the first order form or in the second order form. To calculate the probability of vibration type of the first order (or the second

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order), this paper designs the following random emulation experiment method:

(1) Use the random numbers generated by computer to give values to the six random variables which are magnitudes and angles of declination of the unbalance vectors of three impellers.

(2) Project the unbalance vectors to X axis and Y axis and get six unbalance vectors in X and Y direction(Fig. 1):

U_{x1}, U_{y1}, U_{x2}, U_{y2}, U_{x3}, U_{y3}

As Fig. 1 shows, suppose the total off-center quality moment is a constant in every experiment, G_1, G_2 and G_3 represent the location of the unbalance particles.

(3) Calculate separately the vibration response of the six vectors with the data table in literature[6], then make superposition, and get the combined response x_1, y_1, x_2, y_2, x_3, y_3 (to simplify the calculation, we only consider the vibration of the impellers).

(4) If x_1, x_2, x_3 have the same sign, they can be appreciated as the first order vibration, or else it is the second order vibration.

(5) Because the probability distribution of vibration type in Y axis should have the same laws as that in X axis, it can be statistic as another random experiment. The method is the same as the above.

(6) Repeat (1) ~ (5) and write down the times of the first order vibrations and the second order vibrations in every experiment.

Adopting this kind of random experiment method, this paper have made one million times emulation tests. The results showed: the first order vibration accounted for 85.72% and the second order vibration accounted for 14.28%. As far as this blower is concerned, the first order vibration is a kind of vibration form which is above the critical rotating speed. This is the prerequisite[7, 8] to adopt auto-balance technology to weaken vibration. So the result of the experiment verified that the scheme of adopting auto-balance technology to weaken vibration is basically practical.

3 CALCULATION AND ANALYSIS OF AMPLITUDE DISTRIBUTION

The fundamental steps of the random emulation experiment method to calculate amplitude distribution are:

(1), (2) and (3) are the same as the previous.

(4) Calculate the maximum amplitude

$$S_m = \max[(x_1^2 + y_1^2)^{1/2}, (x_2^2 + y_2^2)^{1/2}, (x_3^2 + y_3^2)^{1/2}]$$

The original unbalance amount in calculation is: $U = U_1 + U_2 + U_3 = 0.016(\mathrm{Nm})$

(5) According to the calculation method of block diagram, divide the probable range of S_m (0~ 10μm) into 1000 lattice. When S_m located in the Ith lattice of them, the count number $f(I)$ add 1.

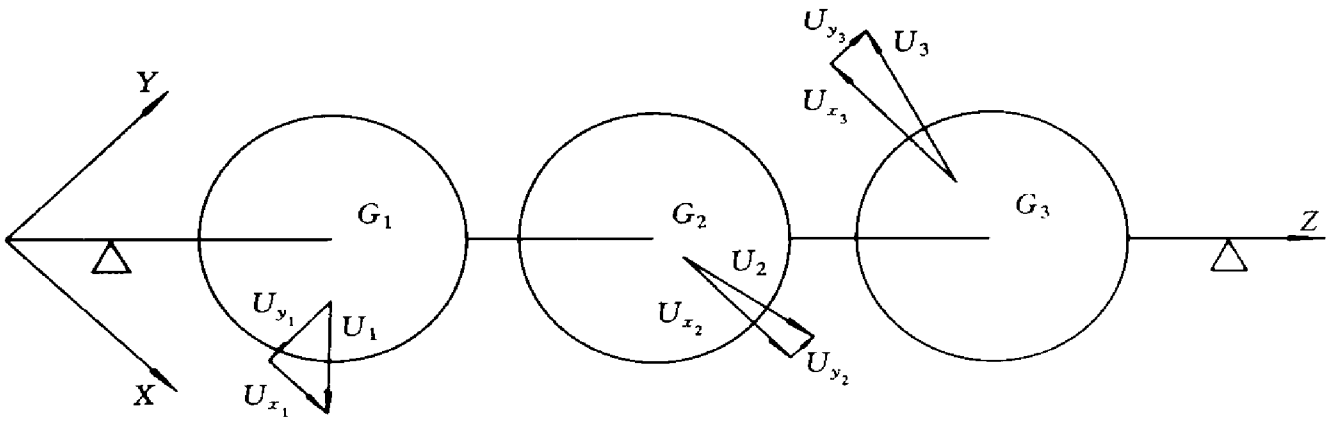

Fig. 1 Mechanical model of blower rotor system

(6) Repeat (1) ~ (5), write down the times that S_m appeared in some lattice in every experiment. After one million experiments, we got the distribution figure of maximum amplitude(as Fig. 2 shows) under complex and unbalance distribution.

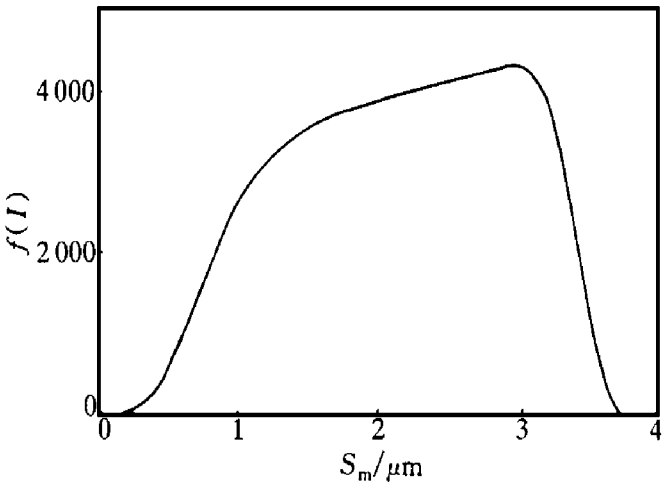

Fig. 2 Distribution laws of maximum amplitude S_m

Relative characteristic values are:
$(S_m)_{max}$= 3.17 μm (appear 12 times)
$(S_m)_{min}$= 0.09 μm (appear 1 time)
average value μ= 2.1519 μm
square error σ^2= 6.027×10^{-3}

A further observation at the 12 $(S_m)_{max}$ indicated that the original unbalance distribution is close to the single unbalance pattern. As Table 1 shows, if the total unbalance amount is a constant, it will be the most dangerous when unbalance amount concentrates on one disk, which is also the common sense of the field engineers and technicians, and which has also been tested and verified in this paper.

The physical meaning of $(S_m)_{max}$ is, when the total unbalance amount is 0.016 Nm, there exist accordingly the corresponding amplitude of all kinds of possible distribution, so a corresponding relationship between admissible error and vibration standard is set up. D900 blower assembly drawing technology requirements showed[6] that unbalance admissible error is 0.016 Nm, which is the total error in equipment machining, assembling and installing, but it does not include that of unbalance produced when equipment is running. The corresponding maximum amplitude of this value is 3.17 μm, which corresponds to a kind of vibration standard, it can't be used to direct operating condition diagnosis when equipment is running, but it can be used to check after every capital repair.

As the monitor of unbalance failure when the blower is running, at present, the vibration monitor is the most popular method at home and abroad. According to the meaning of $(S_m)_{max}$, we can transform conveniently the relative unbalance standard into vibration standard[9] (limited to D900 blower).

4 CONCLUSIONS

(1) As to the unbalance appeared randomly on the three impellers, composite vibration types are mainly the first order vibration type (account

Table 1 Original unbalance distribution of $(S_m)_{max}$

Unbalance amount	Original unbalance distribution			
U_1	1.331 531 E- 06	1.583 693 E- 03	4.153 62 E- 06	1.656 521 E- 07
U_2	1.580 583 E- 03	6.313 168 E- 06	1.588 146 E- 03	1.593 794 E- 03
U_3	1.808 555 E- 05	9.993 67 E- 06	7.700 135 E- 06	6.040 171 E- 06
U_1	2.936 208 E- 06	1.599 005 E- 03	1.913 087 E- 06	1.591 77 E- 03
U_2	1.594 468 E- 03	2.257 04 E- 07	1.595 788 E- 03	4.492 685 E- 06
U_3	2.596 224 E- 06	7.692 459 E- 07	2.299 255 E- 06	3.737 342 E- 06
U_1	1.607 075 E- 06	3.143 154 E- 06	1.588 971 E- 03	1.579 706 E- 03
U_2	1.585 495 E- 03	1.579 805 E- 03	1.016 158 E- 05	1.948 822 E- 05
U_3	1.289 786 E- 05	1.705 205 E- 05	8.688 298 E- 07	8.053 401 E- 07

for 85.72%), so it is practical to apply auto-balance technology to this kind of blower.

(2) If the total unbalance amount is a constant, it is the most dangerous when unbalance amount concentrates on one disk, which is also the common sense of the field engineers and technicians, and which has also been tested and verified through this paper's analysis.

(3) To a fixed unbalance (0.016 Nm), there exists a corresponding maximum amplitude (3.17 μm), which sets up a corresponding relationship between unbalance admissible error and vibration standard and it is useful to enlarge the application range of all kinds of standards.

(4) The random experiment method designed in this paper is a better method to calculate the distribution of the random unbalance response, it is handy and easy to practise and it is fit for the field technicians use.

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