THE INFLUENCE OF SUPPORTING STRUCTURE ON THE DYNAMIC BEHAVIOUR OF LARGE INDUSTRIAL FANS

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INTRODUCTION

Over the years fans have become larger and tip speeds have increased. A floor to shaft centre height of 4,000 mm is not uncommon. The combination of reduced structural stiffness in the horizontal plane and increased out of balance centrifugal forces cause larger vibration levels in the least stiff plane.

Large fans, in general, run well below their first critical speed. A common cause of vibration problems is a reduction in the system resonant frequency in the horizontal plane. This increases the dynamic magnification factor giving increased vibration amplitudes for a given amount of out of balance.

This paper reviews techniques which have been developed to identify, at site, factors causing this reduction in system resonance.

SHAFT AND SUPPORT STRUCTURE DYNAMIC BEHAVIOUR

A fan shaft is designed so that the critical speed of the impeller/shaft assembly is well above the running speed of the fan. When it is installed the system resonance is influenced by the total effective stiffness of the supporting structure as well as the stiffness of the shaft.

The bearing pedestal and grillages are designed to be sufficiently stiff to ensure that they only marginally lower the critical speed. Stiffness values are specified to the civil engineering consultants to ensure that the foundation is designed to have adequate stiffness in both the vertical and horizontal directions.

There are three main factors which can affect support stiffness:-
(i) cantilever bending (ii) rocking of the foundations and (iii) separation of any interfaces in the supporting structure.

TEST METHODS AND INTERPRETATION OF RESULTS

The rapid advance in recent years of electronic frequency analysing equipment has opened the door to new fields in diagnostic vibration measurement. The main tests which we carry out are grouped under the following headings:

(1) Forced vibration tests with the fan stationary.
(2) Measurement of system resonance from run down tests
(3) Vibration signatures, and surveys on bearing support structure

1. Forced vibration tests with the fan stationary

This method enables the system resonance to be obtained before the fan is run. Hence if there is coincidence between running speed and system resonance it can be determined without risk. The forced vibration tests are carried out in both the horizontal and vertical planes.

Figure 1 illustrates the method of mounting the exciter and the basic instrumentation. A special clamp is attached to the shaft close to the hub. The exciter is suspended from a blade via rubber slings. We use a delta shear accelerometer which is attached to the shaft by an electrically

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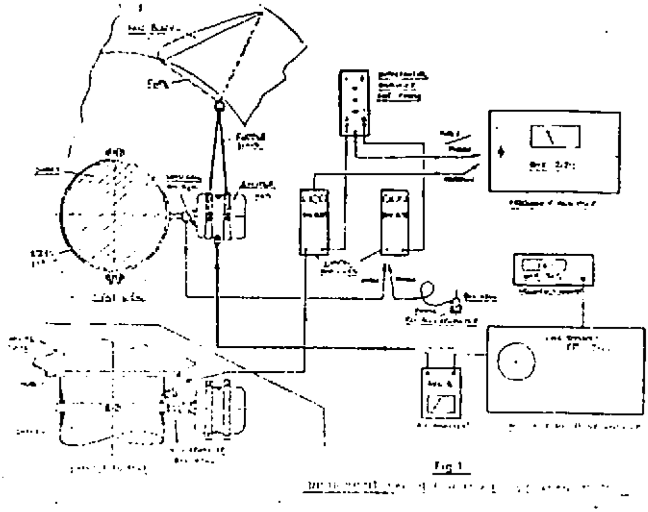


Fig 1

insulated magnet. A typical frequency response curve for a large Power Station induced draft fan is shown in Fig. 2.This chart illustrates the dramatic difference between the horizontal and vertical resonant frequencies. The oscillator is tuned to the fundmental resonant frequency and cyclic displacement levels in the horizontal and vertical planes are measured at selected positions on the support structure of the fan bearings.These measurements are plotted on a scaled drawing of the support structure as shown on Fig. 3. This diagram illustrates two main weaknesses- rocking of the foundations and an inadequate connection between the baseplate and concrete plinth.

A fully automated method of determining the frequency response of fan shaft systems can be carried out by using a digital function generator, real time analyser, mini computer and printer plotter. Very accurate resonant frequencies can be obtained in a few minutes after the equipment has been set up and programmed.

2. Measurement of system resonance from run down tests. The vibration signature from a typical large fan contains a dominant peak at the running speed frequency. There are also less significant peaks at harmonic frequencies of the fundamental. During fan run down these harmonic peaks pass through the system resonant frequency and excite peak vibration levels

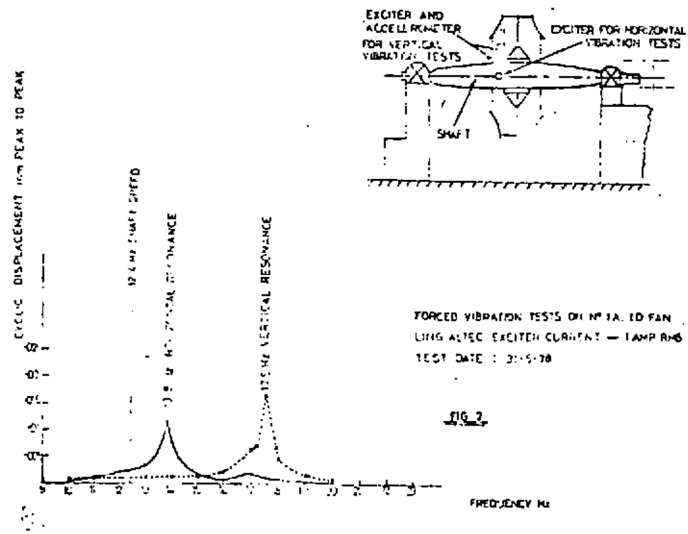
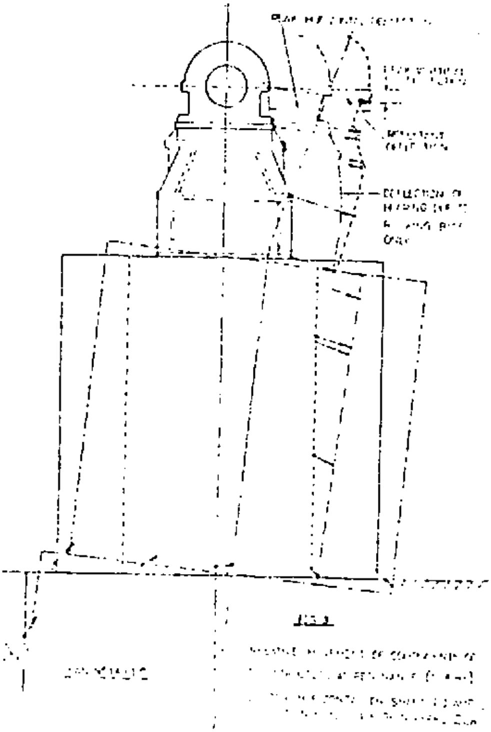


FIG 2

THE INFLUENCE OF SUPPORTING STRUCTURE ON THE DYNAMIC BEHAVIOUR OF LARGE INDUSTRIAL FANS

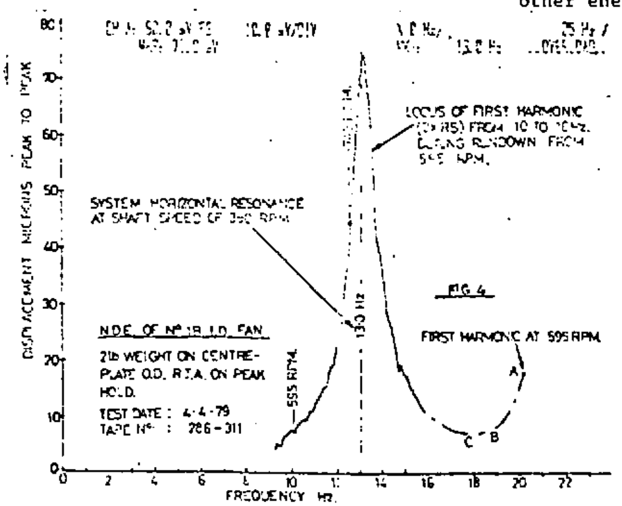


which can be analysed to obtain the resonant frequency at several shaft speeds. The principle is illustrated in Fig. 4. The locus of the first harmonic (2 x RS) indicates a system resonant frequency of 13 Hz at a shaft speed of 390 r.p.m.

A signal from an accelerometer on the bearing housing is tape recorded during fan run down. This signal is processed on an R.T.A. Using the peak hold facility the value of the (2 x RS) signal is obtained at sufficient shaft speeds to accurately determine the system resonance. With a combination of mini computer, printer/plotter and R.T.A. it is possible to obtain a 'three dimensional' chart as shown in Fig. 5. This diagram illustrates the effect of speed and decreasing cyclic load on the amplitude of the running speed and twice running speed signal.

3. Vibration signatures, and surveys on bearing support structure.

For some fans it is possible to determine the system resonance frequency from vibration signature at running speed. Acoustic and/or other energy sources can excite the shaft/support structure at sufficiently high amplitude to be measured by the digital equipment. During a site investigation at a Petro-Chemical plant there was an interesting vibration problem. The vibration signature had two unusual features - large low frequency amplitudes and a higher first harmonic signal than the fundamental. Run down tests indicated a resonant frequency just slightly above the twice running speed frequency.



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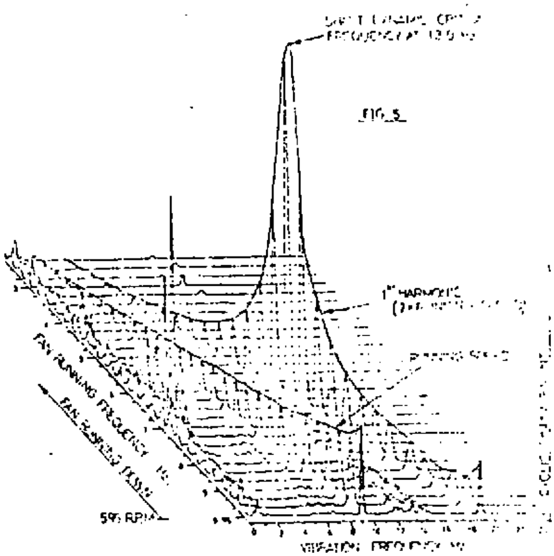

A detailed investigation revealed that, after many years running, there had been a loss of interference fit between hub and shaft. After repair the low frequency amplitudes were considerably reduced and the fundamental vibration peak became larger than the first harmonic. The latter could have been due to a slight change in the system resonance.

CURRENT PRACTICE AND FUTURE OBJECTIVES

Our Outside Department can now tape record vibration signatures and run down signals on an FM cassette tape recorder. This is being done for most new fans for research purposes and to eventually assist in planned maintenance. Sometimes the source of a vibration problem can be established by examining the vibration signature . Hence it may not be necessary to stop the fan and interfere with plant operation. Some useful information can be obtained by simply tape recording horizontal and vertical accelerometer signals after striking the stationary shaft. These results are processed and analysed in our Laboratory.

In time we will greatly increase our knowledge of vibration cause and effect. This will help trouble shooting diagnostic work and our design practices will be modified to minimise the cost for trouble free operation.