Exploding the myth.

EXAMPLE 1

Brief

To investigate the vibration from a motor/ coupling set. This set being the inbye, or number 2, set of a pair; part of a new installation.

To give a considered opinion of the acceptability or otherwise of that vibration, the cause of the problem and to identify possible solutions.

Description of work carried out

Vibration data were collected from the number 2 motor/coupling set and from the bed in order to establish the pattern and magnitude of the vibration.

Comparison data were also collected from the number 1 set and, as a control, from a second installation which utilises similar equipment. The 'control' installation had been established and run for a number of years and was considered to be of a good, satisfactory standard.

Discussion of results

Both the coupling sets on the new installation were found to be moving excessively when compared to the older, established installation.

Both sets were moving in a similar manner but the number 2 set showed a higher vibration amplitude.

When the data from number 2 set were examined it was apparent that the coupling end of the set was moving excessively in the horizontal, transverse axis; but there was comparatively little movement vertically or axially.

The data showed that the vibration was predominantly at 1X shaft speed with very little axial component, indicating a balance problem.

The amplitude of horizontal movement in the vertical and horizontal cross-sections were plotted using the shaft speed peak from the relevant vibration spectra collected.

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Fig 1: Original Bed.

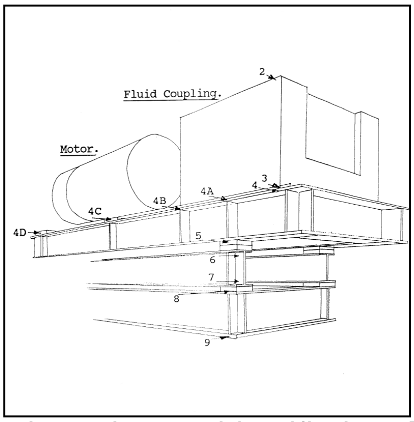

Fig 1 is a schematic arrangement drawing showing the monitoring positions from where the data selected to illustrate the problem were collected.

Fig 2: Elevation View showing relative Vibration Amplitude

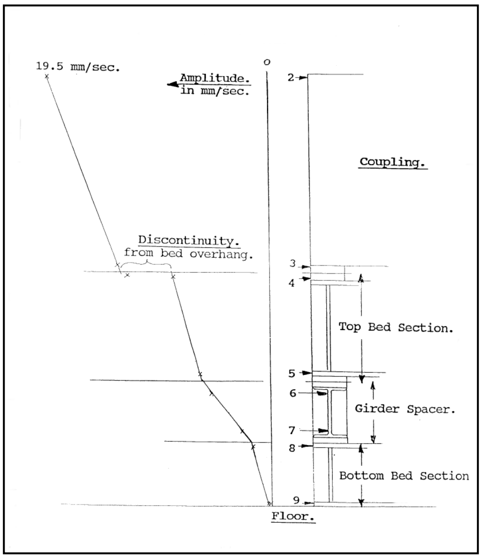

Fig 2 shows the data plotted against a vertical cross section of the bed. The plot utilises data collected from points 2 to 9 inclusive, as identified on Fig 1. On the right of Fig 2 is an end view of the left hand side of the bed, looking from the coupling end.

The plot clearly shows that the girder spacer is considerably more flexible than the other sections of the bed.

Note the discontinuity which occurs where the top section of the bed is overhanging the other sections.

The velocity of 19.5mm/s from point 2, which is just above the output shaft means that the shaft is moving from side to side by approximately 0.75 mm, twenty five times per second.

Fig 3: Plan View showing relative Vibration Amplitude

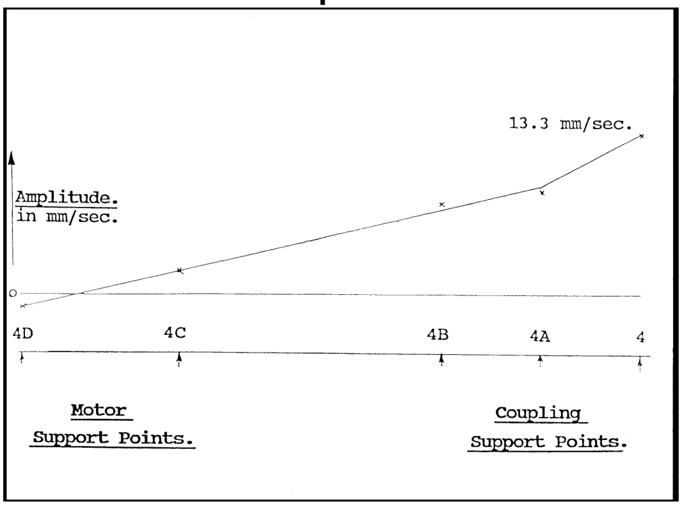

Fig 3 shows a plan view of the relative movement of the edge of the bed. This plot utilises data collected from points 4 to 4D inclusive, as identified on Fig 1.

Note the deflection of the bed at monitoring point 4A, which is above the supporting lower sections of bed while point 4 is overhanging.

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Conclusions and Recommendations

The level of vibration from the coupling end of this set is not acceptable.

The out of balance forces from the coupling are relatively high (considerably higher than the out of balance from the motor), but are not necessarily above the stated acceptance limits from the manufacturer.

The final design of the machine bed has two features, which allow the bed to flex, i.e. the girder spacer and the overhang of the top section beyond the support of the bottom section.

The problem can be defined as the ability of the bed to control the out of balance forces exerted by the coupling. There are two possible solutions to this problem:

(a) remove the force source by balancing the coupling to a better standard. This is possible but, if the original coupling is within the manufacturer's normal specification, then this would be a 'special'; also this course of action may prove expensive in money, time and effort

(b) strengthen the bed in the transverse plane. This is by far the easiest, quickest and cheapest method since the overhung sections of the bed could be utilised for this.

The recommended bed modifications were carried out and the equipment was re-monitored.

Fig 4: Modified Bed.

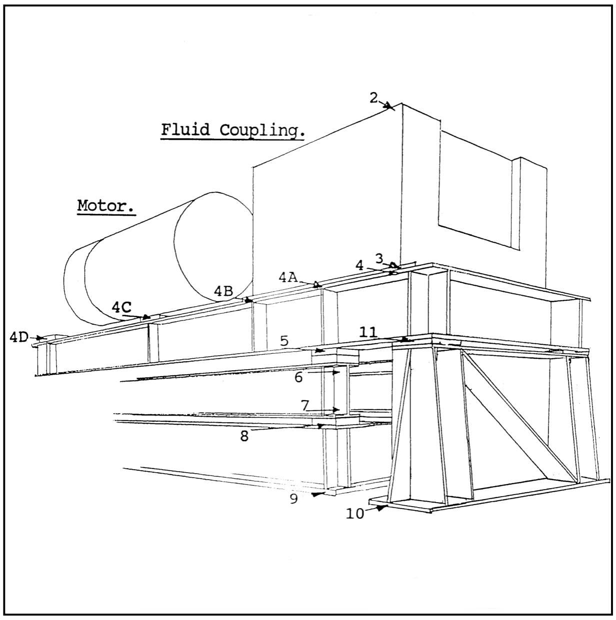

Fig 4 shows the new bed configuration and some extra monitoring points.

Fig 5: Elevation View showing relative Vibration Amplitude

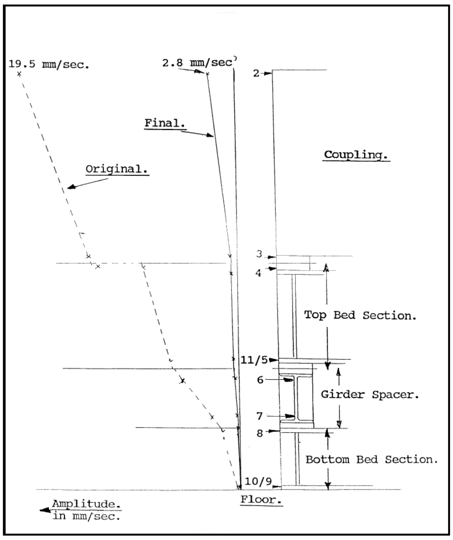

Fig 5 shows the new data plotted against the old for the vertical cross-section of the bed.

The maximum amplitude of vibration, measured at the top

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of the fluid coupling, is reduced to 2.86 mm/s rms. This is less than 1 5 per cent of its previous value and is well within acceptable values for this class of machine. It is also similar to that of the 'control' installation.

Fig 6: Plan View showing relative Vibration Amplitude

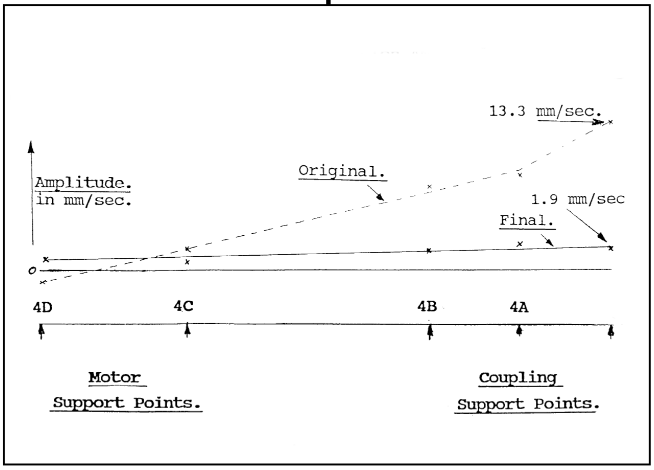

Fig 6 shows the new data plotted against the old for the plan view of the relative movement of the edge of the bed.

Following the success of the bed modification of the number 2 set, a similar modification was made to the number 1 set but, initially, without the drastic improvement experienced with the number *2* bed. On investigation it was found that the new bed section was not taking any of the weight and was effectively hanging from the original structure rendering it ineffective even though the floor bolts were well tightened down.

Proper load sharing will always be a potential problem when trying to give additional support to a structure. If there has to be a choice between the new bed section and the coupling end of the old bed, then the load must be on the new section. It is easier to ensure this by installing the new section so that the coupling end of the old section has a small gap under it. Subsequent grouting will improve the overall support but it is far less critical when the fallback situation is for the new bed section to be carrying the majority of the load.

This instance is an illustration of the importance of remaining aware of the 'principle of minimum support' and its practical applications.

The use of a vibration analysis survey enabled the source and amplitude of the vibration to be clearly identified.

Comparison of the existing vibration amplitudes against standards, whether local, industry or international, clearly defines the problem and is the starting point for any analysis.

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Once the problem has been clearly defined, it is relatively simple for the engineer to find and evaluate the possible solutions and *know* that the final solution will work. If the expected result does not occur, then it is important to know why, so that the situation can be corrected or avoided in the future.

In this example the plots shown in Fig 2 and Fig 3 clearly illustrate the results of various design features of the bed. The bottom bed section was not measurably lifting from the floor so the difference in movement amplitude between the bottom and top of each section is due to distortion of girders not rocking. The slope of the lines is an indication of the relative stiffness of the different sections. Using these facts we can make fairly accurate estimates of the effects of each separate section of the structure and also estimate the effect of alterations. There are two features of the design of this bed each of which have detrimental effects on the resulting structure.

(1) The girder spacer was not part of the original design, but an amendment, it is clearly the weakest of the three sections, even though the web had been gusseted between the flanges to increase the stability in this plane. It is estimated that this section alone allowed approximately 4.8 mm/s of the total of 19.5 mm/s.

With rotating machinery of this nature the largest forces are likely to be transverse to the shaft axis rather than along the axis. If the girder spacers had been installed across the bed rather than along the bed and gusseted in the same manner, the probable effect would be to make it as stiff as the other bed sections in this plane, reducing the movement of the top of the coupling by approximately 3 mm/s.

(2) The overhang of the top section of the bed beyond the bottom sections has a very large effect on the resultant structure. The case of the fluid coupling is of a rigid design, the thickness of the material of the large end plate will produce a very stiff structure. The result of this should be that the top of the coupling should be moving very little more than the bottom and the amplitude line between points 2 and 3 should be near to vertical. This is obviously not the case.

Clues to what is actually happening are: the discontinuity from the bed overhang highlighted in Fig 2, and the deflection of the top flange of the top bed section between points 4 and 4B, shown in Fig 3.

There is good support in a vertical line up from the floor at point 9 to the top flange of the top bed section at point 4A but the coupling is not supported at 4A, it is supported at points 4 and 4B by the top bed section cantilevered from point 4A.

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The designed strength of the top bed section is in the vertical direction not the horizontal-transverse direction. The immediate and obvious effect is that, under the forcing effect of the coupling, the cantilevered end of the bed, at 4, is moving, in the transverse horizontal direction, markedly more than its support at 4A. The bed girders are flexing — twenty five times per second.

The second effect is that point 4 is also relatively free to move in the vertical direction. While the tip of the left hand girder is moving down, the tip of the right hand girder is moving up, allowing the coupling to rock on top of the swaying bed. This explains the observed action and the theory was confirmed by taking vibration spectra from the top flange of the bed at points 4 and 4A, in a vertical direction.

The combined effects result in the bed twisting and flexing and at a cycling rate of 90 000 cycles/h has great potential as a cause of fatigue failure.

The vibration survey carried out to check the integrity of such an installation must be exhaustive. The monitoring engineer cannot assume that the obvious problem is the only problem.

The final set of readings, on which the report was based, was a set of 55 spectra from the number 2 motor coupling set. This does not include the initial work to establish the source of vibration, or the data collected from other sets as a control.
The results recorded above are based on only a small part of the data collected. During the investigation data was collected to check the other facets of the installation, e.g. alignment, but, since no problem was highlighted, they have no place in the report.

One problem detected early in the investigation was a bearing fault on the non-drive end of the motor. The envelope spectrum indicated a bearing outer race defect. An attempt to grease the bearing proved impossible, further investigation found that the grease tube was screwed down onto the bearing race thus sealing itself as well as putting pressure onto the outer race. The tube was refitted properly and the bearing was lubricated, the fault indications disappeared. This fault was located and corrected quickly, before it could develop and before the completion of the investigation; since it was not associated with the major problem it did not feature in the main report. However if this type of fault is not located very early during the working life of the bearing, then real damage usually follows quickly. The clearance within bearings are small and very little localised pressure is required to deform the race enough to turn a clearance fit into an interference fit. The resulting high rate of deterioration often leads to failure before routine monitoring can be established.

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Examination of the bearing and housing following such a failure will often not find the true cause, since the secondary damage to the bearing housing destroys the evidence. With the majority of failures in service, the secondary damage is far more extensive than the original fault. The subsequent analysis for the cause of failure is often difficult and the results uncertain. If, however, the unit is removed and examined before secondary damage occurs, then the true mode of deterioration towards failure is clearly identified. Based on such detailed information, modifications to equipment, manufacturing methods or working methods can be introduced to eliminate, or at least reduce, the recurrence of that particular fault.

It is important that the results of condition monitoring be used not only to avoid the failure of individual items, but also in a much wider way, to develop and modify both 'the equipment' and 'the maintenance strategies and techniques'.

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