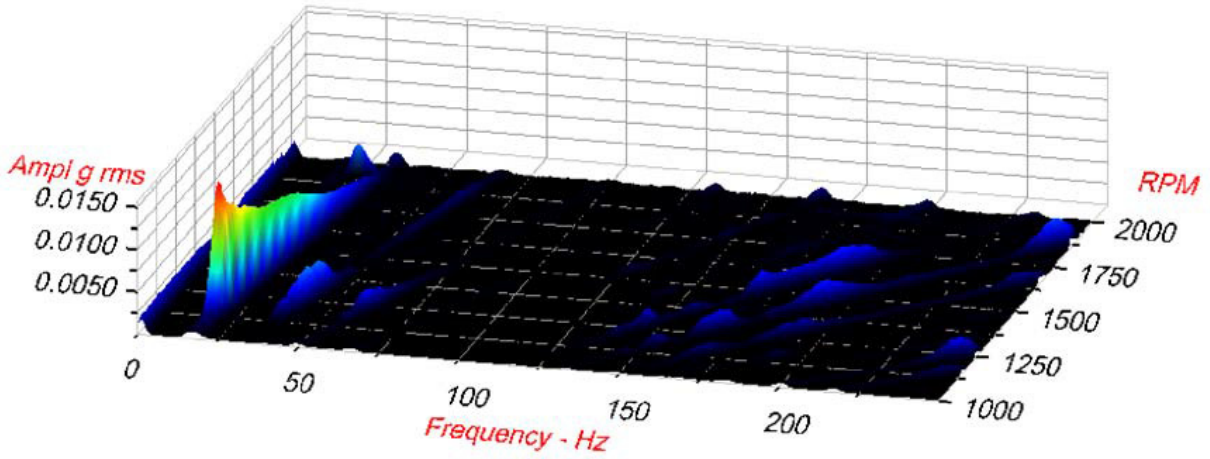
Application Note

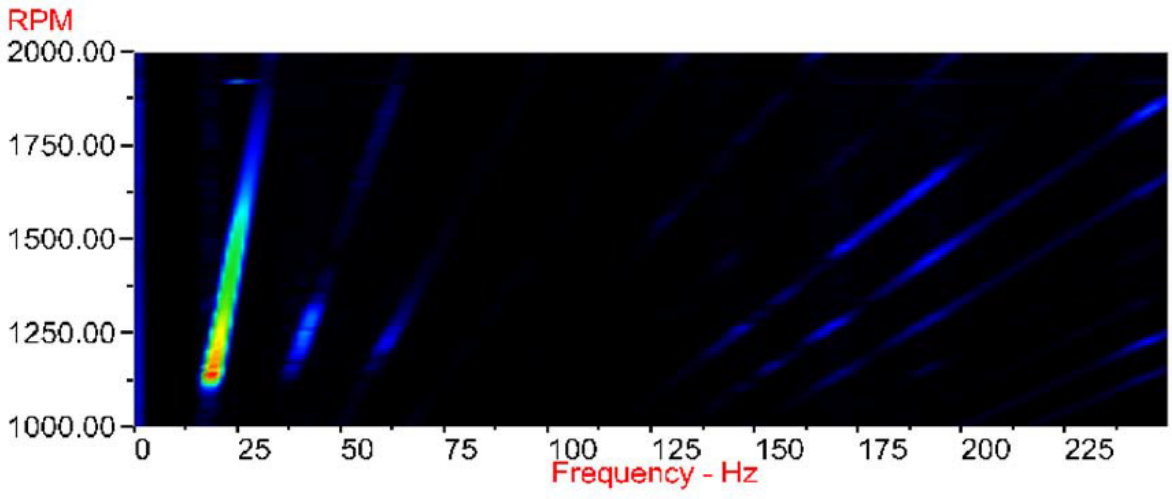
Fan Housing Vibration

m+p international's SO Analyzer was used to investigate the dynamic response of a fan system which exhibited high levels of vibration as it swept up to its normal operating speed.

The fan was instrumented with a tachometer which provided a pulse every revolution. This signal was captured to trigger acquisition and enable the plotting of frequency information versus RPM. Initially vibration was measured in two orthogonal directions on the fan casing. The following waterfall plot shows the vibration spectra in one direction as the speed was increased.

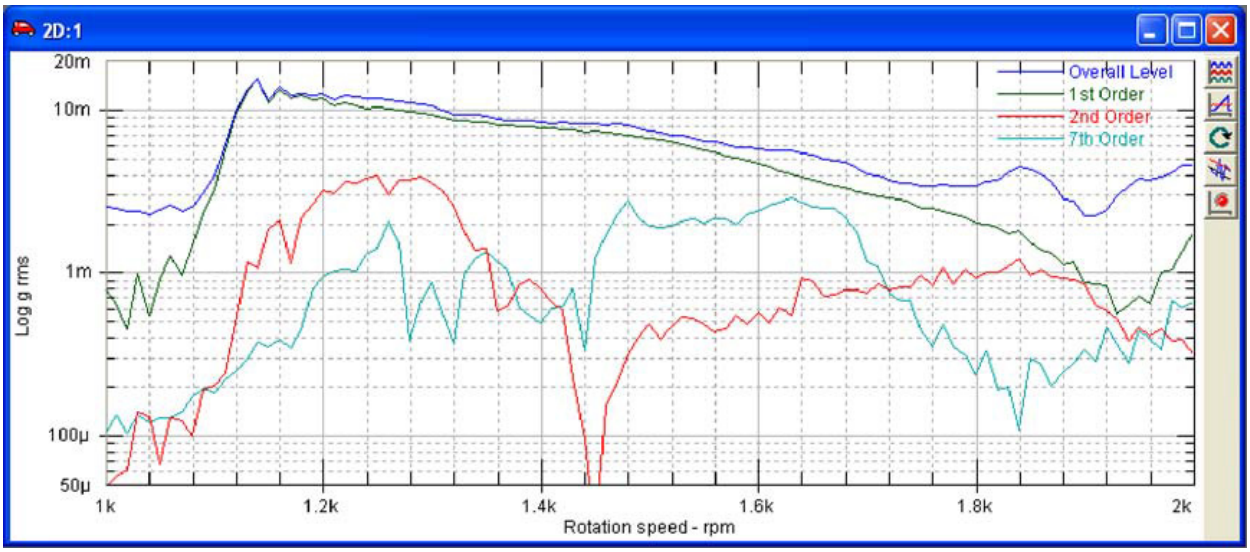


The following colour map shows the same information as the waterfall plot but using a top view. It was evident that the major response came from a 1st order (imbalance) and that higher orders were present but less significant. The higher orders would have been even less significant if the data was presented as displacement instead of acceleration.



Inspection of the colour map shows that the 1st order response rose rapidly from 1000 RPM to a peak at 1110 RPM, reducing gradually as 2000 RPM approached. This asymmetry is because the forcing function is proportional to the speed squared ($F = mr\omega^2$). Hence, below resonance the force and dynamic amplification are both increasing whereas above resonance the force is still increasing whilst the dynamic amplification is decreasing. Because the forcing is 1st order, the resonant frequent corresponded with 1110 RPM / 60 = 18.5 Hz.

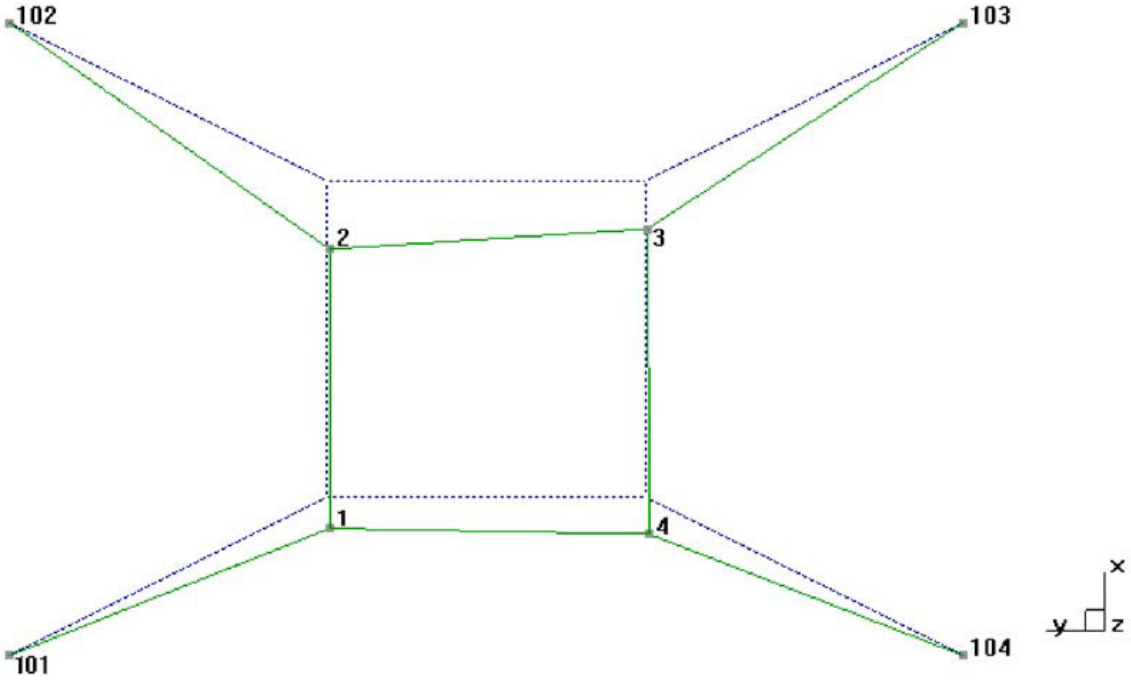
The 3D colour map is a useful tool for showing qualitative information, particularly which orders excite which resonances; some extrapolation is possible to determine what would happen at higher speeds. However, these plots are not ideal for extracting numerical values and comparing data from different measurements or alternative configurations – this is best achieved using 2D order tracks. Order tracks are the vibration amplitudes extracting along the diagonal order paths. In the following plot the green, red and cyan traces represent 1st, 2nd and 7th order, respectively. The blue trace represents the overall level and it is apparent that from 1000 RPM to 1400 RPM the overall level is accounted for by 1st order. At speeds above 1400 RPM the significance of 1st order decreases whilst the significance of other orders increases.



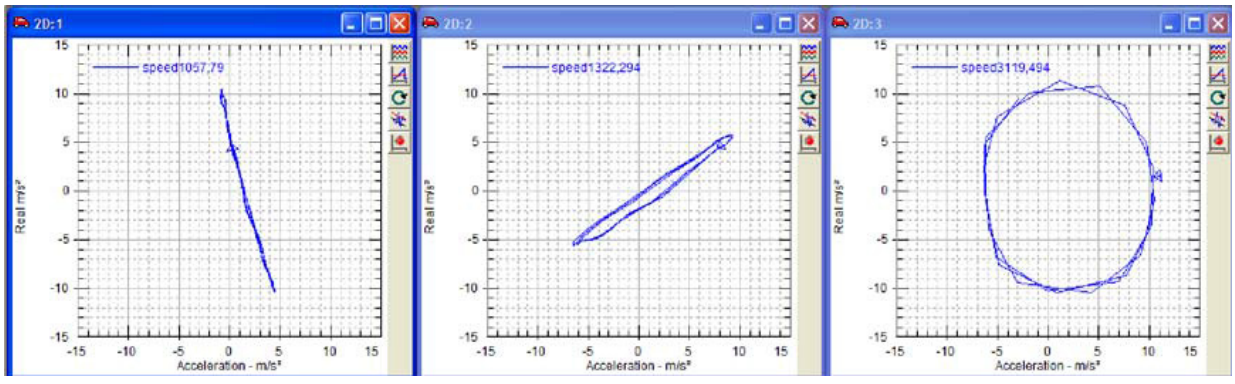
The accelerometer at right angles exhibited a similar trend but its resonance was at a slightly higher frequency (24.8 Hz) due to the asymmetry of the fan's mounting system.

An Operating Deflection Shape was produced to further understand the physical motion of the fan's housing at its resonances. Points 1, 2, 3 and 4 represent the accelerometer positions on the four corners of the fan housing. Points 101, 102, 103 and 104 represent the fan housing's mounting positions. Phased order tracks were measured as the fan speed was increased. m+p international's resampling order tracking technique coupled with the ODS Analysis Wizard of the SO Analyzer enables animations to be produced.

The dotted line is the undeformed position and the solid line shows the deformation. It can be seen that the fan housing exhibits a rigid body motion in the X direction at the 18.5 Hz resonance. The fan's rotation axis is shown by the circular arrow.



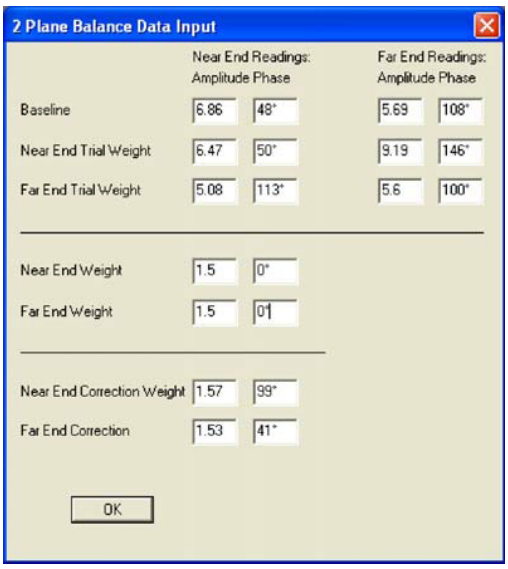
An additional technique, perhaps more suited to condition monitoring than troubleshooting, is orbit plotting. This is measured with a pair of transducers at right angles. Measurement at a bearing location with proximity (displacement) transducers is typical. These three plots indicate three operational speeds with the left-hand plot being the 18.5 Hz mode previously discussed. The central plot shows the 2nd mode at a slightly higher frequency. The right-hand plot shows the fan housing at a high speed where its response is controlled by inertia, with the orbit following a roughly circular path. Due to the high force level at high speed the non-resonant responses are similar in magnitude to the resonant responses at lower speeds.



Inspection of the data indicated two actions which might reduce the fan housing vibration, as follows:

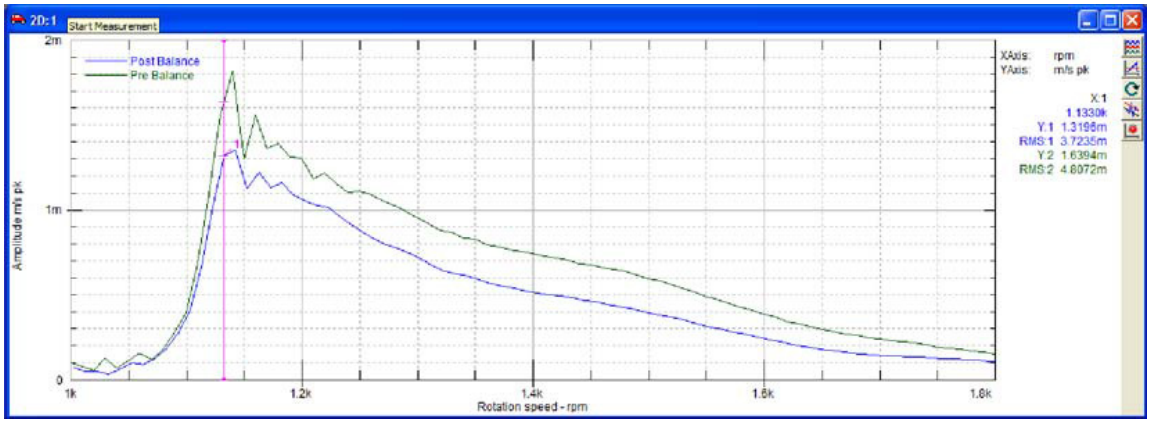
1. Reduce the frequency of the resonances so that the excitation force would be lower at the resonances.
2. Reduce the excitation force by balancing the fan.

There were concerns about the durability of Option 1 so, in conjunction with m+p international's Balance Wizard (shown below), Option 2 was implemented.



Input to the Balancing Wizard is vibration amplitude and phase under baseline and known imbalance conditions. Output from the Balance Wizard is correction mass and position around the rotational axis.

Balancing the fan reduced the 1st order forcing resulting in a 26 % reduction in vibration response at the resonance:



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