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Vibration Control of Dragline Swing Motors

Impedance Modeling Techniques For Structural Dynamics Modification

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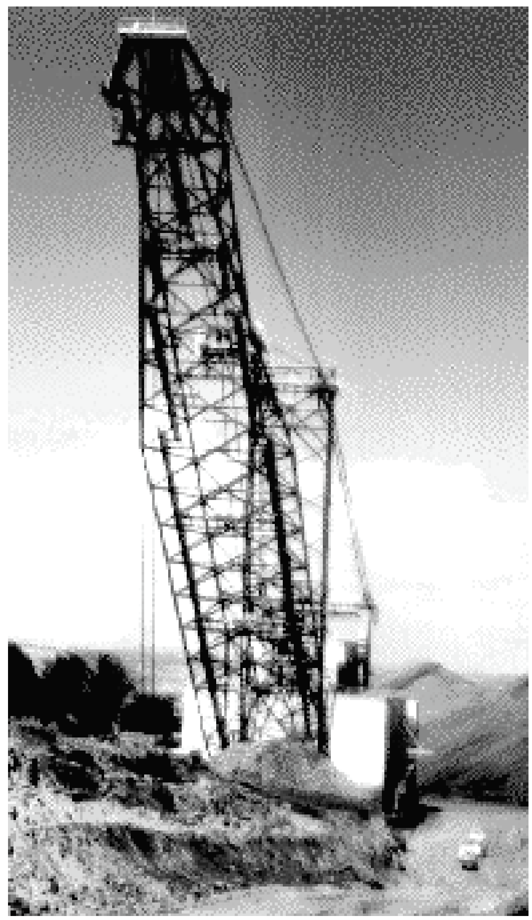

The problem involved the vibration control of 14 vertical motor/gearbox assemblies (i.e., the swing motors) in a 16 million pound Walking Dragline. [*Draglines (which incidentally, are bigger than a Brontosaurus) are used to move the overfill.*] Initial test results indicated that the source of the vibration was the internally generated inertial forces produced by the motor and gear train. These dynamic forces excited structural resonances in the swing motor assemblies. We investigated various vibration control measures and determined that the most effective solution was the installation of a tuned vibration damper on each of the swing motors. In addition to the initial diagnostic work, we also designed, fabricated, installed and verified the damper performance.

During the first phase of the project we conducted a series of tests to diagnose the root cause of the vibration and to characterize the vibration in terms of its spectral and modal characteristics. We utilized Structural Dynamics Modification (SDM) techniques (using MATLAB), to develop a plan for mitigating the vibration. We investigated both stiffness and damping modifications and determined that the most practical solution to the problem was with the installation of a tuned damper on the top of the brake flange. We fabricated and tested a prototype damper during the second phase. The third phase included the fabrication, installation and tuning of the production dampers.

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We have included several graphics from this project which might give you a better understanding of this approach to solving resonance related problems. ***Figures 1 and 2*** show that the swing motor's peak vibration response occurs in the 18 to 20 Hz range. The corresponding operational deflection shapes (time domain response) are presented in ***Figure 5***. The frequency response measurements plotted in ***Figure 3*** show the swing motor's dominant structural resonances in the 18 to 20 Hz range. The mode shapes (frequency domain response) corresponding to the structural resonances are presented in ***Figure 6***. The fact that the peaks in the vibration response coincide with the resonance frequencies, and the operational deflection shapes and mode shapes are nearly identical, indicates that the excessive vibration is a resonance related problem.

Upon talking with the manufacturer and plant personnel, it was determined that it would not be possible to significantly reduce the dynamic forces generated within the motor and gear train and that it would be necessary to modify the resonances. However, the question was how? ...

We developed an analytical model of the swing motors based upon the test data acquired during the first phase. The model was verified by comparing measured frequency response functions with synthesized functions. A typical comparison is shown in ***Figure 4***. The "test" model was then used to evaluate possible stiffness and damping modifications as shown in ***Figures 8, 9, 10 and 11***. The stiffness approach was quickly rejected for a number of reasons: **1)** first, it was not physically possible to change the dynamic/modal stiffness by the required amount without major (and maybe impossible) structural modifications to the Dragline, **2)** the initial cost estimates of such modifications were considered financially unreasonable, and **3)** since the swing motors operate over a broad RPM range (i.e., frequency range), the resonances would still be excited even if they were raised in frequency. Based upon the predicted vibration reductions, cost and timing issues we recommended that we pursue the damping solution.

The dampers were mounted on the top of the brake flange as shown ***Figure 7***. They were designed to operate in a shear mode with their radial resonance approximately 1 Hz lower then their tangential resonance. Referring to the test results presented in ***Figures 11 and 12*** (Swing Motor No. 5) and ***Figures 13 and 14*** (Swing Motor No. 10) the dampers reduced the vibration by a factor of 5^+ (or approximately 14^+ dB).

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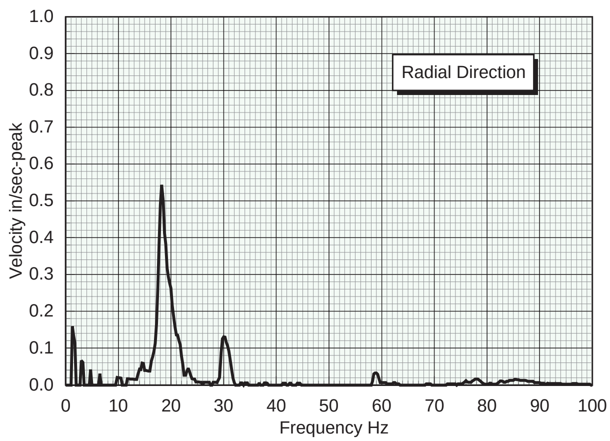

Figure 1: Typical peak-hold vibration spectrum measured radially during operation of the swing motor.

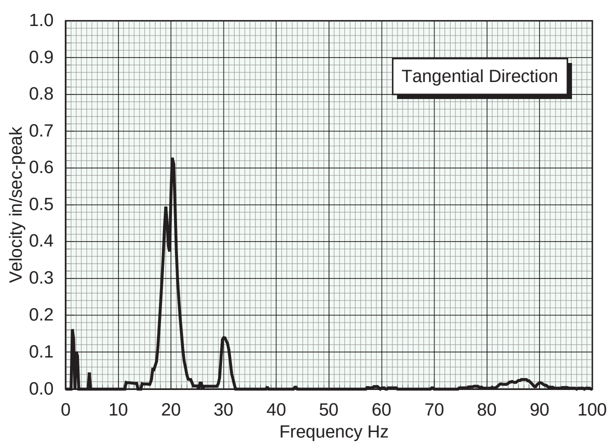

Figure 2: Typical peak-hold vibration spectrum measured tangentially during operation of the swing motor.

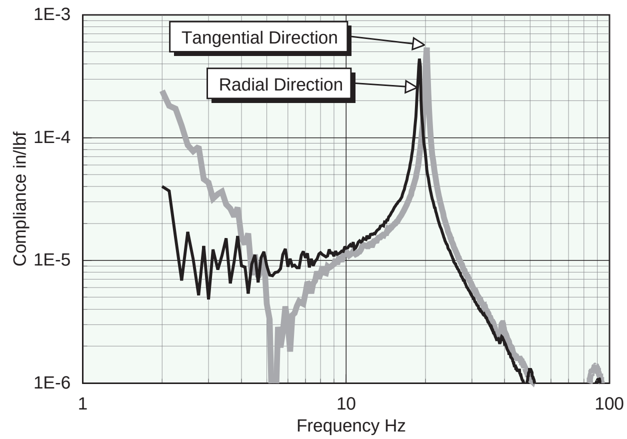

Figure 3: Driving-point frequency response functions measured at points near the top of swing motor with impact excitation.

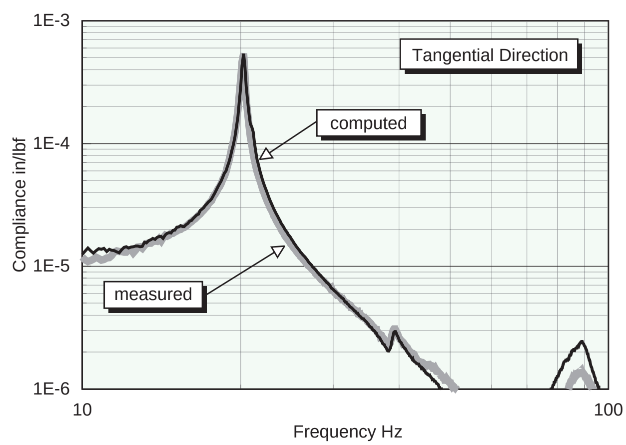

Figure 4: Model verification - analytical (black lines) and measured (grey lines) frequency response functions for the swing motor.

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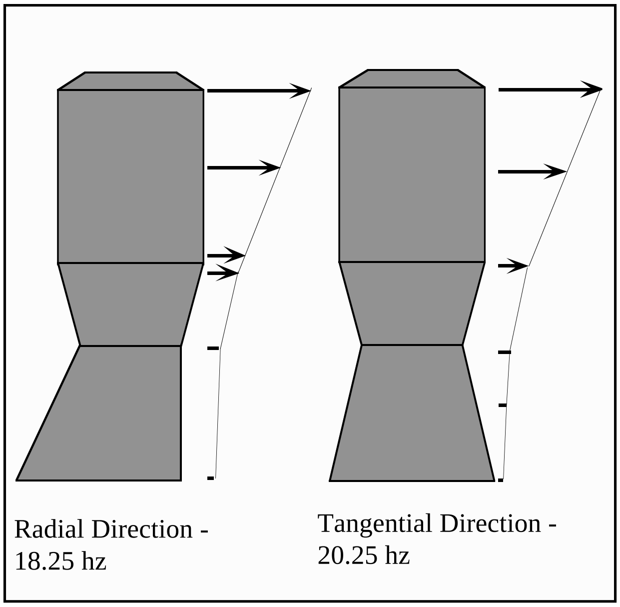

Figure 5: Operating deflection shapes of the swing motor.

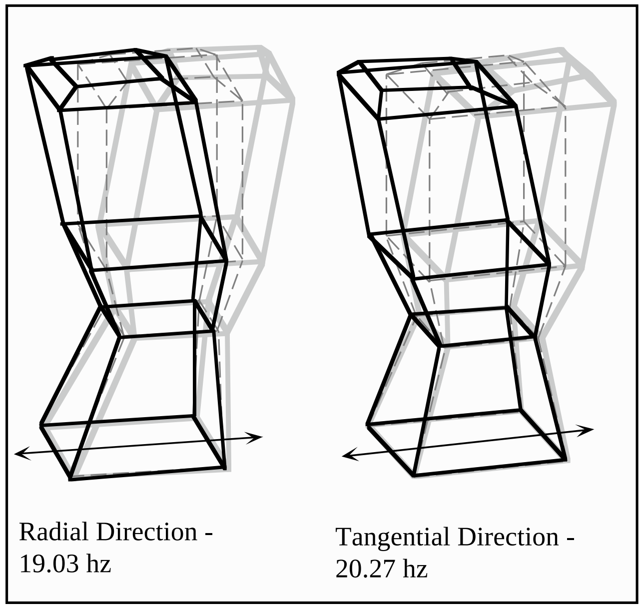

Figure 6: Resonance mode shapes associated with the dominant structural modes of the swing motor.

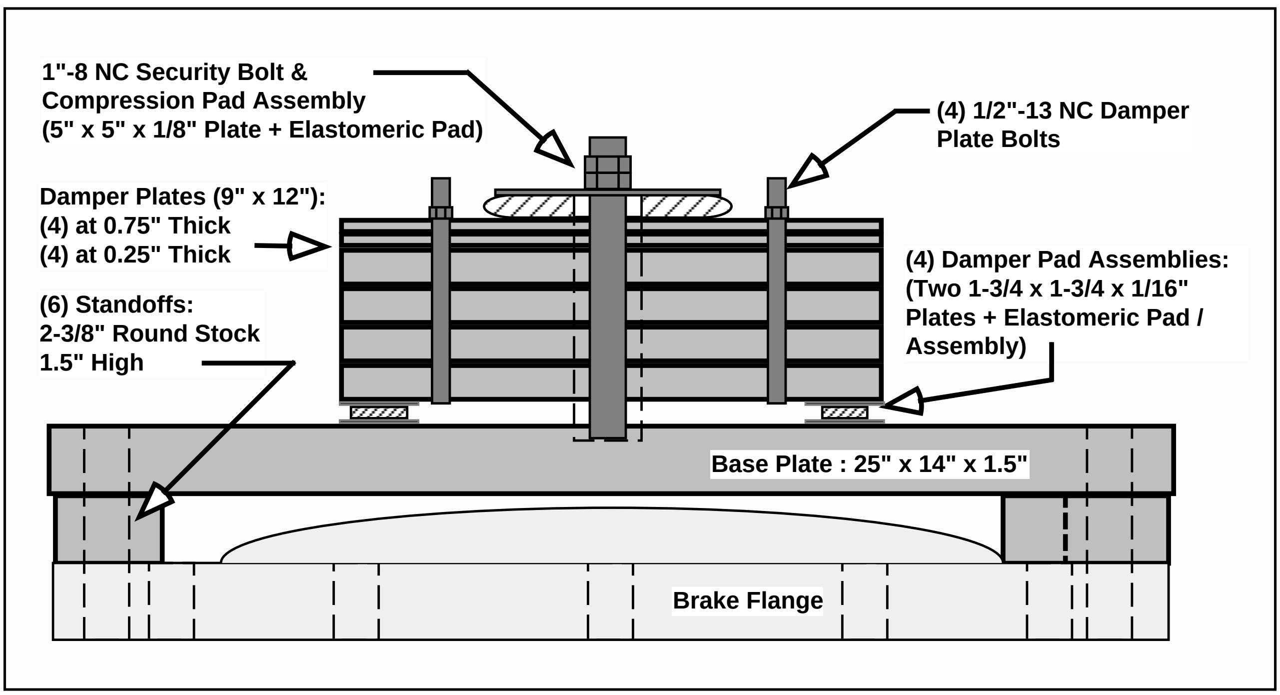

Figure 7: Sketch of Tuned Vibration Damper on Swing Motor Brake Flange

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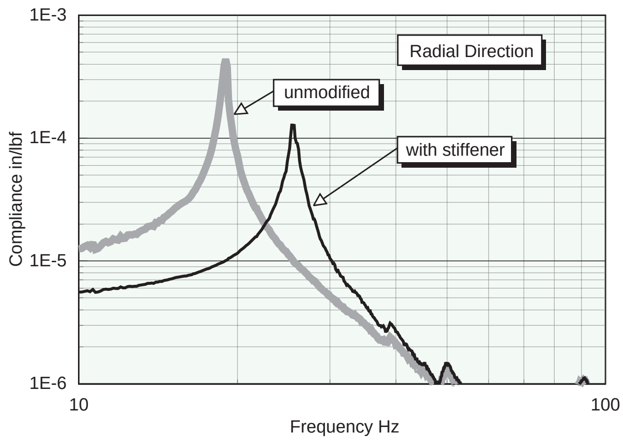

Figure 8: Predicted effect of adding a stiffener from the top of the swing motor to ground in the radial direction. Gray lines are measured data, black lines are predicted.

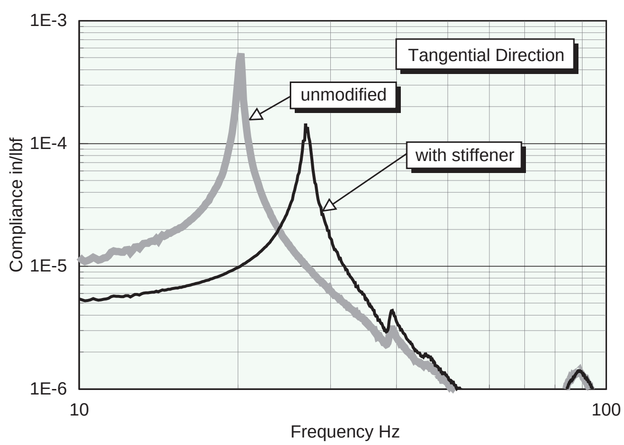

Figure 9: Predicted effect of adding a stiffener from the top of the swing motor to ground in the tangential direction. Gray lines are measured data, black lines are predicted.

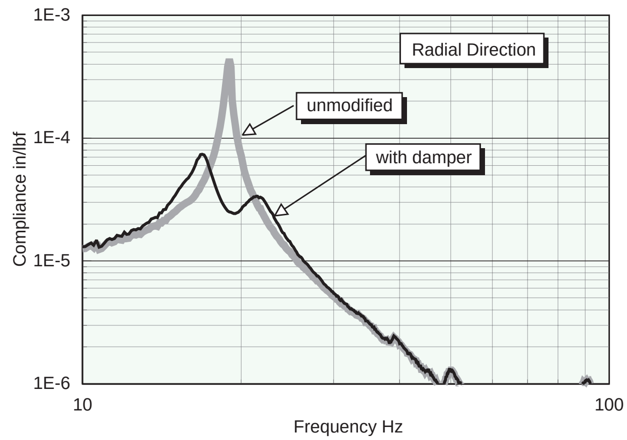

Figure 10: Predicted effect of adding tuned damper at the driving point measurement location. Gray lines are measured data, black lines are predicted.

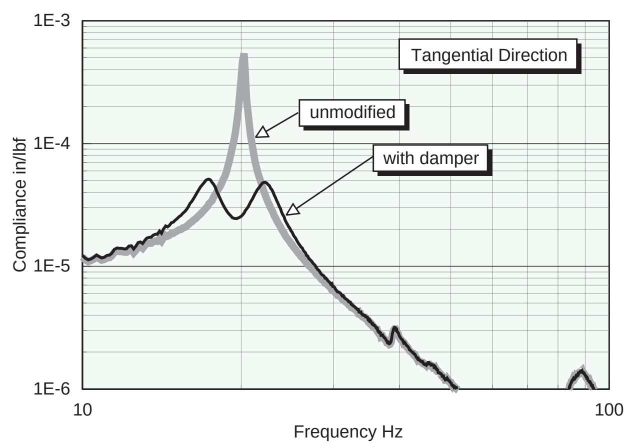

Figure 11: Predicted effect of adding tuned damper at the driving point measurement location. Gray lines are measured data, black lines are predicted.

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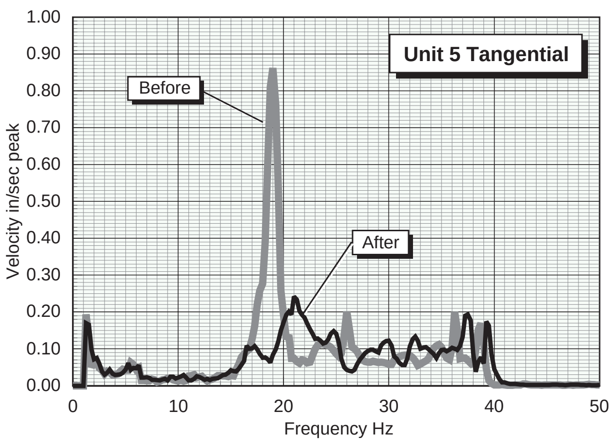

Figure 12: Peak hold vibration response measured tangentially on Swing Motor No. 5. The gray line is measured data before the installation of the damper. The black line is measured data after the installation of the damper.

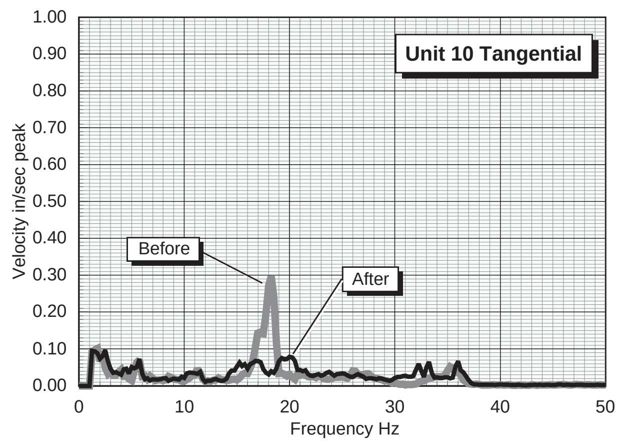

Figure 14: Peak hold vibration response measured tangentially on Swing Motor No. 10. The gray line is measured data before the installation of the damper. The black line is measured data after the installation of the damper.

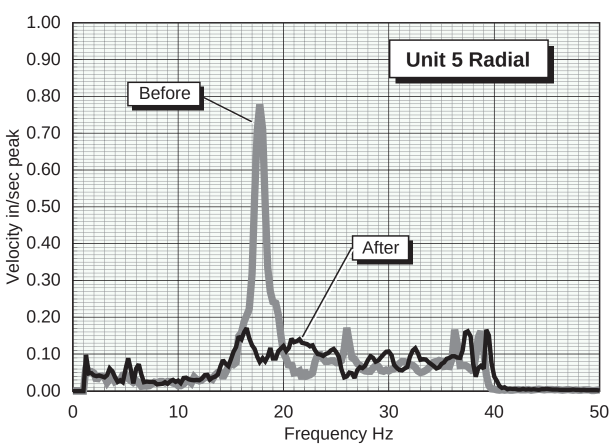

Figure 13: Peak hold vibration response measured radially on Swing Motor No.5. The gray line is measured data before the installation of the damper. The black line is measured data after the installation of the damper.

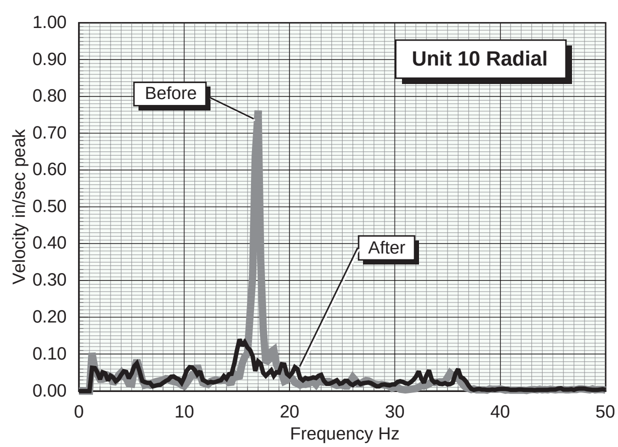

Figure 15: Peak hold vibration response measured radially on Swing Motor No. 10. The gray line is measured data before the installation of the damper. The black line is measured data after the installation of the damper.