ANALYSIS OF THE OPERATOR'S SUSPENSION SYSTEM WITH QUASI-ZERO STIFFNESS BASED ON THE ADAPTIVE PIEZOCERAMIC ELEMENTS

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The long-term impact of vibrational loads on heavy machinery operators poses a considerable risk to their health and compromises the operational precision of machinery. This requires a good vibration isolation system.

Quasi-zero stiffness means that the system demonstrates almost zero dynamic stiffness around the equilibrium position, offering superior isolation from low-frequency excitations while maintaining load-bearing ability. A main innovation of this system is the batching of piezoceramic component which could improve the adaptation capability of the system to external disturbances. The study validates that, with the correct geometry and stiffness parameters, a zero dynamic stiffness state can be realized, which is vital for the best energy dissipation to be achieved.

The result shows an important relationship between the geometry of the arrangement and the resultant stiffness of the system, resulting in a dynamic stiffness of zero at the static equilibrium position. The values of dimensionless force and stiffness were determined for different stiffness ratios and geometry parameters in a static equilibrium position, namely stiffness is zero, combined stiffness is positive and combined stiffness is negative. To facilitate the dynamic analysis, a polynomial approximation of the force-displacement interaction is suggested, with the final stiffness equation being only 2% different than the correct solution. The results show the system's promise for compactness, efficiency, and precision.

For this application, adaptive piezoceramic materials are found to be specifically suitable doe to their low noise, high responsiveness, and the versatility of their form factor. Combining these approaches enables real-time stiffness modulation, widening the frequency range and speed of the system.

Overall, the QZS-based semi-active suspension system with active piezoceramic elements has the potential to significantly reduce the harmful effects of vibrations on machines operating in construction, agricultural and logging conditions experienced by operators. The findings from this investigation provide a foundation for future refinement enabled by dynamic analysis and active control development for broader operational capabilities at a wider spectrum of vibration frequencies.