Bellows Characterization for Dynamic Systems with Damping and Multiphase Flow

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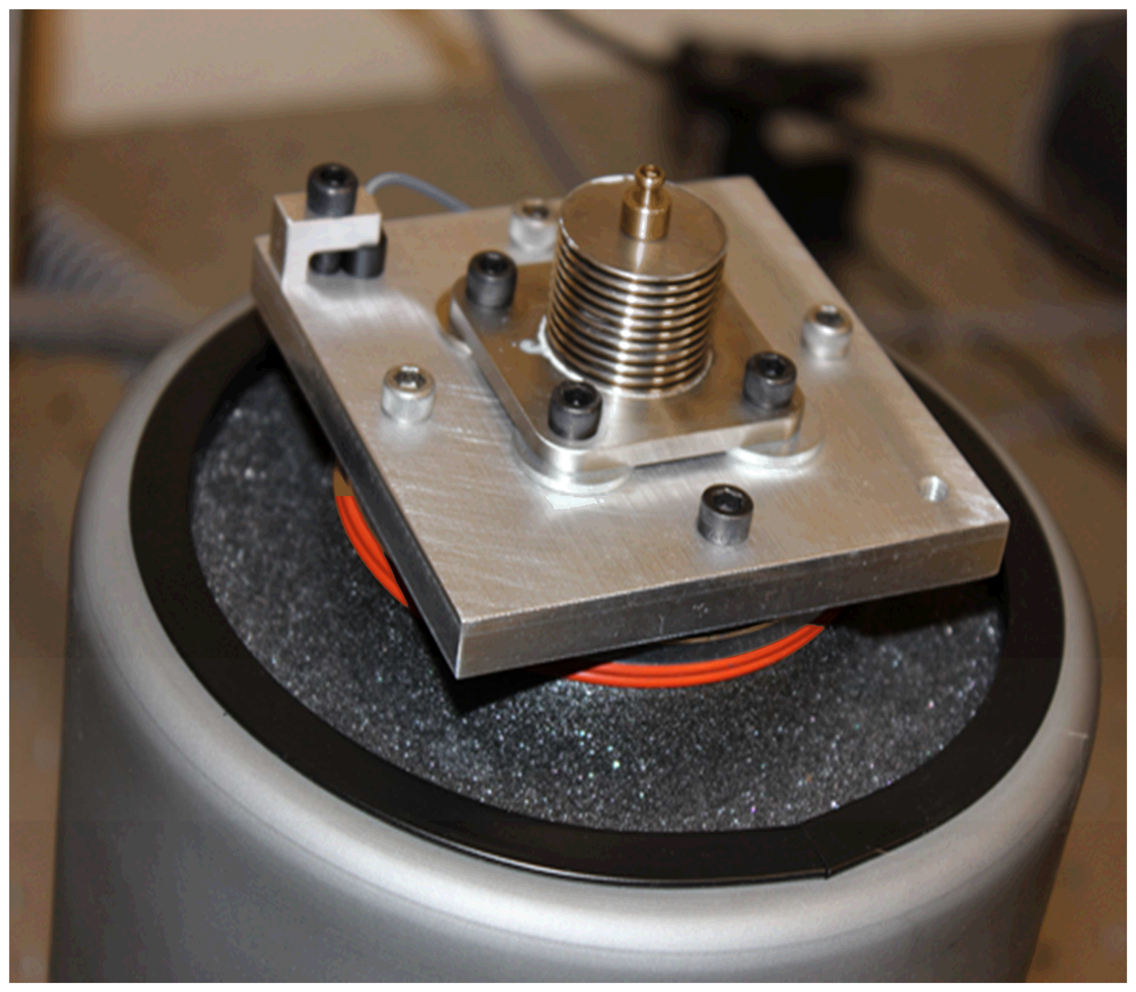
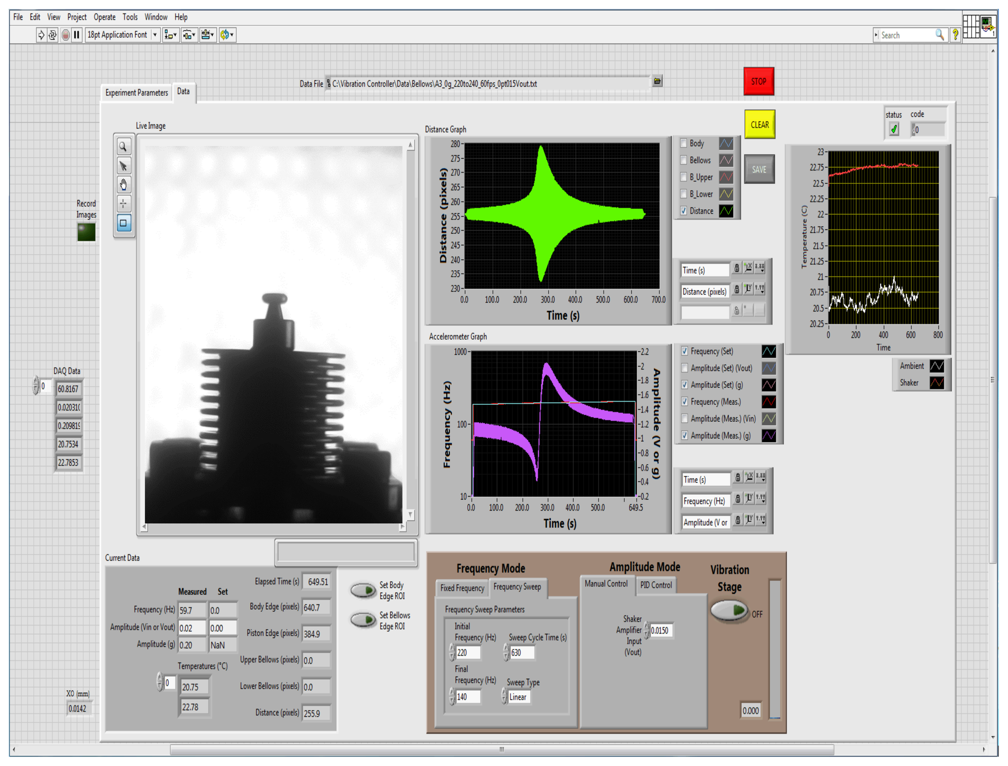
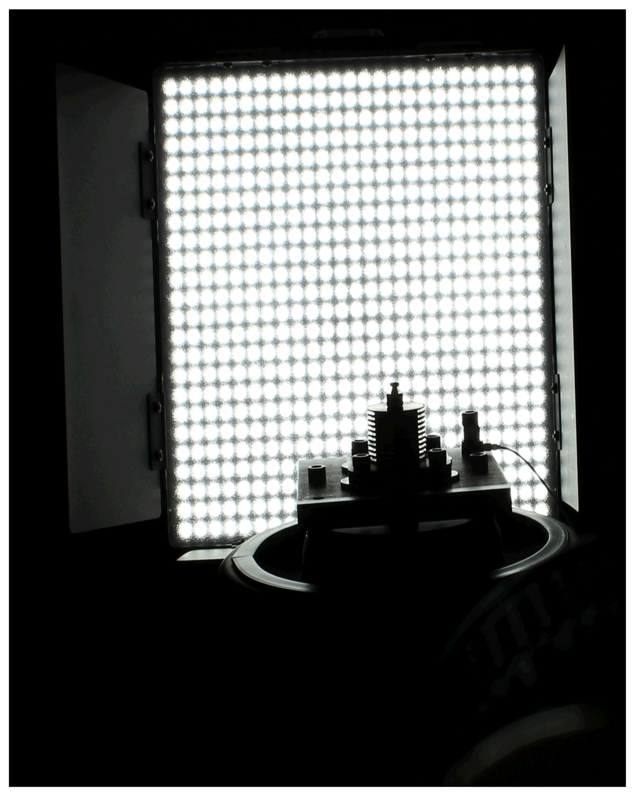
Abstract

The presence of gas bubbles in otherwise liquid-filled mechanisms can lead to unusual behavior when the system is vibrated. This is important for any system where gas-liquid systems are subject to vibration, for example in liquid-filled rocket fuel tanks, since the gas can form bubbles and create a multiphase mixture. The resonance of the system changes when gas is present. In order to understand and model this behavior, experiments were conducted with simple spring-mass-damper systems with pistons enclosed in silicon oil. However, these experiments proved very difficult to repeat since bubble sizes and locations could not be controlled from test to test. It was therefore decided to replace the gas with three different bellows types which were selected to have compressibility similar to the bubbles so that experiments could be run multiple times to gather sufficient data to gain statistical significance.







Experimental

Two experiments were performed to measure the bellows characteristics. One was a dynamic experiment where the bellows , with a small attached mass, was subjected to vibration on an electromechanical shaker to measure its response. This experiment is shown in the photographs above. The measured resonant frequencies for different masses were used to calculate the bellows effective mass, damping, and spring constant k. The other experiment used a commercial texture tester to push each bellows, measure its displacement, and calculate its spring constant.

Conclusions and Future Research

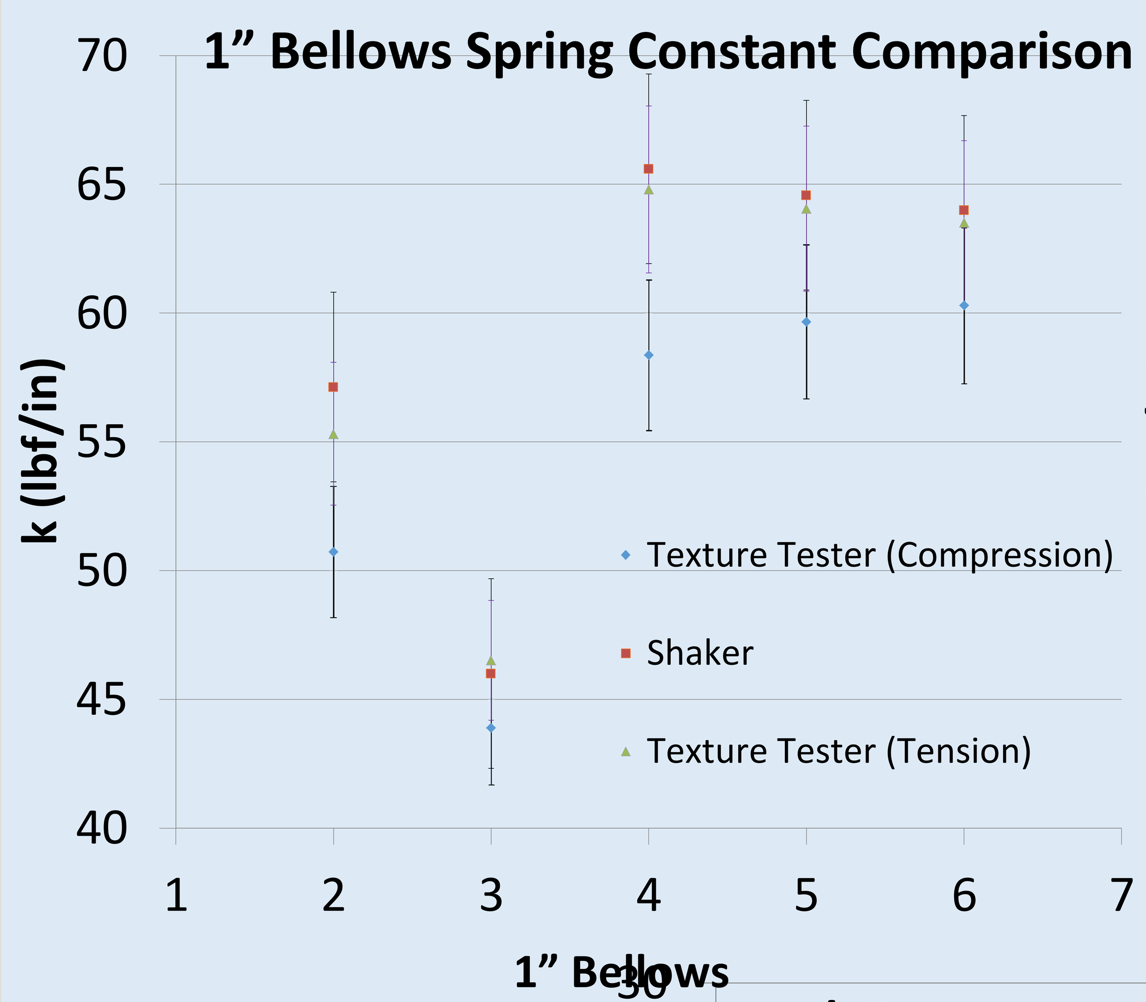
Findings showed that the respective bellows types possessed similar spring constant and resonance values and fell within the ranges given by the bellows manufacturer catalog. However, there were discrepancies between the spring constant determined from the shaker and texture tester experiments. The results from the Shaker consistently gave higher values than the Texture Tester. Further tests are being conducted to gain more understanding of why this is. The results also showed how the spring mass damping systems varied with different bellows types.

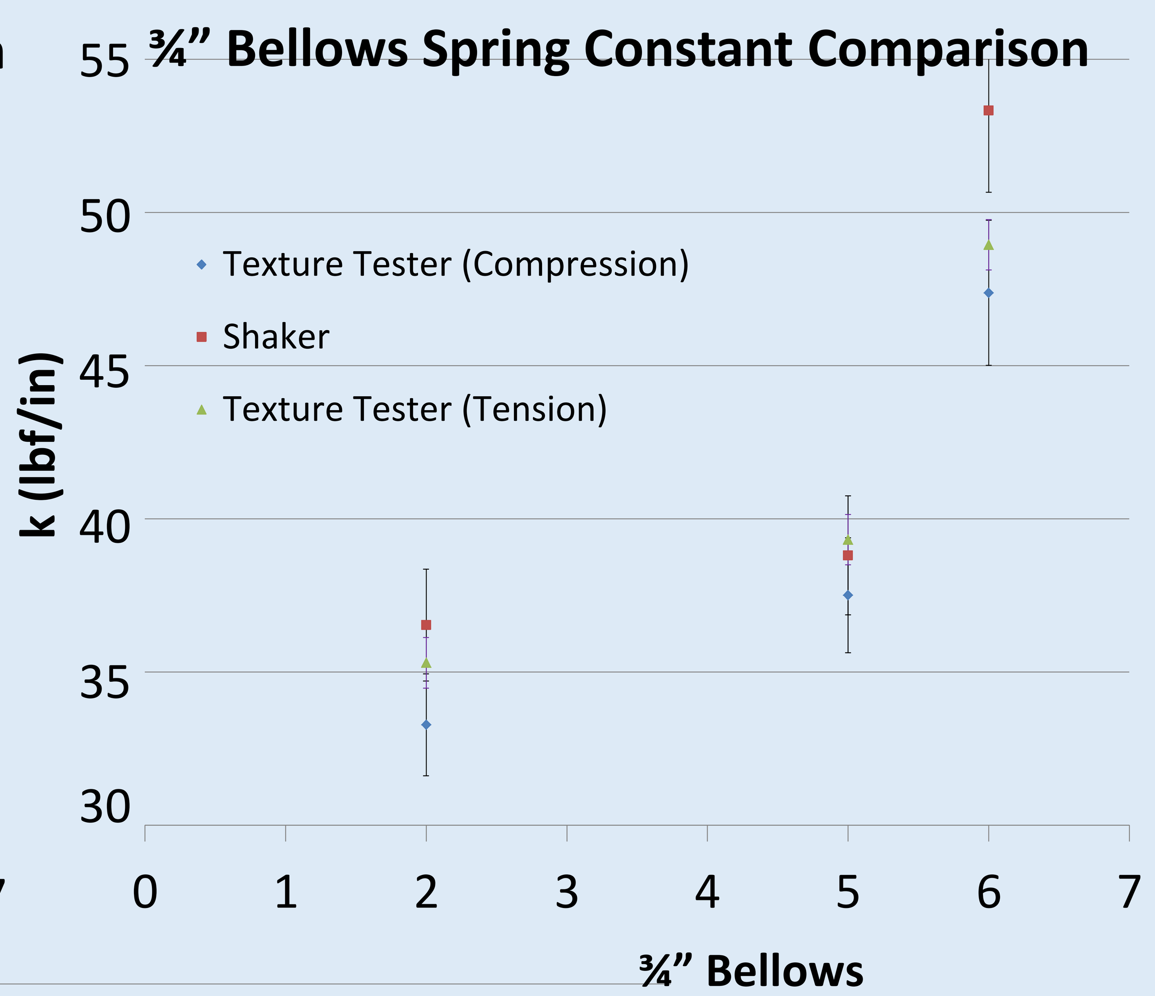
Theory

PV = nRT $K_B = (M_B + M_W)\omega_o^2$ F=ks

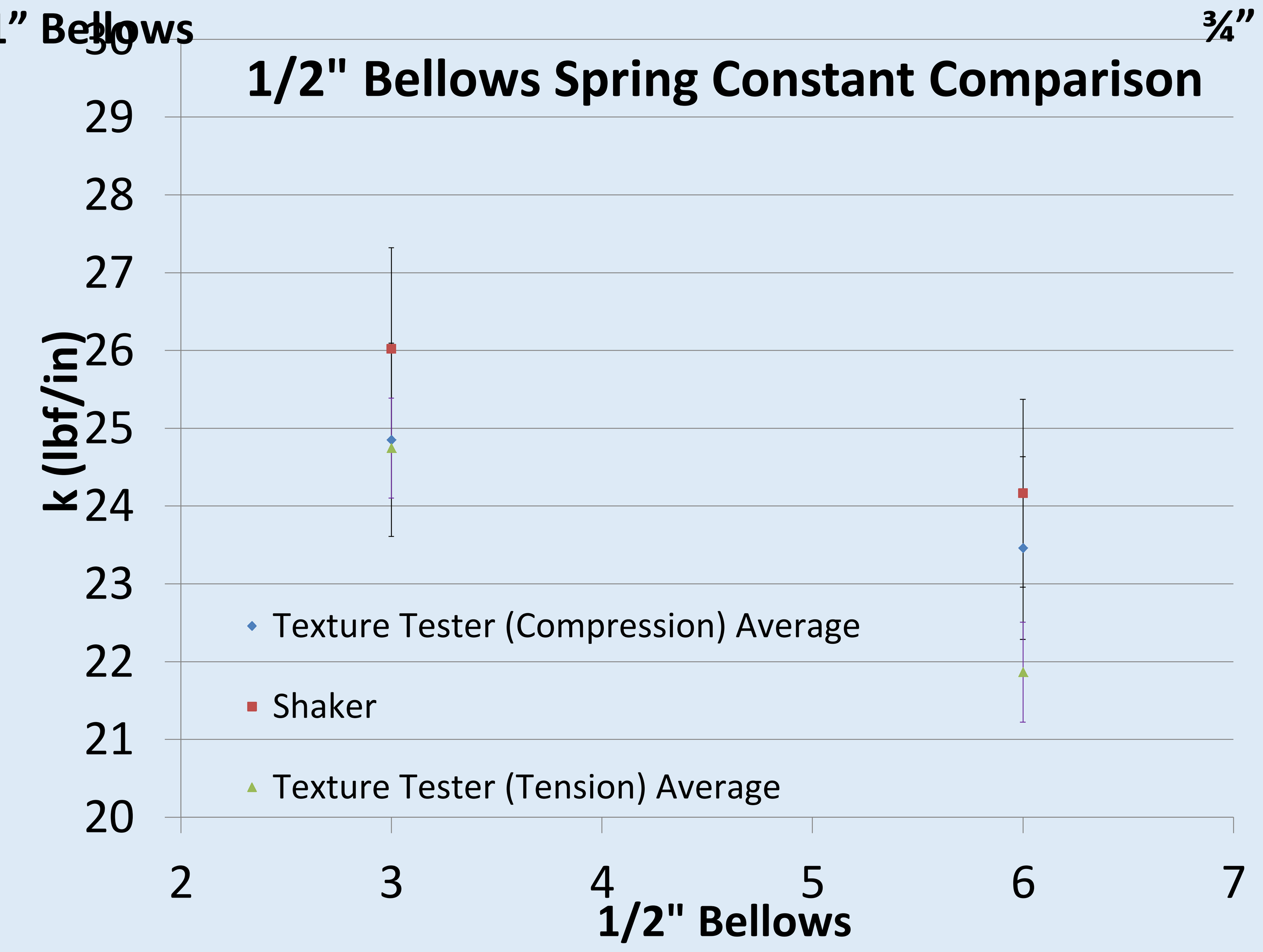
The pressures and volumes were determined for the specific bubble sizes to be tested. From there, using the ideal gas law, and known atmospheric pressure and desired volume, it was possible to solve for the change in pressure with change in volume that corresponded to the bellows' spring constant. Using the equation for a lightly damped driven oscillator, with the known resonant frequencies at varying weights, it is possible to solve for the bellows effective mass, damping, and spring constant k.

Results





Servometer Catalog Values for Spring Constant:
1": 44.7 lb/in
¾": 40.3 lb/in
½": 21.6 lb/in



References and Acknowledgments

Servometer Manufacturer Catalog www.servometer.com/products/metal-bellows

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