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LIGO Damped Coil Spring on Fluorel - Comparison of Mechanical Behavior for Six New Coils

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Abstract

This document presents test results for dynamic axial and shear stiffness and damping of six LIGO coil springs on viscoelastic seats made from Fluorel 2180 formulation. The present results are compared with test data from earlier damped coil assemblies. The six present coils measured reasonably similar test results; however, there are notable differences between the present coils and the original test coil and some differences with a set of three previous coils.

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LIGO PROJECT

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1. Summary

The purpose of this work is to compare the stiffness and loss factors for six identical damped coil assemblies on Fluorel 2180 seats. Each individual damped coil was placed between the seats to measure free vibration decay responses in both axial and shear directions. Measured results for the six coils showed reasonable comparison among these coils; comparison with previous coil assemblies is not as favorable with variations appearing in both stiffness and loss factor data.

2. Test Procedure

Damped coils (DC05, DC06, DC07, DC08, DC09, and DC10) were mounted between Fluorel (formulation 2180) seats in the pendulum test apparatus[1]. Tests were conducted in the axial and shear directions in a range of frequencies from approximately 0.5 Hz to 1.7 Hz. Ambient temperatures during these tests ranged from approximately 21.5 ^{0}C (70.7 ^{0}F) to 22.3 ^{0}C (72.1 ^{0}F).

3. Test Results and Discussion

Figures 1 and 2 present the six coil assembly test results for axial loss factor and stiffness, respectively.

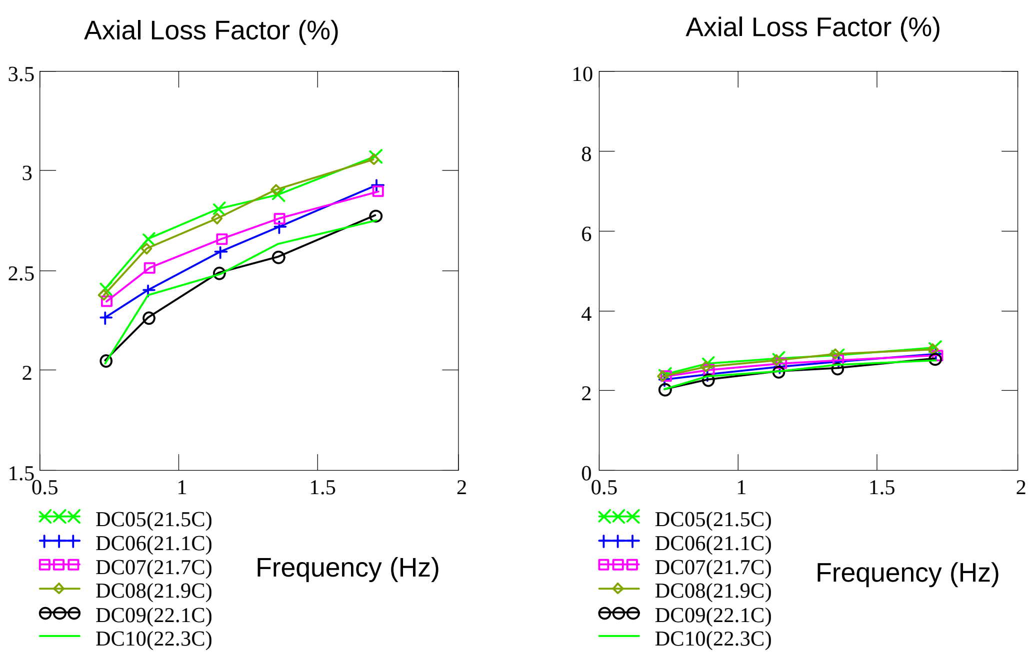

Figure 1: Axial loss factor for the six coils as a function of frequency (note expanded scale on right plot).

Inspection of Figure 1 reveals some variation in measured loss factor among the six coils, some of which may be attributed to an attenuation with increased temperature[2]. Coils DC05, Dc07, DC09, and DC10 exhibit this loss in damping with increased temperature quite clearly. Coils DC06 and DC08 fail to follow the this temperature-loss factor pattern. Figure 2 contains the measured axial stiffness data for the six coils.

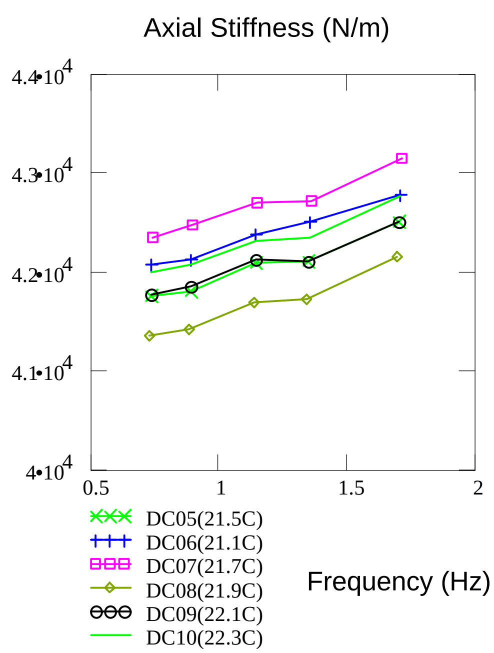

Figure 2: Axial stiffness for the six coils as a function of frequency.

Figure 2 shows that the stiffness relationship with frequency is a loss in stiffness with decreasing frequency. It should be noted that the apparent static stiffness as determined by the measured static spring length in the test apparatus was very consistent at 6.3 cm. The variation in stiffness is relatively small when viewed on the expanded scale in the right plot.

Shear loss factor and stiffness for the six coils are presented in Figures 3 and 4, respectively. Figure 3 shows that the shear loss factor for the six coils is greater than the axial loss factor which is consistent with previous loss factor measurements. Again the loss factor attenuates with decreasing frequency as in the case for axial loss factor. Also the temperature effect[2] is apparent as a smaller loss factor is measured at the warmer ambient temperatures. It should be noted that measured temperatures refer to ambient air temperature at the time of the test data acquisition. Viscoelastic damping material inside the coils would likely be at an unknown different temperature.

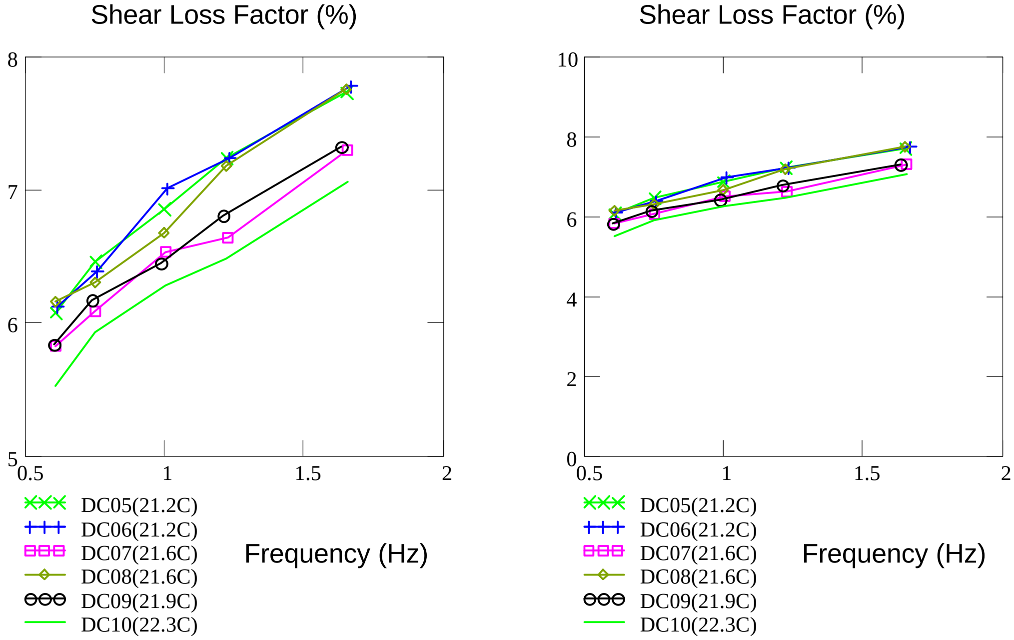

Figure 3: Shear loss factor for the six coils as a function of frequency (note expanded scale in plot on right).

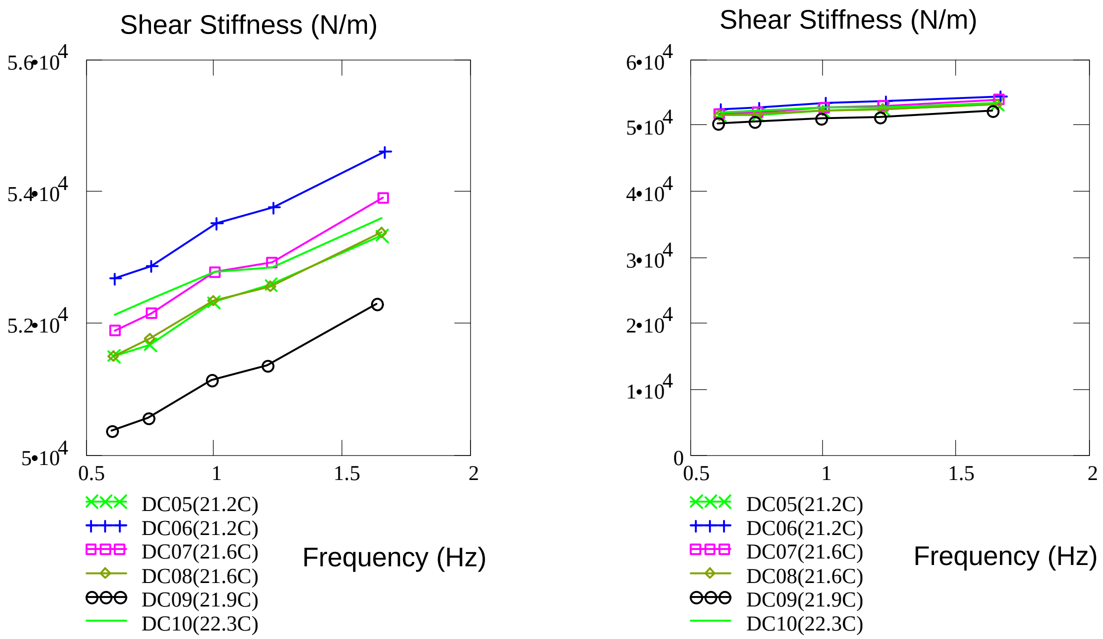

Figure 4: Shear stiffness for the six coils as a function of frequency (note expanded scale in plot on right).

4. Comparison with Previous Measured Coils

Measured test data for the present six coils are compared with the initial test series for damped coil DC00[1] and with the first three coils that featured welded ends[3]. (The present six coils also have welded ends). Coil DC00 test data is used to develop analytical expressions for loss factor and stiffness as functions of frequency[4] plus interpolation routines to extend the frequency range of the measured data. The interpolated data for coil DC00 is employed for comparison in this document.

In the figures that follow, the curves denoted by '6 spr test' refer to the present six coils, the curves '3 spr test' the welded end coils, and the curves labeled 'fit data' refer to the interpolated DC00 coil data. The curves for three weld coils and for the present six coils are obtained by averaging the data at each discrete test frequency. Loss factor and stiffness values are measured at five pendulum mass levels, where the measured frequency for the coils within one set (three weld end or present six) are nearly identical at each individual mass setting. Figures 5 and 6 present axial loss factor and stiffness comparisons, respectively.

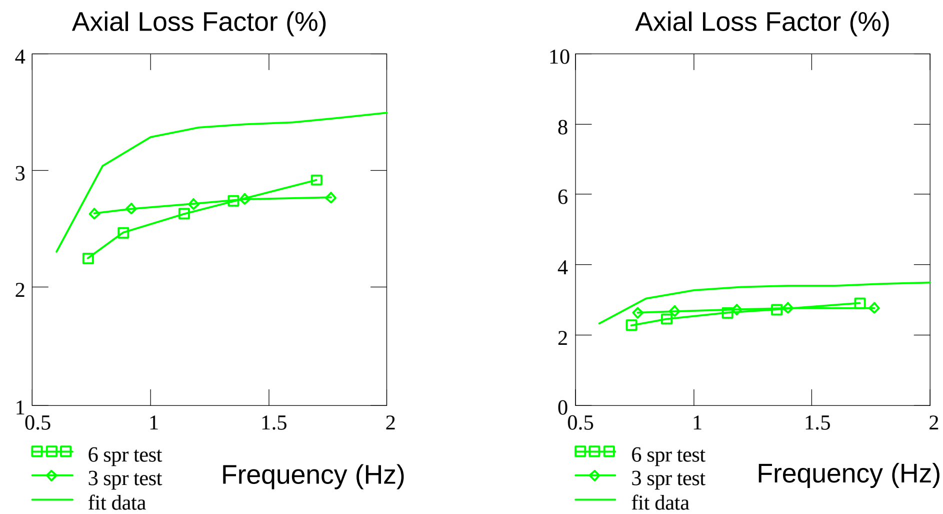

Figure 5: Comparison of present six coil axial loss factor measurements with previous coil measurements.

Figure 5 shows the comparison for axial loss factor indicating that the fit data indicates about 40% more damping (relative basis) than the present six coils or the three weld coils. In addition, the present six coils tend to show a greater dependence on frequency. Also note that the discrete frequencies (denoted by discrete symbols) for the present six springs are slightly lower than the frequencies for the three weld end springs. Axial stiffness results confirm this observation as presented in the discussion that follows.

Axial stiffness comparison is presented in Figure 6. Examination of Figure 6 reveals that frequency dependence is nearly the same for each test series and that the three weld coils appear to be slightly more stiff than the fit data or the present six coils.

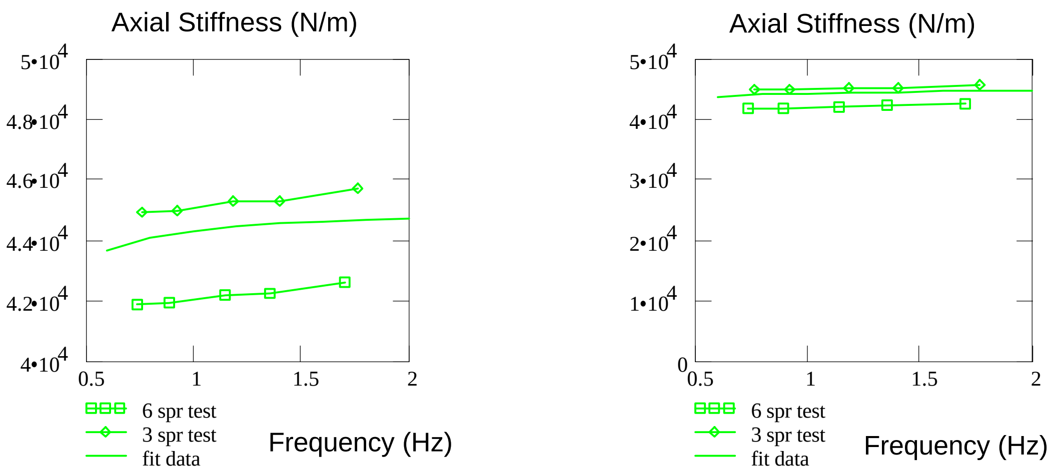

Figure 6: Comparison of present six coil axial stiffness measurements with previous coil measurements.

Shear loss factor and stiffness comparisons are depicted in Figures 7 and 8. In contrast to the axial loss factor results, shear damping for the present six coils exceed that for the three weld coils and the fit data as shown in Figure 7. The frequency dependence appears to be similar for the three different data sets.

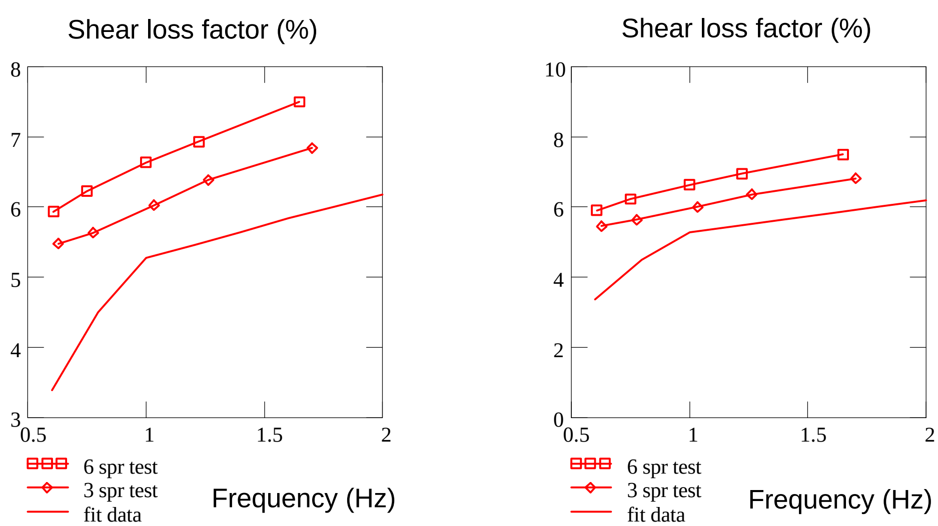

Figure 7: Comparison of present six coil shear loss factor measurements with previous coil measurements.

Shear stiffness results shown in Figure 8 indicate that the frequency dependence is similar and that the 'fit data' shows increased stiffness relative to the three weld spring and present six spring assemblies.

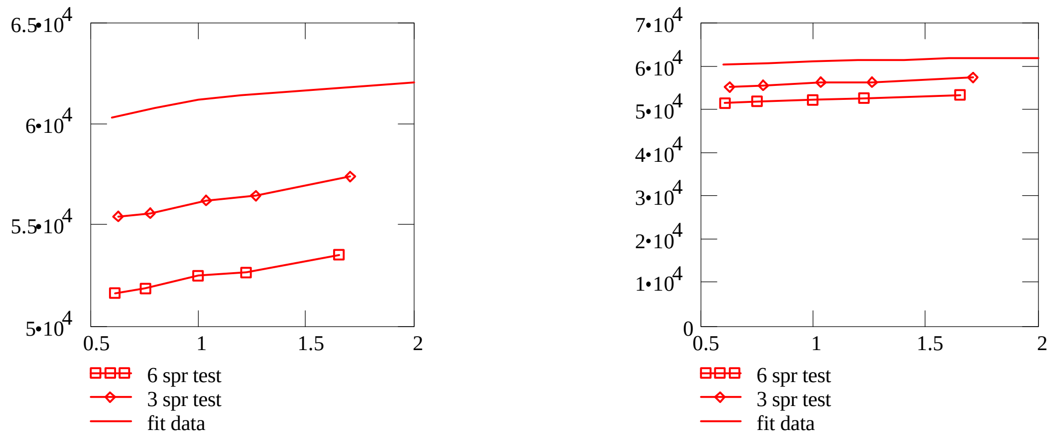

Figure 8: Comparison of present six coil shear stiffness measurements with previous coil measurements.

5. Conclusions

The primary conclusion to be drawn from the comparisons shown in the figures is that the fit data is more unlike the weld coil and six coil data than the differences between the weld coils and six coils. These differences may be due to variations in the seat properties, in particular to changes in the axial and shear damping characteristics. The present six coil data will be used in place of the fit data for subsequent stack spring assembly analyses.

6. References

1. E. Ponslet, *Low Frequency Damping Measurement Setup and First Results*, HYTEC Inc., Los Alamos, NM, document HYTEC-TN-LIGO-17, June 1997.
2. F. Biehl, *Temperature Effects on LIGO Damped Coil Springs,* HYTEC Inc., Los Alamos, NM, document HYTEC-TN-LIGO-18, July 1997.
3. F. Biehl, *LIGO Damped Coil Spring Test Data - Non Welded and Welded Springs,* HYTEC Inc., Los Alamos, NM, document HYTEC-TN-LIGO-22, July 25, 1997.
4. F. Biehl, *Analytical Expressions and Interpolations for Coil Spring Experimental Data,* HYTEC Inc., Los Alamos, NM, document HYTEC-TN-LIGO-19, August 4, 1997.

Note 1, Linda Turner, 09/03/99 02:23:16 PM
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