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LIGO Damped Coil Spring Test Data Non Welded and Welded Springs

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Abstract

Experimental results for the LIGO damped coil springs with welded end caps are compared to the experimental data for the same springs without the welded end caps. Flourel seat support designs were used in both test series; however, the actual seats used were different. The test results show a decrease in stiffness for the weld end coils relative to the non weld coils of up to 5% in the axial direction and up to about 10% in the shear direction. Coil loss factors are mixed; from a relative gain of up to 5% to a relative loss of up to 10%.

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LIGO PROJECT

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1. Summary

The purpose of this work is to show that welding end caps to the damped LIGO coils has negligible effect on the coil stiffness and damping properties. Earlier test results with non welded coil ends are compared with current test data on the same coils with welded end caps. Relatively good agreement is found between the previous and current test results. Several possible reasons for differences in the measured data are presented.

2. Test Configuration and Procedures

The same damped LIGO coils designated DC01, DC02, and DC03 were used for both the non welded and welded end cap configurations. Both configurations were tested on Flourel viscoelastic seats using the pendulum test apparatus[1]. Tests were conducted in the axial and shear directions at a range of frequencies from 0.5 Hz to 2 Hz. Test ambient temperatures ranged from approximately 20 ^{0}C (68 ^{0}F) to 22 ^{0}C (71.6 ^{0}F).

3. Test Data

Axial and shear stiffness test results for both configurations are shown in Figure 1 for all three springs. As the legend indicates, green denotes axial tests results while red denotes shear test results. Test data for non weld coils is given in Reference 1.

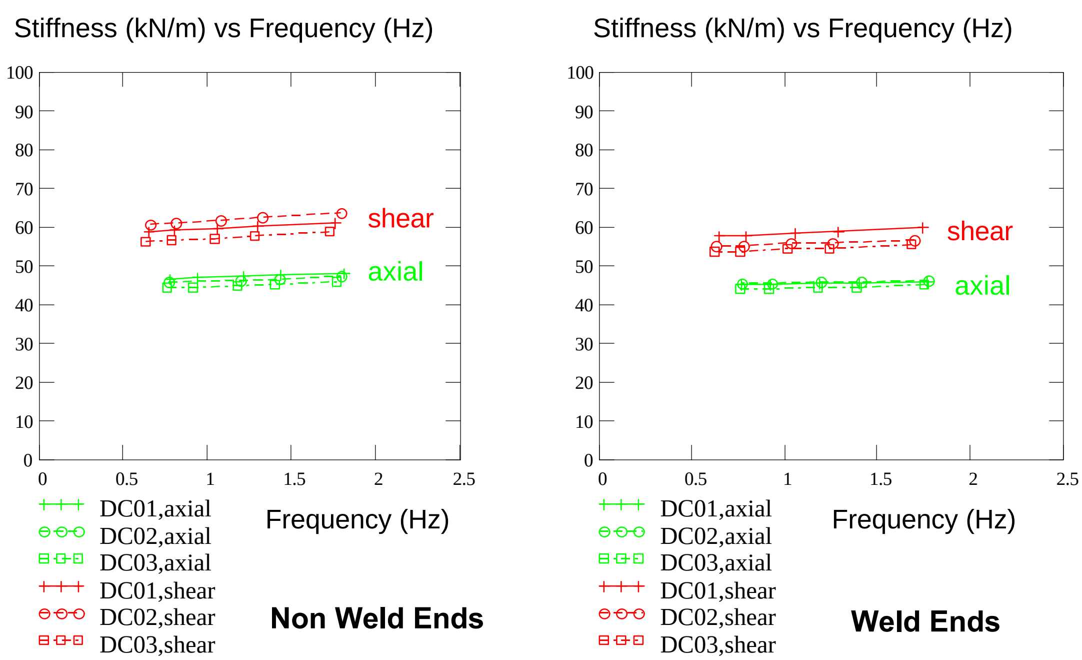

Figure 1: Axial and shear stiffness as a function of frequency for the non weld coils (left figure) and weld end coils (right figure) .

Inspection of Figure 1 reveals minor differences in the measured data comparing the non weld to the weld end configuration. Weld end coils are slightly shorter in length due to material removed to facilitate the welding operation. This modification could contribute to the stiffness change observed; however, there are other factors discussed in the next section that may be more important.

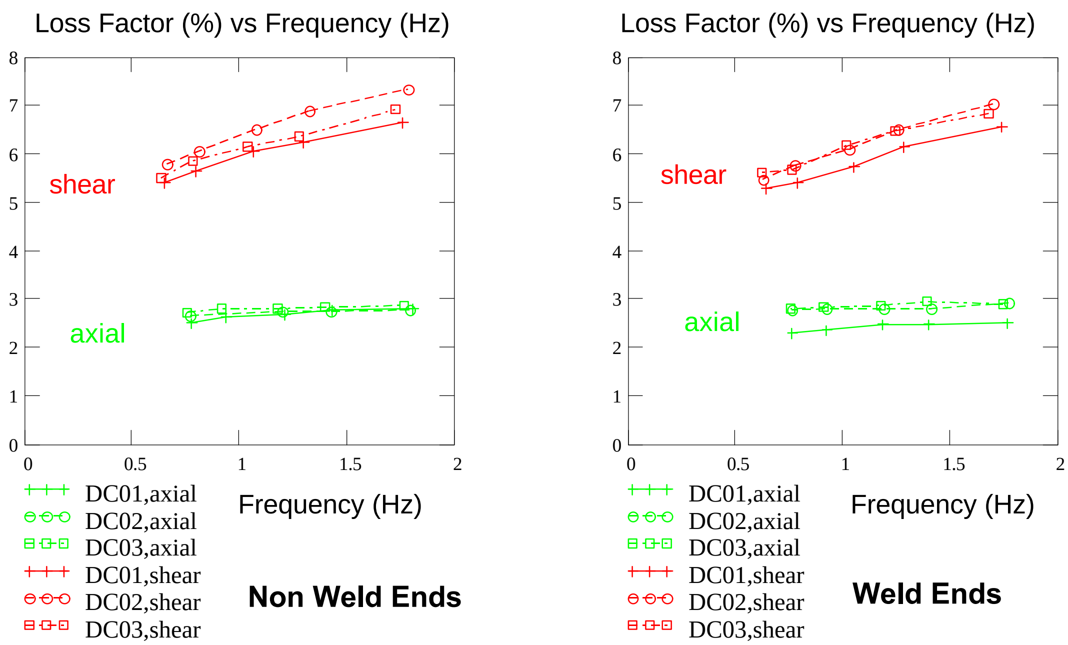

Figure 2: Axial and shear loss factor as a function of frequency for the non weld coils (left figure) and weld end coils (right figure).

Figure 2 shows good agreement in loss factor for coils DC01 and DC02; however, a slight decrease in loss factor is apparent for coil DC03 weld end compared to non weld end.

Figures 1 and 2 are difficult to interpret in terms of stiffness and loss factor changes from the non weld configuration to the weld configuration. Figures 3 and 4 present the same data in terms of percent change where the percent change is defined as

$$\%\,change = \left[\frac{non\ weld - weld}{non\ weld} \right] 100. \qquad (1)$$

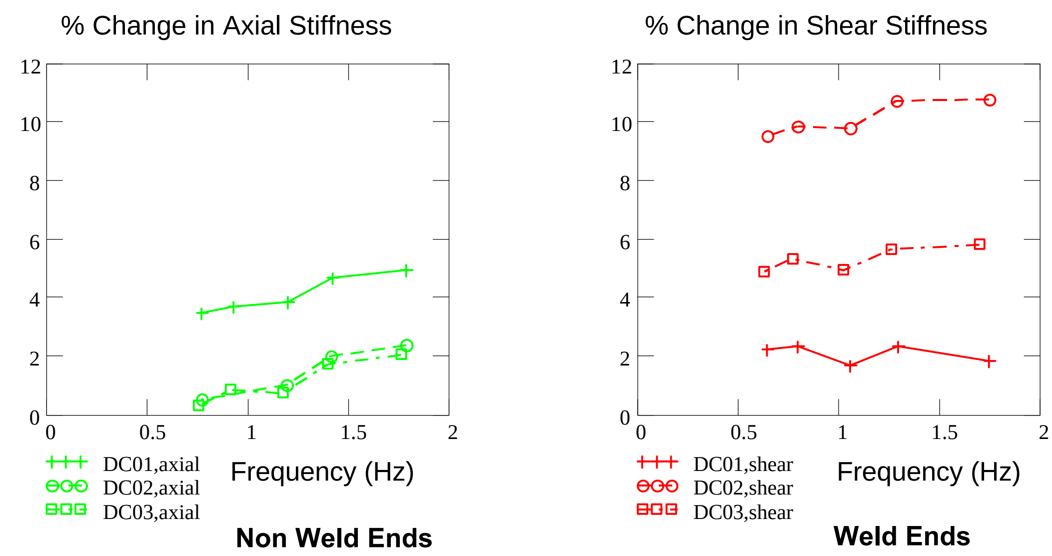

Figure 3: Percent change in axial and shear stiffness from non weld coil to weld coil.

Figure 3 shows that the percent change in axial stiffness is about 2% or less for coils DC02 and DC03 and about 5% or less for coil DC01. In addition, the shear stiffness change is around 11% or less for coil DC02, about 6% for coil DC03, and about 2% for coil DC01. Because all these changes are positive, adding the weld end caps appeared to have decreased the stiffness for each coil. Some changes may be the result of different test temperatures and the result of averaging test frequencies at the same pendulum mass. Note that stiffness is a function of frequency as shown in Figure 1.

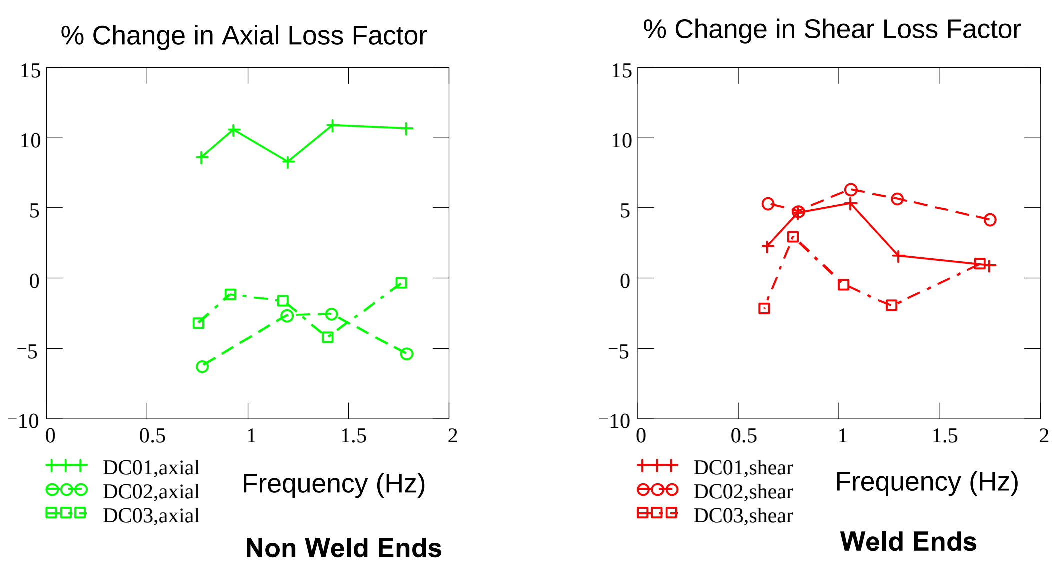

Figure 4: Percent change in axial and shear loss factor from non weld coil to weld coil.

Figure 4 shows that the change in axial loss factor is about 10% for DC01 and a negative 5% or less for DC02 and DC03. Thus, there is a slight gain in damping for the weld end coils DC02 and DC03. In the shear direction, there is a loss in damping from the weld coils to non weld coils of approximately 0 to 5%.

4. Discussion of Test Results

Based upon the reported test results, it appears that the welded end caps introduced some minor changes in the coil structural and damping characteristics. Some of the change may be attributable to a variation in the test apparatus with time. Factors that could influence measured stiffness and damping are

- Temperature has a measurable effect[2] on epoxy supported coils. Current tests were conducted on viscoelastic seats where temperature is likely to have more influence. As indicated previously, current test temperatures ranged from 20^0C to 22^0C. Temperatures for the non weld case[1] were 21.1^0C to 22.1^0C that were obtained from a different thermometer that generally measured higher than in the present case.
- Because the present weld end coils are slightly shorter prior to welding an increase in stiffness might be expected. However, the welding operation may have altered the structural integrity and affected stiffness and damping.
- The coil stiffness is a calculated quantity[1] that involves the pendulum pivot stiffness and pendulum mass properties. It is entirely possible that the pivot bending resistance has changed from the initial tests thus contributing to slight modifications to the comparable stiffness.
- Coil deflection drift tends occurs after each pendulum mass addition. Variations in the pendulum mass provide the desired changes in measured coil frequencies. In some cases, the coils may not have reached a steady state deflection position so that a variation from the precise stiffness and loss factor are measured.

5. Conclusions

Test results presented in this document support the conclusion that welded end caps produced some variations in performance for the LIGO damped coil spring design. These changes are deemed unimportant with respect to coil vibration performance and may in fact be due primarily to other environmental factors.

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.

Note 1, Linda Turner, 09/03/99 02:14:03 PM
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