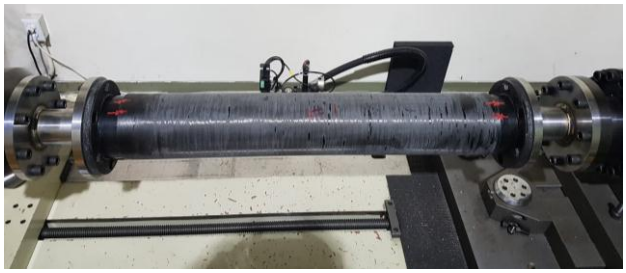
A study that performed the natural frequency analysis and critical speed evaluation based on the critical speed calculated for the cooling tower long shaft coupling was previously carried out.[7]

### CFRP Spacer Torsional Test

The torsional strength of the carbon fiber reinforced polymer (CFRP) spacer used for the cooling tower long shaft coupling was investigated to determine whether failure and deformation occurred at the maximum torque of 6,200Nm for the prototype, which was manufactured according to the designed dimensions. The testing was carried out with a torque limit of about 6,800Nm considering the allowable strength of the jig and bolts.



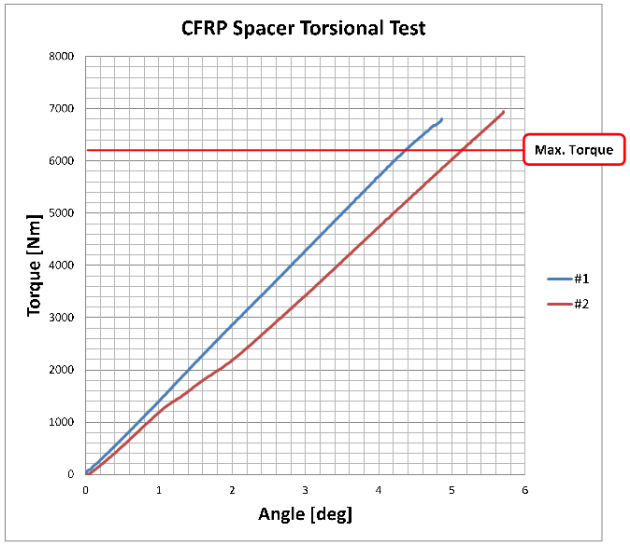



**Figure 12:** CFRP spacer torsional test result

**Table 7:** Maximum Torque of Torsional Test

| Case | Max. Torque [Nm] |
|---|---|
| #1 | 6,787 |
| #2 | 6,928 |

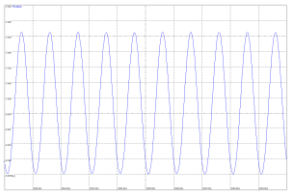
The test results showed that failure and deformation did not occur at the maximum torque of 6,200Nm, verifying the safety of the CFRP spacer with regard to torsional strength. Figure 12 and Table 7 show the test results.

### Long Shaft Coupling Durability Test

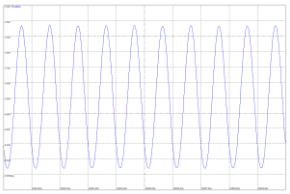
The final prototype for the cooling tower long shaft coupling was fabricated and the design safety of each part was verified through analysis and testing. In order to investigate the validity of the final design, a 1,000,000 cycle static durability test was conducted.

**Figure 13:** Prototype for the long shaft coupling durability test

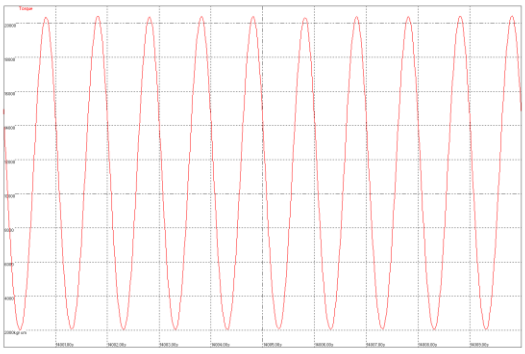
The prototype with the assembled GFRP disc pack and CFRP spacer was installed in the testing machine and the test was carried out under conditions of 2 mm axial misalignment, 1˚ angular misalignment, and 2,000Nm operating torque, where 1 cycle was 200 ~ 2000Nm (R=0.1).



(a) Initial Angle



(b) Final Angle



(c) Feedback Torque

**Figure 14:** Long shaft coupling durability test result

No failure or deformation were observed for the final prototype of the long shaft coupling. The test results verified the endurance life and reliability of the final prototype.

## CONCLUSION

A design process, finite element analysis, and verification testing were performed for various GFRP disc packs and CFRP spacers, which are major components of the long shaft coupling for cooling towers. The following conclusions were obtained.

1) The finite element analysis was conducted for 9 design cases of GFRP discs with varying thicknesses and numbers of stacking ply. The analysis result revealed that the 2.75mm thickness and 4 ply structure was the most stable among them.
2) The disc pack prototype was manufactured based on the design selected from the analysis results. Torsional testing was carried out on the prototype with an axial misalignment of 2 mm, an angular misalignment of 1˚, and torque of 6,200Nm, and the test results verified and validated the analysis results.
3) The Rayleigh-Ritz method was used to design the dimensions of the CFRP spacer considering vibrations and to calculate the critical speed.
4) Torsional testing was conducted on the prototype of the designed CFRP spacer, which verified the safety of the design.
5) The final long shaft coupling prototype was manufactured and part designs verified for safety, and the endurance life and reliability of the final prototype was verified during 1,000,000 cycle durability testing.

## ACKNOWLEDGEMENT

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