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the factory than it can in the built-in situation aboard the ship. The different test conditions during the back-to-back test are listed in Table 3.

Building the test rig was something new for the engineers at Schelde Gears. Because of this, the influence of each part of the test rig needed to be evaluated, as direct experience with this type of test rig was not directly available. Each component in the test rig, as well as the gear itself, could influence the test results in either a positive or negative way. Therefore, the first objective was to recognize those parameters of influence and eliminate them as much as possible.

In the back-to-back configuration, the main shafts are coupled. Then, depending on the test mode, either the diesel input shaft or the gas turbine input shaft is also coupled to drive the slave gearbox (see Figure 8).

The gears were mounted on a resilient mounting like those designed for the ship's foundation during all the tests. The alignment of the gearboxes in the back-to-back test needed special attention because the bearing loads had to be about equal to the loads expected under operational conditions. This required different alignment procedures for the diesel and gas turbine engines. The main concern for this part is the flexibility of the main shaft line. In this shaft line, torsional stiffness needed to be combined with a certain degree of bending flexibility in order to maintain the proper bearing load division on the main bearings.

The input shafts were connected to the torque actuator with flexible couplings on the intermediate shafts. The weight of the intermediate shafts was limited in order to realize a bearing load distribution that is equal to that in reality. The balancing and alignment of all those parts is of significant influence on the test results. Some of those results are presented in Figure 10.

During the back-to-back test, the gear driven pumps supplied the lubricating oil to the gear components. The skid with all the oil equipment is placed close to the test bed. The test conditions for the gear were to be close to normal operational conditions.

The tooth load is generated with a torque actuator. This torque actuator is designed for a torque of 45 kN at a maximum speed of 3,500 RPM. This actuator is designed and built by the Design Unit from the University of Newcastle. The concept of this design has been presented in Ref. 2. The tooth load is adapted in accordance with the output shaft load curve of the gear during operation.

The torque actuator is a vane-type coupling, which enables the torque to be changed during running. The actuator is mounted between the interme-

mediate shafts. Although the shafts had flexible couplings, the influence of the alignment and stiffness of the actuator foundation was considerable. From the actuator, a constant peak of one times the shaft speed influenced the measurements. Improvements of the foundation stiffness and the shaft balancing improved the results. Therefore, the flexible couplings were balanced in their mounted position. The shafts were well balanced, but tests showed that the flexible part in the shaft had a negative influence on the measurements. Balancing the hubs at the primary and secondary sides of the flexible elements of the coupling showed improvement. The shaft orbit was changed from a diameter of approximately 50 microns to less than 10 microns.

The oil pump characteristics also had a great influence on the results. This influence was clearly shown in the frequency area of 60 to 400 Hz and was greatly alleviated by improving the pump design. The pulsation in the oil flow and the stiffness of the pump foundation was shown to have a considerable influence on the vibration levels of the gear. Both of these aspects were improved during the testing phase. The tests for the diesel propulsion mode were influenced by the internal alignment in the multiplate friction-type clutch. Due to the low engaging energy required for this test, special engaging procedures were used for better plate alignment. In Figure 10, the achieved level of vibration is given.

**Results.** The results of the tests show that the requirements of the specification were met. The realization of the test rig required a careful setup, alignment and local balancing. Above the mountings, the required values are met. At higher frequencies, the line is even below the specification. Each component mounted on the gearbox has its own contribution to the vibration spectrum.

**Conclusions**

The design of low noise gears requires careful attention for all components, not only for design but also during the manufacturing process. This is in respect to the gear elements and to all rotating equipment that is mounted on the gearbox, e.g. gear-driven pumps.

The back-to-back testing of a gear can only be successful and representative when all operational conditions can be reproduced. This is valid, especially for the balancing of all shafts and couplings, especially for the high-speed shafts. The engagement sequences should be as close as possible to the conditions on board the ship. In case these conditions are not met, the result will give an approximation, but will be contaminated with disturbances from the test rig.

**References**

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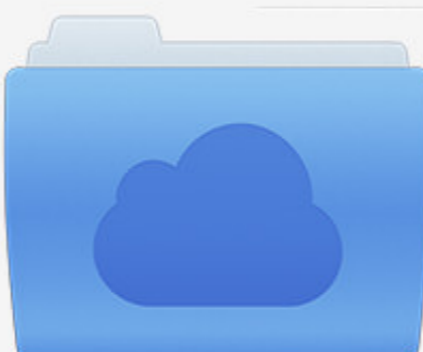
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