

Design and Testing of a Low Noise Marine Gear

by: J.J. Bos, Schelde Gear

American Gear Manufacturers Association



TECHNICAL PAPER

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[The statements and opinions contained herein are those of the author and should not be construed as an official action or opinion of the American Gear Manufacturers Association.]

Abstract

Schelde Gears is a Dutch gear manufacturer specialized in gear transmissions for merchant and marine naval applications, especially those with special requirements for noise and vibration levels. Typical for naval application is the underwater noise requirement and for merchant ships the structural vibration level for the passenger comfort.

The purpose of this paper is to give an overview of design, back to back testing and test results of gearboxes designed for low noise and vibration levels. In 1998 several designs for low noise gearboxes have been made such as for the Royal Dutch Navy, Spanish Navy and for a cruise ship. The presentation will focus on the design for the Royal Dutch Navy LCF frigate. This gearbox is of a propulsion mode of 5000 kW at 1000 rpm and a gasturbine propulsion mode of 19000 kW at 5450 rpm. The propeller speed for this gearbox will vary from 50 to 164 rpm, with a respective input power of 1200 kW to 19000 kW. The specific requirements for underwater noise are defined for diesel and gasturbine propulsion modes at a ship speed of 18 knots (93 rpm of the output shaft).

In order to meet the design requirements for low noise special attention was paid to all aspects that will influence the noise and vibration performance of the gearbox. The design aspects, such as tooth corrections, tooth loading, gear lay-out, balancing, lubricating system and resilient mounting system will be discussed.

The performance of the gearbox is tested for acceptance in a back to back test for both diesel engine and gasturbine drive modes. The tests were performed for an input power of 3000 kW, corresponding with a propeller speed of 93 rpm. The required tooth loading during testing is obtained by a means of a torque actuator.

Typical results of the back to back test will be presented at the end of this presentation.

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DESIGN AND TESTING OF A LOW NOISE MARINE GEAR

J.J.Bos

Schelde Gears, Vlissingen, The Netherlands

Introduction

Schelde Gears is a Dutch gear manufacturer specialised in gear transmissions for merchant naval and marine naval applications with special requirements for noise and vibration levels. Typical power ratings are 5 MW up to 40 MW, with centre distances ranging from 800 to 4500 mm. The dimensions of these gears vary from 2 x 2 x 2 to 5 x 5 x 5 (l x b x h) metre. Typical for marine naval applications is the underwater noise requirement and for merchant naval applications, passenger ships and car ferries, the structural vibration level for the passenger comfort.

In 1998 several designs for low noise gearboxes have been made such as for the Royal Dutch Navy, Spanish Navy and for a cruise ship.

This presentation will give an overview of the practical design of a naval gear for combined diesel or gasturbine propulsion (CODOG type). The performance of the gear regarding the vibration levels is tested in a back to back test. The gear presented is a design for the Royal Dutch Navy LCF frigate. The gear has been designed for low noise. The design aspects for low noise operation were incorporated in the design, therefore special attention was required for all parameters of influence for the noise and vibration performance of the gearbox. The design aspects, such as tooth corrections, tooth loading, gear lay-out, balancing, lubricating system and resilient mounting will be discussed.

The back-to-back configuration was built with two gears, intermediate shafts and a torque actuator for load simulation. The tests were done for gasturbine and diesel engine

propulsion modes at approximately 3000 kW power input corresponding with a propeller shaft speed of 93 rpm. The torque actuator for this test configuration was rated for a maximum torque of 45 kNm and a maximum speed of 3500 rpm. The required torque during testing amounts to 33 kNm at 875 rpm.

Design requirements

The propulsion system for the LCF consist of two independent opposite handed propulsion lines, one for the starboard and one for the portside propeller shaft line with Controlled Pitch Propeller (CPP), each with a boost gasturbine and a cruising diesel engine propulsion mode.

The design of each gearing had to meet the specific requirements of which the most important are listed below:

- Gear ratings:

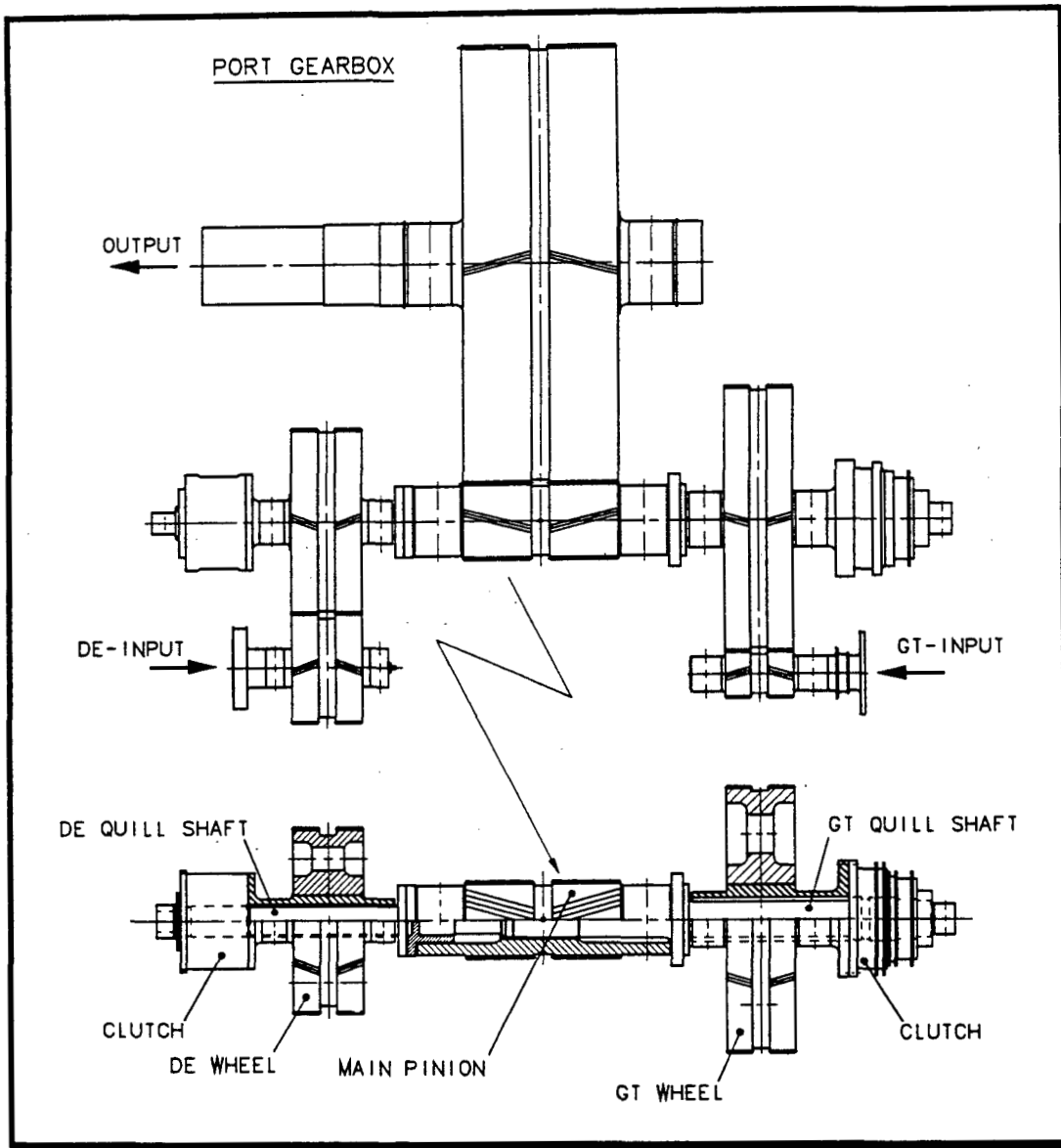
Diesel engine propulsion:

Power	5000 kW
Input shaft speed:	1000 rpm
Output speed	103 rpm

Gasturbine propulsion

Power	19500 kW
Input speed	5450 rpm
Output speed	164 rpm

Figure 1: Lay-out of the gear elements



- Propeller shaft speed
Range min. 50 - max. 164 rpm
- Input power range
min. 1200 kW - max. 19500 kW
- Oil supply for the gear by a gear driven pump in the propeller speed range of 64 - 164 rpm
- Shock resistant for shocks up to 13 g
- The structure borne noise requirements for above and below the resilient mounting are defined for a shaft speed of 93 rpm.

- The fulfilment of the structure borne and air borne noise requirement shall be demonstrated in a back to back test.
- Noise requirements for airborne and structure borne noise according to Navy specification

In respect to the above mentioned design requirements special attention was given to minimize the number of rotating elements under load for both gasturbine and diesel engine propulsion, to have optimal corrections for loaded conditions and to optimize the tooth loading. The gears are mounted on a resilient

mounting in order to optimize damping of the higher frequency range vibrations and therefore to reduce the underwater noise level.

The thrustblock for this design is a separate item rigid mounted in the propeller shaft line.

The whole geartrain in the gear box has therefore the freedom of movement of 15 mm to accommodate the relative movement of gearbox to shaftline. This movement is caused by displacements of the gearcase due to the resilient mounting and due to shock loads.

The size of the gear, overall dimensions appr. 5 x 5 x 4 (l x b x h) metre, and the number of flexible mounts ,35 in this case, require a rigid casing for optimal performance of the flexible mounting. The stiffness of the casing was checked by means of a FEA analysis. In combination with the flexible mounting the stiffness of the gear casing is an important feature.

Lay-out

The first objective was to design a gear lay-out, see figure 1, that could meet the requirements as specified within the available space in the gear compartment and the geometric positions for the input shafts of the diesel engine and gasturbine and the output shaft.

Important features for the design are a balanced tooth load and to minimise the number of rotating elements together with the elimination of rotation of elements in an unloaded condition.

The lay-out that was chosen for this purpose is a two stage reduction for both diesel and gasturbine propulsion. The second stage is a

common stage for both propulsion modes.

The thrustblock is an separate item in the shaftline. The whole geartrain is axially positioned by this thrust bearing. The first reductions of diesel and gasturbine input require therefore a connection to the second reduction pinion in axial direction for those conditions that the reductions are running disengaged or engaged. The clutches are therefore equipped with a axial bearings. The rotating parts therefore float in the gear casing in axial direction.

Gear design

The construction of the first reduction pinions and wheels is based on solid forgings. The construction of the second reduction is based on assemblies. The main wheel is a fabricated structure shrunk on to the main shaft. A centre driven second reduction pinion was required to be able to establish a good tooth contact pattern in both gasturbine and diesel engine propulsion. The construction of the second reduction pinion is a centre shaft with a special designed intermediate sleeve on which the pinion body is shrunk. Due to this

Table 1: Overview of all rotating parts

	<i>GT pinion</i>	<i>GT wheel</i>	<i>DE pinion</i>	<i>DE wheel</i>	<i>Main pinion</i>	<i>Main wheel</i>
Material	17CrNiMo6	17CrNiMo6	17CrNiMo6	30CrNiMo8	17CrNiMo6	32CrMo12
Heat treatment	Carburized	Carburized	Carburized	Through hardened	Carburized	Nitrided
Module		6,5		6,5		8
Number of teeth	40	231	94	158	53	305
Quill shafts		30CrNiMo8		30CrNiMo8	30CrNiMo8	
Mainshaft						C50E+QT