TECHNICAL NOTES
Research and Innovation

MMG

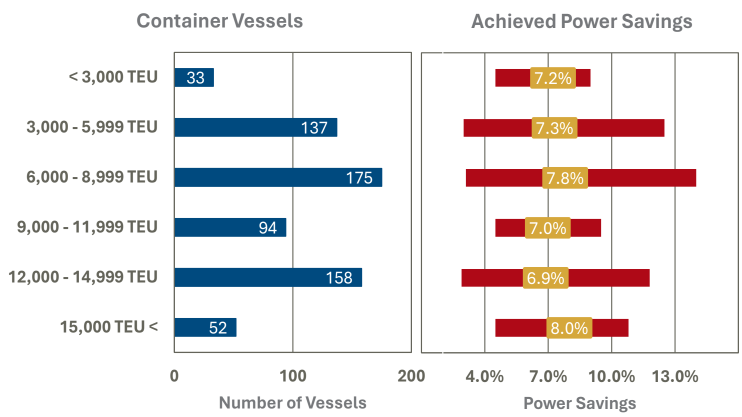
Mecklenburger Metallguss GmbH | September 2024

10 years MMG re-design programme

Our redesign program began over 10 years ago with a convincing pilot project. Our first propeller conversion to an efficiency-enhancing propulsion system showed fuel savings of over 10 percent on a 13,000 TEU ship. Many projects with different configurations and technical requirements followed, so that we can look back on over 660 orders in the area of propeller redesign projects. Although most of these retrofit projects are carried out in the container ship fleet, there is a lot of movement in the area of other ship types such as bulk carriers, gas tankers and cruise ships. If we look at the projects that have been implemented, we see savings potential of 2-14% in power consumption.

digital view

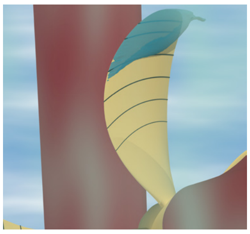
In relation to the group of container ships, this results in an average saving of 7-8% depending on the size of the ships. In total, the re-designed propellers delivered by MMG to date contribute to reducing CO_2 emissions by more than 3 million tons per year. Re-design projects of the first generation with moderate power reductions at the time still have savings potential in the second retrofit based on current analyses based on current power reductions, which make a business case quite reasonable. Therefore, the number of second conversions in the order backlog is continuously increasing. MMG technologies such as power train calculation (PTC) and virtual contact test (VCT) help to technically secure the conversions so that the vessel can get back on track safely and quickly.



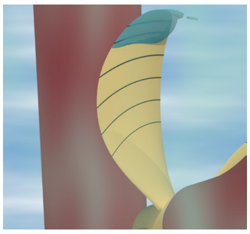
Enjoy the Silence
- Talk is silver, silence is brass (golden)!

MMG continuously improves its capabilities to design silent propellers, wherever it is needed. Regardless of whether your next project is a fishery-, scientific-, seismic-, cruise- or even a merchant vessel with specific class notations to underwater noise (URN) – MMG will design the optimal trade-off between efficient and silent propulsion device, called the MMG espro silent. Within a recent joint industry project between MMG and A.P. Möller Maersk a systematic analysis is made, in order to answer one of the main questions in shipping: "What is the efficiency sacrifice for a low noise propeller design?" With the expertise of optimizing propeller designs with regards to high efficiency a typical MMG propeller design applied to a commercial new building project was selected as a baseline for the investigation. Design changes to reduce URN are restricted to radial blade distributions of characteristic values, such as chord length, pitch and camber. All design versions have been evaluated with BEM and RANS CFD-codes. The Ffowcs-Williams-Hawkings acoustic analogy is used for underwater noise prediction. Figure A shows the development of different designs with decreased sheet cavitation volume. Selected findings and outcomes of this project will be discussed. With dedication to filtering the different sources and contributing phenomena for propeller induced underwater noise the investigations indeed identified the link between propeller born noise and progressively decreasing cavitation behaviour, see Figure B.

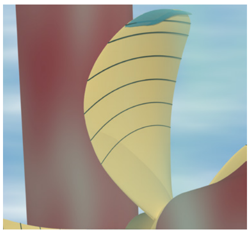
Figure A: Evolution of a low cavitation and underwater noise propeller design



Baseline Design



Intermediate Design



Final Design

It can be shown that there is no linear behaviour between cavitation volume and radiated noise. Whereas the reduction of cavitation volume to abt. 50% from the base line design shows only minor effects in the sound pressure level, the slope increases with most significant noise reductions within the last 20% to cavitation free propeller design.

Noise levels in Figure B are grouped into 3 frequency ranges. Lower frequencies show highest improvement potential being in the range of the blade passing frequency and therefore closely connected to the cavitation volume. The higher frequency ranges are less reactive to cavitation volume and understood to be rather dependent on local vorticities, such as tip or hub vortex.

The non-linear behaviour shown in Figure B. raises the question of what is the sacrifice of propeller induced noise reduction. Once adding the commercial aspects, propeller efficiency must be included into the equation. Obviously, there is a trade-off between the two values efficiency and propeller radiated noise. As can be seen in Figure B for a wide range within the evaluation window noise can be reduced together with a rather shallow behaviour of efficiency losses.

But the significant gain in reducing propeller noise comes rather costly, with the cavitation free propeller being abt. 17% less efficient that the base line design. As determination of propeller-radiated noise is becoming more important, MMG invests significant amount of time and effort into research on propeller emitted noise over the past years, today and in the future. In current research projects special attention is given to the cavitating tip- and hub-vortex contribution to the source-level. Focus is set on controlling the higher frequency range by the propeller design. MMG is the ideal partner for shipyards to initially develop high-tech projects. It is the clear objective, that MMG supports their customers to be more sustainable in all kinds of emissions.

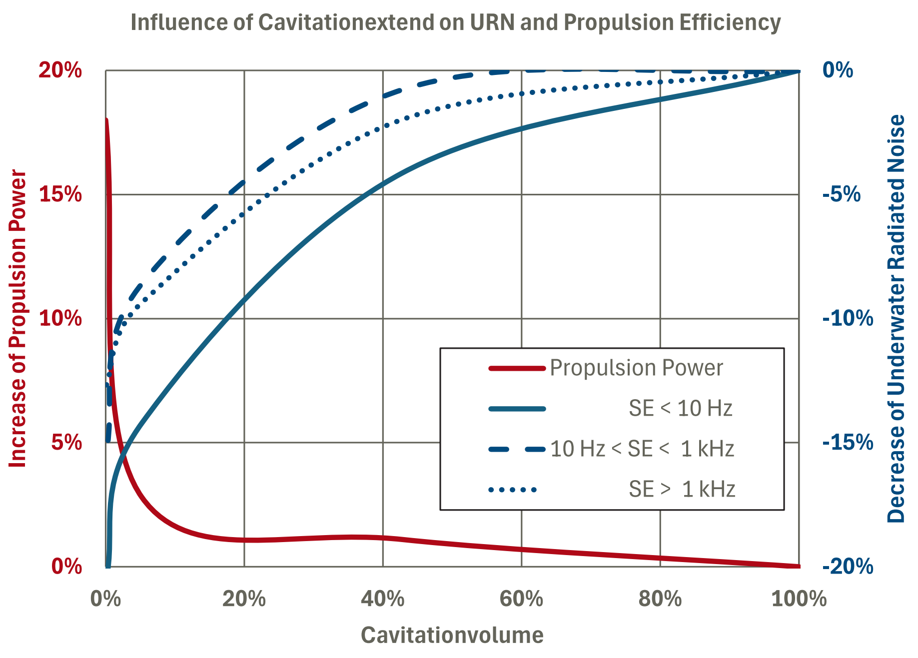
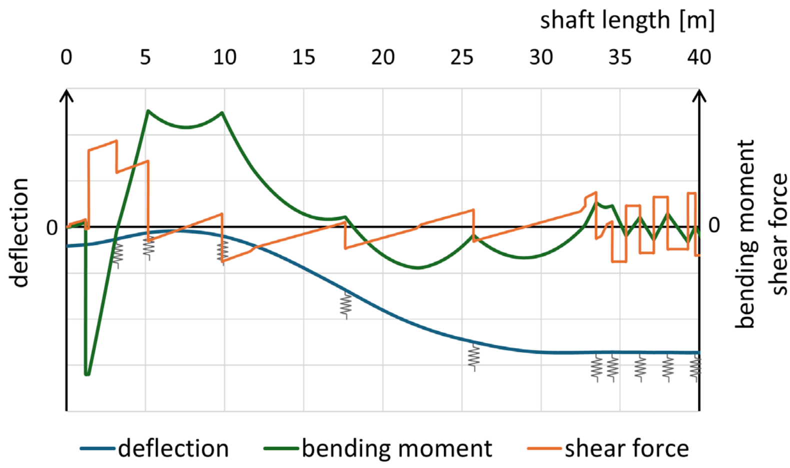


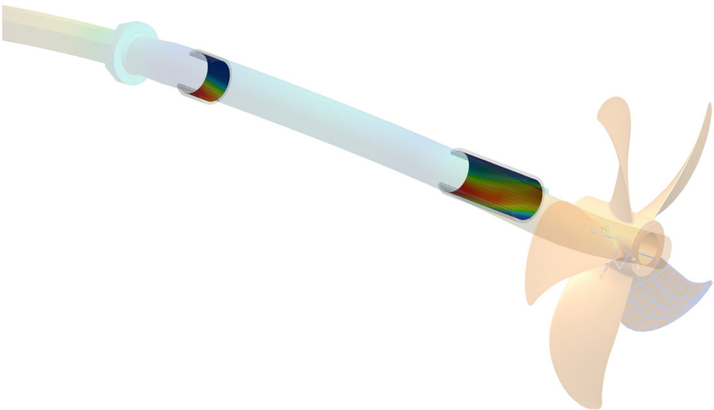
Figure B: Sound pressure level reduction, efficiency loss over cavitation Efficieny

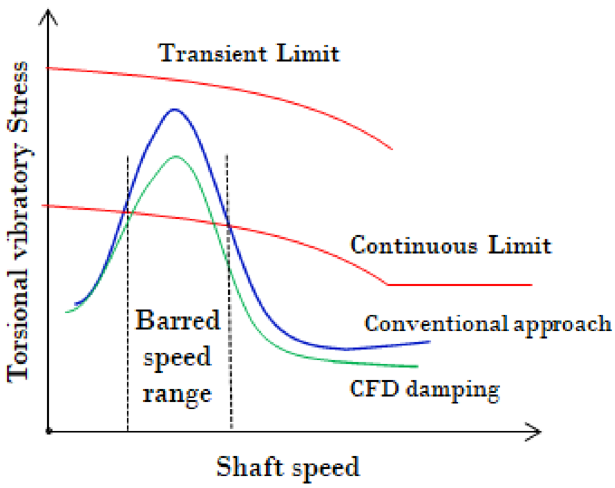
Good Vibration - TVC, SAC, WVC

In the scope of ship building, propulsion shafting design has a major role and it becomes important when it comes to the dynamic structural analysis. During the propeller design stage, the performance of the propulsion drive system is also assessed by carrying out both alignment and vibration analyses. Shafting Alignment Calculation (SAC), Torsional Vibration Calculation (TVC) and Whirling Vibration Calculation (WVC) are the most important steps during the design of the propulsion system. MMG offers a complete shaft calculation package which includes the state-of-the-art methods for evaluating SAC, TVC and WVC. The shafting calculations are not only relevant for new building projects but also for propeller retrofit projects.

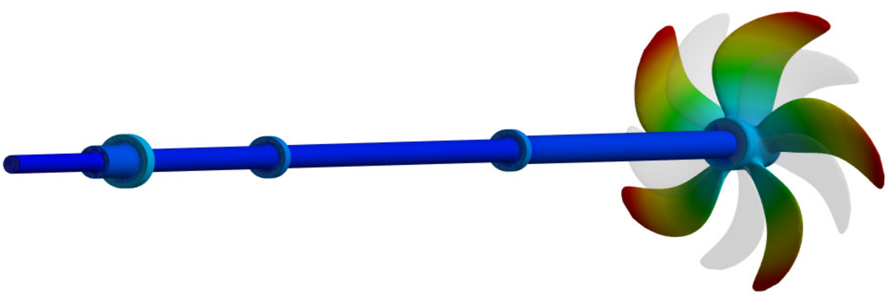


In the SAC, the changes in the bending line and the load distribution on the bearings are calculated at MMG using the latest FE-methods. The position and inclination of the shaft bearings can be analysed in a global consideration. In sensitive cases, the local load and gap distribution in the highly stressed stern tube bearing can be determined by a contact simulation to optimise the bearing design.





From the TVC, the torsional vibration behaviour of the propulsion system is evaluated. In the conventional shafting TVC approach, the propeller damping is selected based on traditional empirical methods while at MMG we can incorporate propeller damping characteristics more realistically using hydrodynamic CFD simulation results. The damping properties of the propeller are determined not only based on its geometry but also respective to its behaviour on the ship wake field. Torsional stress levels in the propulsion shafting line are greatly influenced by the chosen propeller damping approach.



WVC shows the whirling behaviour of the shafting system. Lighter retrofit propellers can improve the whirling vibration to a great extent by shifting of the critical speeds excited by the propeller. A proper validation of WVC can provide data on critical operational speeds and lateral displacements of the shafting at different bearing locations.

On the hybrid path to the propeller

Design and manufacture of small and unconventional geometries is not limited to casting anymore. The MMG Hybrid Manufacturing Process support individual products made from a wide range of materials.

As part of a recent research project carried out by MMG, Fraunhofer IGP and the University of Rostock, the robot-assisted build-up welding of bronze alloys was developed. To produce maritime components, such as propellers, the design process has been extended so that hollow structures can also be represented. The various AM potentials are combined in a new product development process.

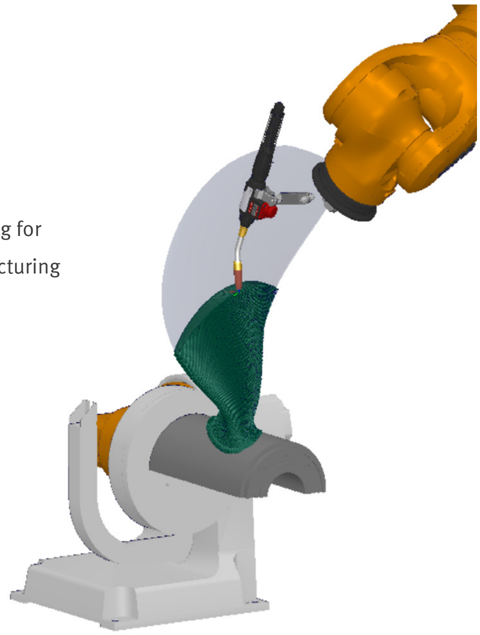


Figure A: path planing for the additive manufacturing

Should my propeller be additively manufactured or sand casted?

With the expertise and decades of experience in propeller production, MMG-manufactured propellers in the size range from 500 mm to 5000 mm diameter were examined to determine the technical and economic boundary conditions. The focus of the investigations was on the costs and expenses for production using the conventional sand-casting process and a comparison of the work steps for the casting and additive process chain. We offer you the optimum solution. The additive manufacturing of large-format components requires an adaptation or expansion of the classic process chain.

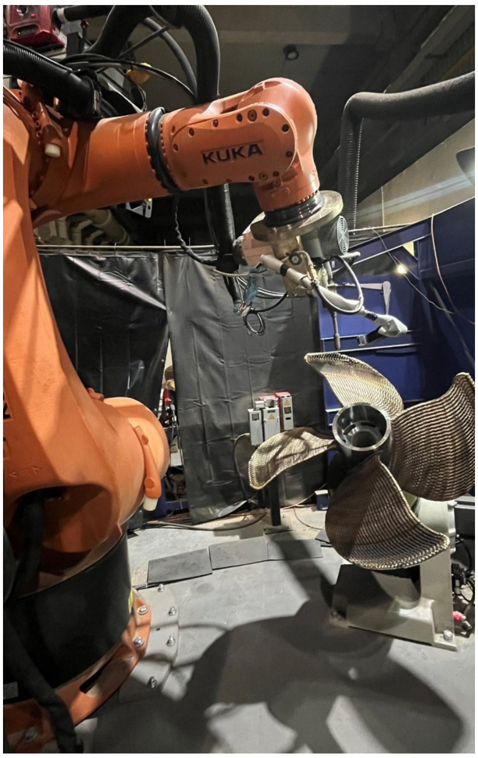


Figure B: Additive Manufacturing of a ship propeller with a diameter of 1050mm

Many process steps in various component areas of the ship‘s propeller were validated through extensive investigations. Starting with the preparation of the CAD data after the simulation, a variety of machining strategies for build-up welding and milling with various tools were tested as an intermediate machining process. With the aim of a high deposition rate and minimal post-processing, MMG was able to develop optimal welding strategies that enable the resource-efficient and fast production of propeller geometries.

For example, the four blades of a ship propeller with a diameter of 1050 mm were welded onto a hub body in 48 hours, see Figure B. The use of additive manufacturing processes enabled the lead time for this propeller product to be reduced by 50%. It was also possible to significantly reduce the overall material costs for single-part production. Individual propeller geometries or spare parts such as tips can be produced easily and perfectly, which adds a new dimension of flexibility to MMG‘s performance. From individual parts to small series, different materials can be combined with each other to make targeted and efficient use of the advantages of the respective properties.

Figure A shows the path planning for build-up welding, which adapts to the geometry layer by layer. By combining welding, measuring, and milling processes in the robot-supported machining cell, hybrid production can be implemented with the component in one clamping. A turn/tilt positioner ensures optimum alignment of the component to the robot, with the robot guiding the respective tool. Extensive sensor technology and algorithms ensure reliable and high-quality production of maritime components.

With the aim of continuously improving our development and production processes, MMG has invested a great deal of time and effort in researching production technology challenges in recent years, today and in the future. The implementation of new manufacturing technologies and robotics are fundamental building blocks for the production of tomorrow.