BETTER SHIPS, BLUE OCEANS

Extension of Wageningen F-Series JIP

Proposal for the Wageningen FC-Series Propellers

Requested by	:	**Wageningen F-Series Propellers JIP**
Attn.	:	**All signed participants**
E-mail	:	
CC	:	
Your reference	:	**Decision made during previous JIP meetings**
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1 BACKGROUND AND OBJECTIVES

In the design phase of the Wageningen F-Series Propellers, both inventory and detailed design work have been carried out for various types of ships, covering merchant vessels to high speed crafts; submarines to cruise ships and yachts. The study showed that the geometric characteristics of the propellers for the cruise ships and yachts distinguished from that of the rest of the ship types studied. It was hence decided during the previous JIP meetings that the cruise ships, the yachts and other ships with high demands on comfort levels should be excluded from the Wageningen F-Series Propellers. Instead, a small series called Wageningen FC-Series, where C denotes for comfort, should be developed.

The objective of the Extension of the JIP towards a Wageningen FC-Series is to design and test 18 additional propellers with focus on energy saving (conforming the requirement of government on subsidies) while assuring the present performance on comfort of such ships. Only 5- and 6-bladed propellers and with a pitch ratio equal to or higher than 1.0 will be considered.

In the next chapters, the scope of work will be defined, followed by the time schedule and the cost/budget estimates. The same terms and conditions of the original signed Agreement for the Wageningen F-series JIP apply.

2 SCOPE OF WORK

Propeller design is becoming a continuous search exercise for the best balance/compromise between propulsive efficiency, hull vibration levels, radiated / on-board noise levels, among other constraints, while the design is pushed ever to the limits nowadays by using advanced design technology.

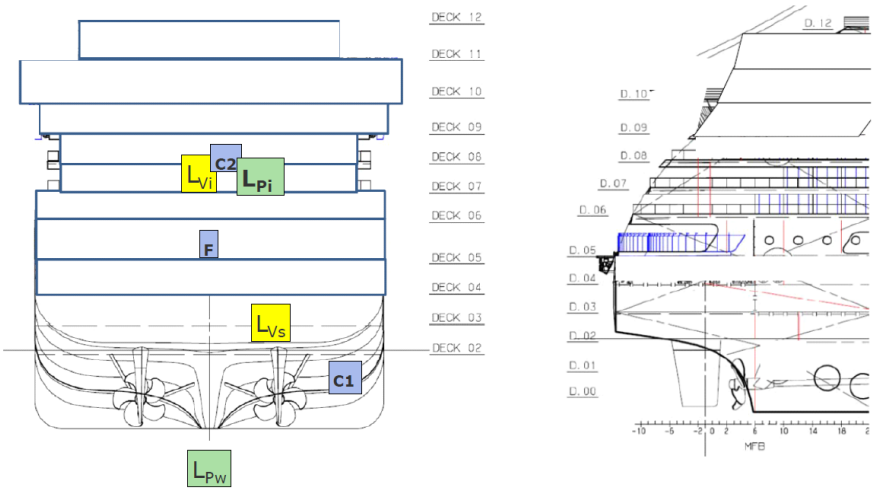
The design approach for the F-series propellers in general has been discussed in detail in the original proposal which applies also to the present FC-series propeller design. This will not be discussed again in the present proposal for the extension.

During the case study of various ship types for the project, it became clear that the geometric characteristics of contemporary propellers for ships with high demand on comfort levels differ from that of the propellers for ships with high demand on propulsive efficiency, such as merchant ships. For those ships, efficiency has the highest weight when considering a good balance with vibration and noise levels. To limit the hull vibration levels in order to prevent structure damage and to enhance the workability of the ship, criterion has been considered to limit the propeller induced hull pressure fluctuations and excitation forces. This has been done under help of the CRS BROADBAND WG which was granted to the F-series JIP to make use of the study outcome in order to link the vibration levels in various places/cabins to the propeller excitations. This can be done without knowing the structure details, but only the type of ships and based on statistic correlation data provided by the classifications, such DNV/GL and LRS. It formed a new criterion/constraint on a propeller design, implemented into the design tool – PropArt, and used for the design of the F-series propellers.

<u>The design tool and implementation</u>

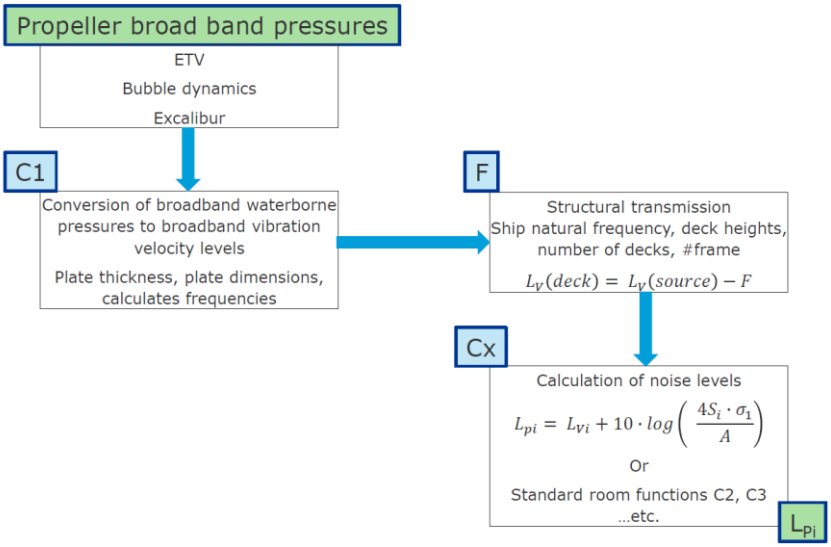
In order to design the FC-series propellers, a similar idea has been discussed during the JIP meetings on a criterion/constraint on propeller induced noise levels (both underwater radiated noise levels - URN and also inboard noise levels) without knowing the structure details but only ships types and their main dimensions. This is important in the early stage of the design and should be implemented into PropArt for the FC-series propeller design.

Granted again by the CRS, the F-series JIP is allowed to make used of the study outcomes from another CRS work group - ONBOARD WG to link the URN levels from the tip vortex cavitation of the propellers to the inboard cabin airborne noise levels in various places on a passenger ship, as sketched in the following figure.



The basic problem, transfer functions from URN to cabin noise levels

The URN from the tip vortex cavitation and bubble dynamics of cloud cavitation transmits into the structure of the ship and travels to various places and into the cabins, resulting in airborne noise in the cabins. A computer model has been established and shown in the following flow chart.



The computer model from URN to cabin noise levels with correlation factors

Under help of the classifications such as DNV/GL and LRS with the correlation factors, the above mentioned approach to assess the cabin noise levels will be implemented into PropArt for the FC-series propeller design.

<u>FC-series propellers</u>

It is not expected that 3-bladed propellers will be used for passenger ships (except for rare situations with podded propulsors). 4- and 7-bladed are also not often used for such vessels. This was hence decided in the JIP meetings that the FC-series will be only a sub set of the F-series with 5- and 6-bladed propellers with light thrust loading, meaning a pitch ratio equal to and above 1.0.

To maintain as a subset of the F-series, it is proposed to design 18 propellers with the following combination of blade area ratios and pitch ratios, showing together with proposed propeller model diameters.

FC-series propeller diameter (18 propeller models)

D [mm]		Z = 3					Z = 4				
EAR		0.30	0.42	0.57	0.79	1.10	0.35	0.47	0.63	0.85	1.15
P/D	0.6	-	-	-	-	-	-	-	-	-	-
	0.8	-	-	-	-	-	-	-	-	-	-
	1.0	-	-	-	-	-	-	-	-	-	-
	1.2	-	-	-	-	-	-	-	-	-	-
	1.4	-	-	-	-	-	-	-	-	-	-
	1.6	-	-	-	-	-	-	-	-	-	-

Z = 5					Z = 6					Z = 7				
0.40	0.53	0.69	0.91	1.20	0.45	0.58	0.75	0.97	1.25	0.50	0.63	0.81	1.02	1.30
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	310	300	290	-	-	310	300	290	-	-	-	-	-	-
-	300	290	280	-	-	300	290	280	-	-	-	-	-	-
-	290	280	270	-	-	290	280	270	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

The matrix of the FC-series propellers

Model tests

All 18 FC-series propeller models will be manufactured and tested for their full 4-quadrant open water characteristics to the highest achievable Reynolds numbers in model scale and in available test facility and test conditions. The propeller quasi-steady open water test technique will be used with trapezoidal variation of both advance speed and the shaft rotation rate. In total, 8 test runs are needed to obtain a full 4-quadrant characteristics. This is identical to the method used for the F-series propellers.

The test results will be reported in two separate reports, one for the 5-bladed and one for the 6-bladed.

Software

The FC-series data sets will be included in the software for the F-series propellers as a subset of the data. All functions of the software for the F-series will be also made available for the FC-series.

3 DELIVERABLES

After the model tests, the results will be delivered in detailed technical reports.

The data set of the FC-Series will be included in the software of the F-Series JIP as a subset and the results can be compared with the F-Series.

All deliverables will be made available only to the extension participants for the FC-series, but not to the original F-series participants who do not sign for the extension.

4 TIME SCHEDULE

The Extension is planned as follows:

Sign the Addendum for all participants	End of August, 2021
Design of the Wageningen FC-Series	September, 2021 to May 2022
Model Manufacturing and tests	May, 2022 to March 2023
Reporting	before May 2023

5 COST AND BUDGET

The estimated cost:

- Design The Wageningen FC-Series Propellers	60,000 euro
- Models, tests and reports of 18 propellers	220,000 euro
- **TOTAL cost**	**280,000 euro**

The estimated budget:

- Participant contribution (about 19, **10k euro each**)	190,000 euro
- TKI	70,000 euro
- MARIN MaFu (2 x contribution fee)	20,000 euro
- **TOTAL budget**	**280,000 euro**

6 PARTICIPATION FEE

The contribution fee per participant to the extension is **10,000 euro**.

7 CONDITIONS AND TERMS OF PAYMENT

The terms and condition of the original signed JIP Agreement, document – “JIP participation agreement F-Series v1.1 august 2018.pdf” with the title “Agreement - Wageningen F-Series JIP” with its addendum, applies to the present Extension of the JIP.

Since the present extension deals with propeller design for low URN, it is under export control of the government. Export license needs to be issued by the government for each signed participants before the signed participants can be officially accepted and the project information can be shared.