MARIN

BETTER SHIPS, BLUE OCEANS

TRIPPING JIP

Tripping JIP

Model scale corrections and CFD correlation for propellers using boundary layer tripping

November 30, 2023

Problem definition

Either model tests or full-scale RANS computations are used to predict the required power for the propellers of the ships sailing the oceans.

Model tests face scale effects; especially laminar flow and flow transition on the propeller give large uncertainty. The flow on model scale does not resemble the full-scale situation.

Full scale RANS computations for propellers require further benchmarks and a sound confidence basis.

Objective

The Tripping JIP aims for better and more reliable full-scale predictions of the performance of propellers, either using model tests or full-scale RANS computations.

Approach

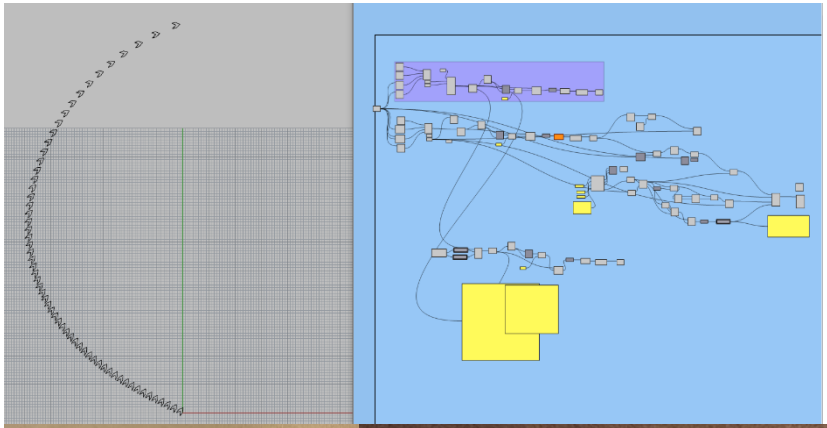
1. Trip the flow on the model scale propellers, such that the flow is turbulent, resembling the full-scale situation. As such, the experimental uncertainty due to laminar flow effects is avoided.

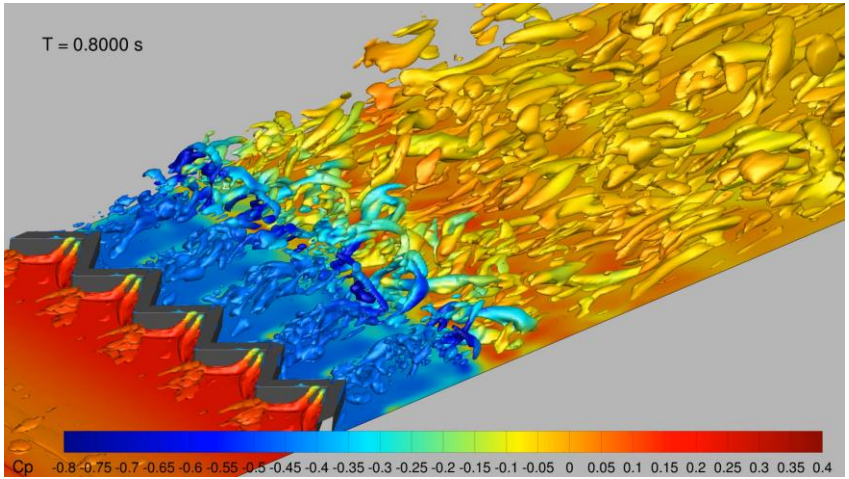
2. Determine new scale corrections (for only the mere viscosity effect on turbulent flow) with standard RANS computations (without transition modelling).

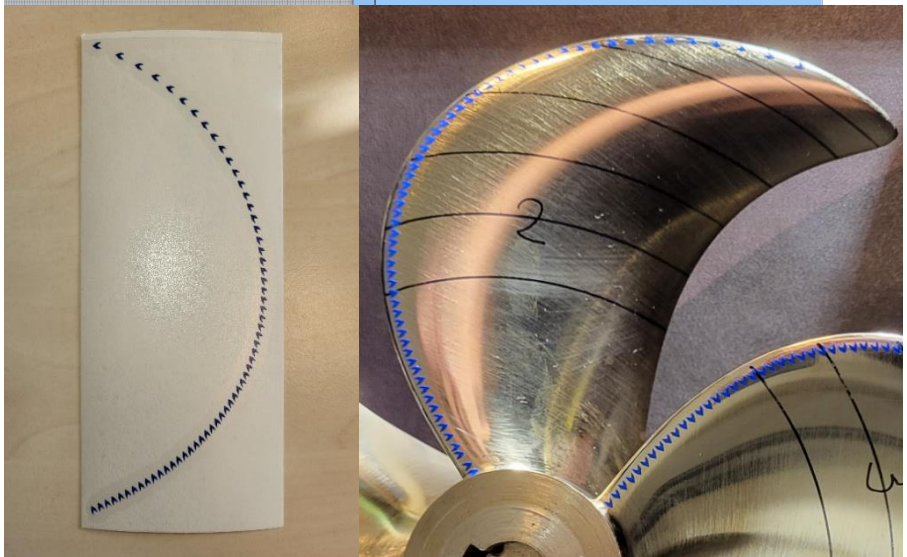
Turbulators

Very efficient in tripping the boundary layer.

Their geometry is based on the well-known zigzag strips as used in the aviation industry

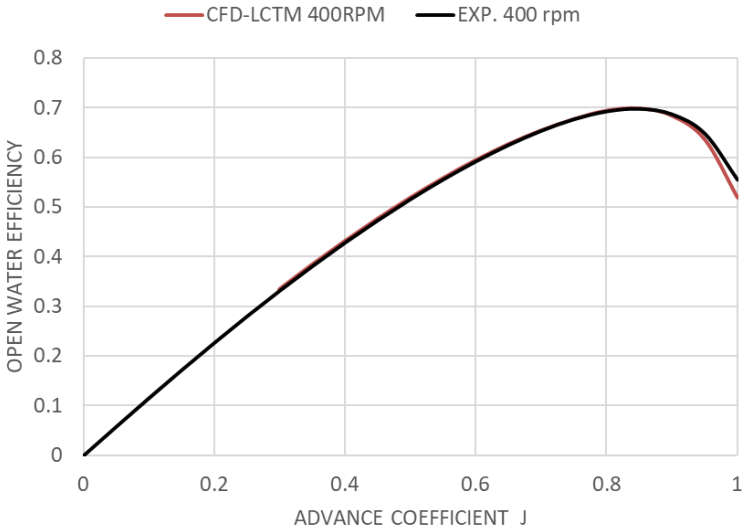


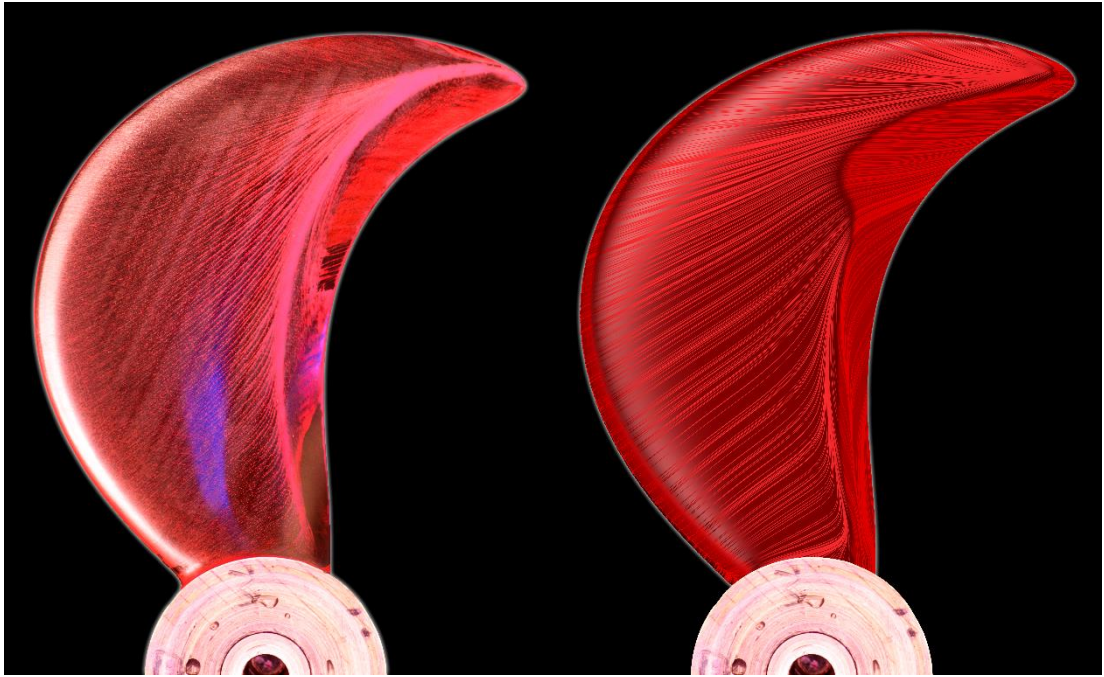




Model scale validation example

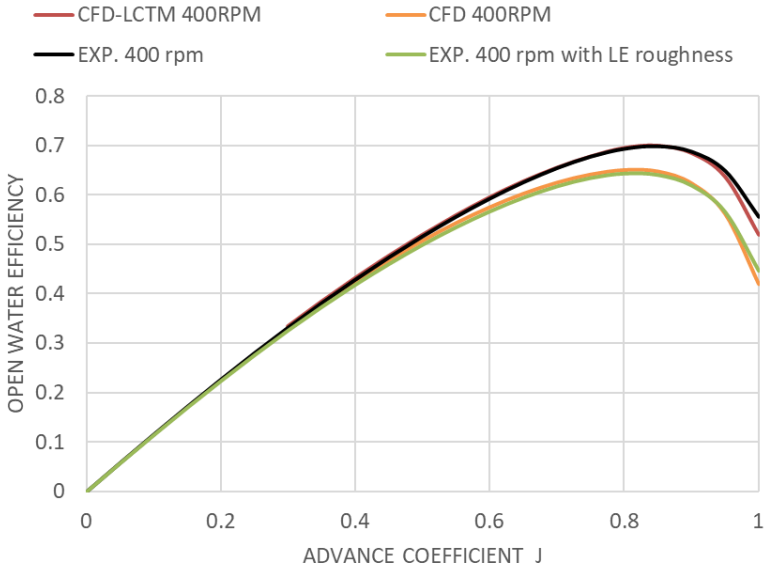
- Using CFD turbulence transition model
- Requires significant tuning, unable to match KT, KQ *and* eta

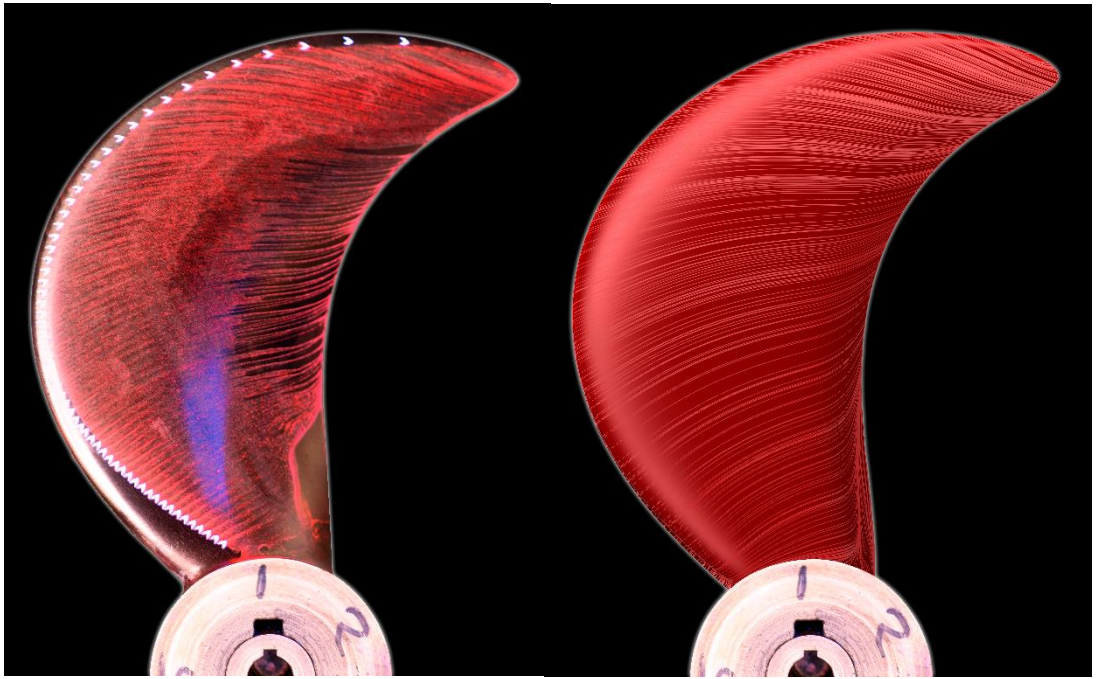




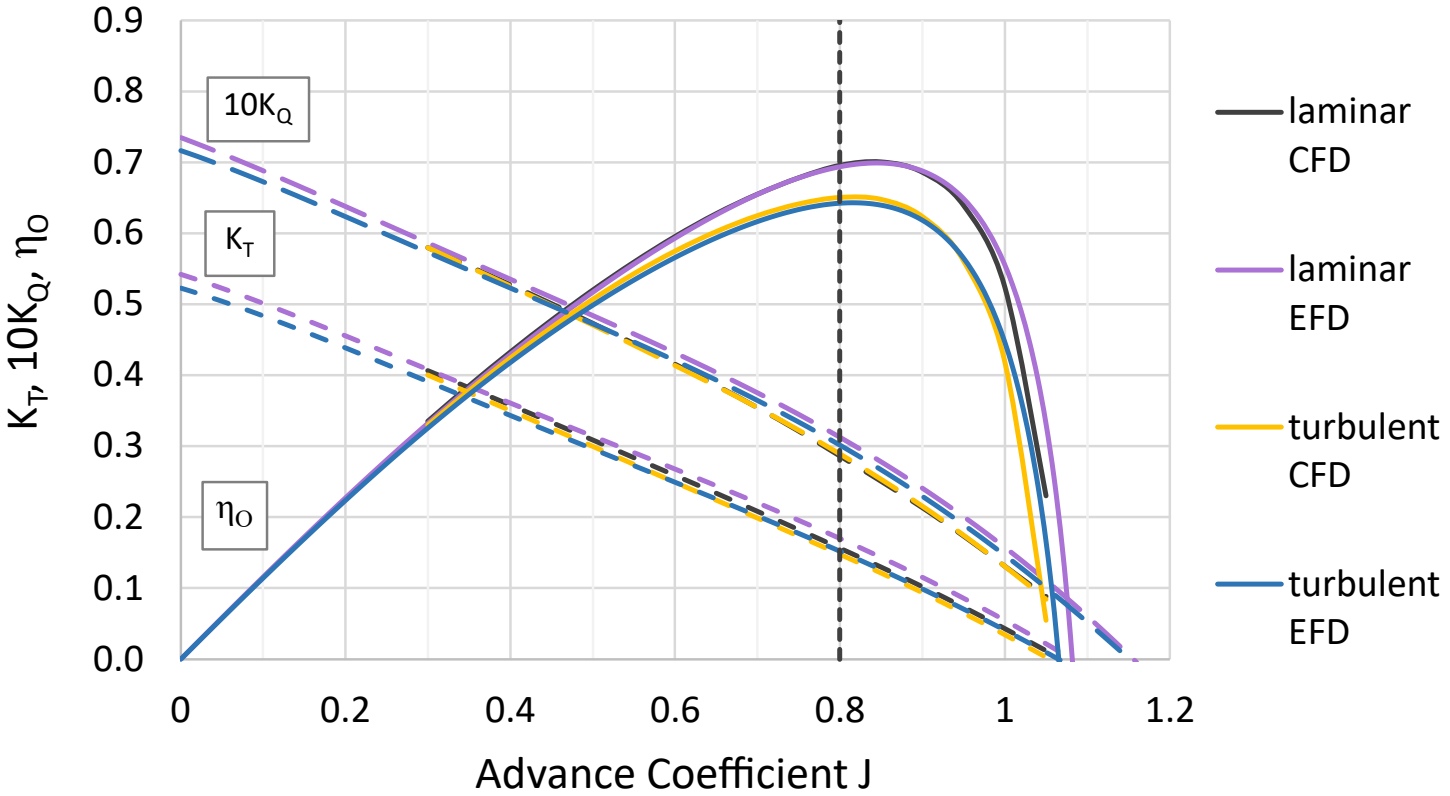
Model scale validation example + boundary layer control

- Using standard CFD turbulence model





Model scale validation example



Scope of work

In the Tripping JIP, MARIN will test and compute a large set of propellers. This dataset shall be used to:

- Provide benchmarks for CFD on propellers
- Develop new generic scale corrections for propellers to be used in model tests
- Develop new generic CFD correlations for propellers to be used for numerical powering predictions
- Provide input to develop a new full-scale polynomial of the performance of the renown Wageningen B-series

WP1: Model tests with turbulators

To build up knowledge over different propeller designs and a range of blade number, blade area ratio and pitch, a selection of F-series, FC-series and C-series (design pitch only) will be retested with turbulators for 4 Reynolds numbers.

Also the B-series will be revisited. Due to the constant and simple design they are believed to be very interesting in the study into scale corrections. Moreover, the B-series are still relevant for the industry.

WP1: Scope of model tests with turbulators

Geometry and results dimensionless	Geometry and results open	Geometry and results open
Existing series propellers	New B-series propellers based on numerical B-series	Other propellers
F4: 13 propellers F5: 13 propellers F6: 13 propellers	B4: 5 propellers B5: 5 propellers	5 propellers from participants
C4-40: 4 propellers C4-55: 4 propellers C4-70: 4 propellers C5-60: 4 propellers C5:75: 4 propellers	B5-60 4 geo-sim propellers	3 existing MARIN propellers with large scale effects
FC5: 8 propellers FC6: 8 propellers		4 public propellers
75 tests	*14 tests, 14 propeller models*	*12 tests, 9 propeller models*
Total of 101 tests at 4 different rotation rates and 23 propeller models to be manufactured.		

WP2: RANS computations

To study the performance of each propeller at a large range of Reynolds number, up to full scale, RANS computations for open water performance will be performed.

The propellers that will be model tested, will also be subjected to extensive RANS computations at 6 Reynolds numbers and 4 variants of full-scale roughness.

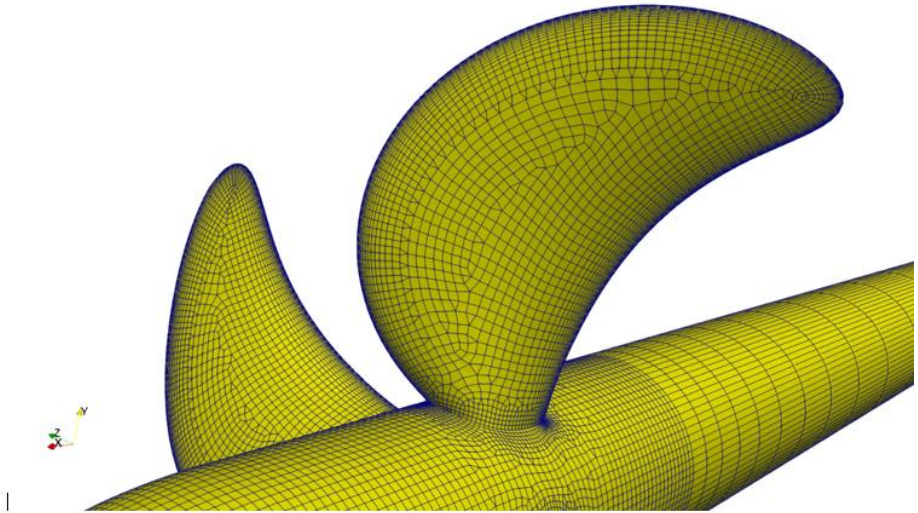


Figure 2-2: Example of Cadence fidelity surface grid

WP2: RANS workshop

- Q3 2024, Wageningen
- To reach for consensus on the RANS approach
- To discuss numerical uncertainty
- Selection of reference propellers (to be selected in April 2024)
- Reference computations from different participants

Participation in the RANS workshop by doing the reference computations will be awarded for 6 k€.

WP2: Scope of RANS computations

It is estimated that 6 Reynolds numbers and 4 different roughnesses will be computed for each propeller totalling 10 computations per propeller. The table below shows the intended scope of the computations

Geometry and results restricted	Geometry and results open	Geometry and results open
Existing series propellers	New B-series propellers based on numerical B-series	Other propellers
F4: 13 propellers F5: 13 propellers F6: 13 propellers	B4: 13 propellers B5: 13 propellers B6: 13 propellers	5 propellers from participants
C4-40: 4 propellers C4-55: 4 propellers C4-70: 4 propellers C5-60: 4 propellers C5:75: 4 propellers	B5-60: 4 geo-sim propellers	3 existing MARIN propellers with large scale effects
FC5: 8 propellers FC6: 8 propellers		4 public propellers
75 propellers	43 propellers	12 propellers
Total of 130 propellers, totalling 1300 computations		

WP3: Generic scale corrections and correlations

Combine the results of the model tests and the RANS computations.

Both the scale corrections and CFD correlation allowances would probably be a polynomial as function of at least blade number, pitch, blade area, J-value, Reynolds at model scale, Reynolds at full scale and full-scale surface roughness. Depending on the results, other geometrical parameters will be regarded as well.

- Scale corrections: used in the extrapolation of model tests
- CFD correlation allowance: used to match the CFD results with experimental results

WP4: Full scale polynomial

Based on the results from the model tests and the RANS computations, the polynomials of the B-series will be revisited and renewed with the latest insights.

The polynomial will become not only a function of blade number, pitch, blade area and J-value, but also of Reynolds at model scale, Reynolds at full scale and full-scale surface roughness.

The full-scale numerical B-series polynomial will be implemented in a software package for first phase propeller design.

Costs and budget

The estimated costs of the described scope of work are specified in the table below, also considering the inflation over the years:

	Description	Costs (k€)
WP1	Manufacturing of 23 propeller models	230
WP1	101 propeller model tests with turbulators	290
WP2	RANS workshop*	80
WP2	130 propellers computed by RANS	220
WP3	Development of scale correction method	205
WP4	Development of full-scale B-series, including software package	90
	Project management, meetings and start-up costs	100
	Contingency	100
Total		**1315**

The funding of the described scope of work is specified based on 21 participants:

	Description	Funding (k€)
	MARIN contribution	45
	Subsidy Dutch government (TKI, ~25%)	330
	Participant contribution (21 participants x 3 years x 15kE)	945
Total		**1320**

Planning

		2024				2025				2026			
WP	Description	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
	Start up and definitions												
WP1	Model tests with turbulators												
WP2	RANS workshop												
WP2	RANS computations												
WP3	Development of scale correction polynomial												
WP4	Development of full-scale B-series and software tool												

Organization

The Tripping JIP is organized by MARIN and hosted within the Vessel Operator Forum

The project will be carried out by MARIN. Participants are expected to actively contribute to the project meetings. Two meetings will be arranged each year.

The first work group meeting will be organized during The Blue Forum, April 2024 in Venezia, Italy.

The results of a JIP will remain for exclusive use by the JIP participants for three years after the finishing of this project.

Registration

Participants are encouraged to sign in onto this project between 1 December 2023 (tomorrow) and 1 March 2024.

The contract (JIP agreement and project proposal) can be found on Tripping | MARIN

After 1 April 2024, new participants will be regarded as ‘late’ participants which involves a 25% higher participation fee and no possibility to perform work for the RANS workshop.

Acquisition and Promotion

- Website MARIN
  - Promotion video
  - Complete project proposal
  - Leaflet
  - *List of participants that have signed*
- LinkedIn
  - Review of the relevant literature
  - Presentation of proposal, part by part
  - Address FAQ
  - Meeting venues
  - *Announcements of new participants*
  - *Introduction of colleagues and their work on the Tripping JIP*
  - *General results and progress*
  - *Etc*

Acquisition and Promotion

- SMP24
  - Two papers, including the reporting of the development of the turbulators, the usage of paint tests and the comparison to RANS computations
- Marin Report 138, to be published soon on magazine.marin.nl

Questions and Discussion

Minutes will follow in due time