BETTER SHIPS, BLUE OCEANS

Tripping JIP

Scale corrections for propellers using boundary layer tripping

Informative meeting, April 9, 2024

AGENDA

Informative meeting

14:00 – 14.10	Welcome, Opening, Introduction, Safety	John Huisman
14:10 – 14:20	Minutes of meetings 30 November 2023	John Huisman
14:20 – 14:30	Starting point and project goal	John Huisman
14:30 – 16:15	Lectures on	
	1. Low Reynolds scale effects	Bart Schuiling
	2. Improving model tests by tripping	Maarten Kerkvliet
	3. A high Reynolds propeller performance model	Douwe Rijpkema
16:15 – 16:30	Coffee/tea break	
16:30 – 17:30	Further presentation of the JIP Proposal	John Huisman
17:30 – 18:00	Discussions on JIP proposal	All

Website of the Tripping JIP

Tripping | MARIN

JIPS > Joint Industry Project > Tripping

TRIPPING

SCALE CORRECTIONS FOR PROPELLERS USING BOUNDARY LAYER TRIPPING

RUNNING

The aim of this JIP is to develop new propeller scale corrections to be able to predict full scale open water performance and propulsive performance more accurately.

< Return to all JIPs

Downloads

PITCH, NOVEMBER 30, 2023

- Pitch
- Recording (mp4)
- Minutes

DOWNLOADS

- Contract and project proposal, version 1.4
- Leaflet

PAPERS

- SMP '24 Experimental study Flow Visualisation and pass. control of Model Propeller boundary layers
- SMP'24 Numerical study Model Prop. performance predict., incl. transitional and passive control b

AGENDA

14:00 – 14.10	Welcome, Opening, Introduction, Safety	John Huisman
14:10 – 14:20	Minutes of meetings 30 November 2023	John Huisman
14:20 – 14:30	Starting point and project goal	John Huisman
14:30 – 16:15	Lectures on	
	1. Low Reynolds scale effects	Bart Schuiling
	2. Improving model tests by tripping	Maarten Kerkvliet
	3. A high Reynolds propeller performance model	Douwe Rijpkema
16:15 – 16:30	Coffee/tea break	
16:30 – 17:30	Further presentation of the JIP Proposal	John Huisman
17:30 – 18:00	Discussions on JIP proposal	All

Minutes of meeting, 30 November

Reference document with main ideas and raised questions

- 1. Transcription of the pitch presentation
- 2. Questions and answers during the meeting
- 3. Documentation of questions via email

AGENDA

14:00 – 14.10	Welcome, Opening, Introduction, Safety	John Huisman
14:10 – 14:20	Minutes of meetings 30 November 2023	John Huisman
14:20 – 14:30	Starting point and project goal	John Huisman
14:30 – 16:15	Lectures on	
	1. Low Reynolds scale effects	Bart Schuiling
	2. Improving model tests by tripping	Maarten Kerkvliet
	3. A high Reynolds propeller performance model	Douwe Rijpkema
16:15 – 16:30	Coffee/tea break	
16:30 – 17:30	Further presentation of the JIP Proposal	John Huisman
17:30 – 18:00	Discussions on JIP proposal	All

Introduction Tripping JIP

The Wageningen C, F and FC-series JIPs are finished: set of high-quality propeller models and **model scale** data

However, propellers are designed for (both model scale and) **full scale**

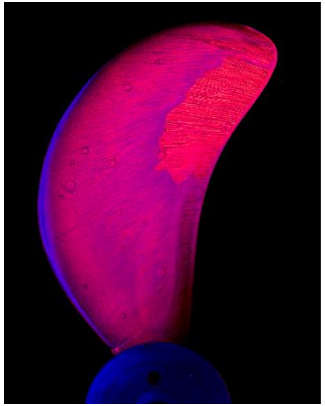
Tripping: how to extrapolate model scale results properly?

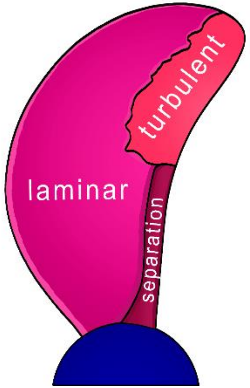
- First idea: Denmark, June 7, 2023
- Launch of proposal: September 2023
- Pitch of the proposal: Busan, November 30, 2023
- In-depth presentations: Today

TRIPPING JIP

MARIN

Problem

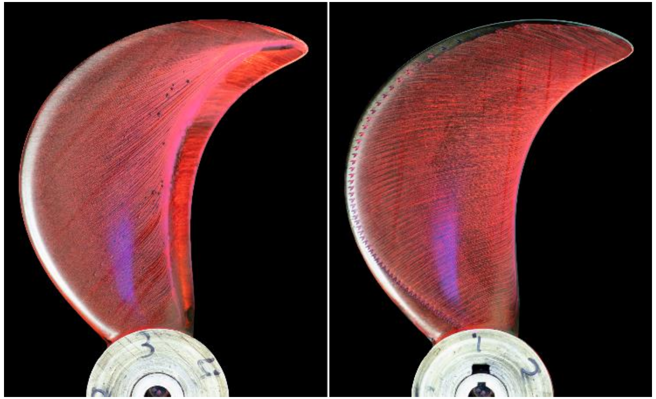




Boundary layer flow transition and flow separation occurs at **model scale** conditions

This complicates the extrapolation process to **full-scale** propeller performance prediction

Solution

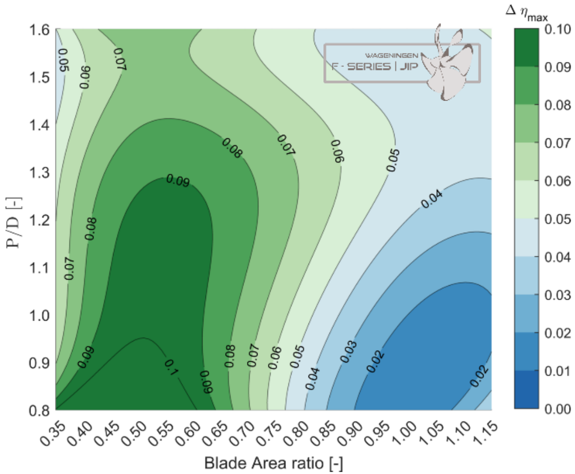


Boundary layer control

Towards flow similarity, i.e. a turbulent boundary layer at model scale

Applying turbulators to efficiently trip the laminar boundary to a turbulent one

Impact



Effect on performance without boundary layer control is highly dependent on propeller design and operation condition

Computational Fluid Dynamics (CFD) should assist towards improved extrapolation procedures

Improve propeller performance prediction

DAMEN
BRUNVOLL
PRECISION IS OUR PASSION
Kawasaki
Powering your potential
Defensie Materieel Organisatie
Ministerie van Defensie
KONGSBERG
SAMSUNG
STEERPROP
TRIPPING JIP
MARIN
ABB
MAN
MAN Energy Solutions
Future in the making
BETTER SHIPS, BLUE OCEANS

Schuiling, Kerkvliet & Rijpkema, *An Experimental Study on Flow Visualisation and Passive Control of Model Propeller Boundary Layers*, SMP'24, Berlin, Germany, 2024
Kerkvliet, Baltazar, Schuiling & Eça, *A Numerical Study on Model Propeller Performance Prediction Including Transitional and Passively Controlled Boundary Layer Considerations*, SMP'24, Berlin, Germany, 2024

Current participation of the Tripping JIP

- 11 core industry participants
  - 10 April they decided on the way forward
- More industry partners are expected
  - 21 industry participants are required for the full scope of work.
  - The normal fee of 15k per year for 3 years is extended until further decision.
- Other model institutes will participate by in-kind contributions, support and reference testing
  - HSVA, SVA, SINTEF, CEHIPAR, QINETIC, RISE have already shown their keen interest and support the ideas behind tripping.

Common Interest

- For propeller designers and manufacturers, the results of this project would provide full scale Wageningen series data. Furthermore, the results would lead to less surprises during model tests and better control of the propeller design on both model scale and full scale. The proposed approach would allow to direct the design focus primarily to full scale, being less limited by model scale limitations.

- For other research institutes and participants with their own model test facilities this project would improve the extrapolation methodology and would give more reliable predictions.

- For yards and operators this project would result in more reliable full-scale predictions and improved propeller designs. Additionally, insight in the effect of roughness on propeller performance could be valuable.

- For R&D, this project would provide benchmark data for RANS computations on propellers for reference and quality checks. As such the quality of and confidence in CFD will improve significantly.

AGENDA

14:00 – 14.10	Welcome, Opening, Introduction, Safety	John Huisman
14:10 – 14:20	Minutes of meetings 30 November 2023	John Huisman
14:20 – 14:30	Starting point and project goal	John Huisman
14:30 – 16:15	Lectures on	
	1. Low Reynolds scale effects	Bart Schuiling
	2. Improving model tests by tripping	Maarten Kerkvliet
	3. A high Reynolds propeller performance model	Douwe Rijpkema
16:15 – 16:30	Coffee/tea break	
16:30 – 17:30	Further presentation of the JIP Proposal	John Huisman
17:30 – 18:00	Discussions on JIP proposal	All

On 10 April 2024, the steering group decided to rewrite the project proposal to fit the budget from 11 participants.

In November 2024, week 47, the scope will be reconsidered together with the new participants

The next slides present the original scope

The new scope is still to be worked out in more detail

Contract including project proposal

Available on the website for download

DOWNLOADS

- Contract and project proposal, version 1.4
- Leaflet

PAPERS

- SMP '24 Experimental study Flow Visualisation and pass. control of Model Propeller boundary layers
- SMP'24 Numerical study Model Prop. performance predict., incl. transitional and passive control b

Agreement Tripping JIP – Version 1.4 1

Agreement Tripping JIP

Issue No.	Originator	Date	Remarks
V1.0	John Huisman	27-09-2023	JIP leaflet on PPA
V1.1	John Huisman	29-09-2023	Typo in the finance table
V1.2	John Huisman	3-10-2023	Final logo
V1.3	John Huisman	15-01-2024	Addition 11.2 and 12.6
V1.4	John Huisman	28-03-2024	Further specification of deliverables in Annex A.3, page 36

Contract

1. Agreement - legal
2. Annex A: Project plan - technical
3. Annex B: Participation fee and terms of payment
4. Annex C: Amendments

Steering group

- MARIN organizes the JIP
- The steering group are all participant representatives

The representative, or alternate appointed by each Participant, will serve as a member of the Participant Steering Group (PSG). The PSG will appoint a chairman of the PSG who shall not be the Contractor's representative.

Participant's representative is: **[name and contact details of representative]**

Participant's alternate is: **[name and contact details of alternate]**

Project proposal

1. Introduction & background
2. Work packages
3. Deliverables
4. Finance
5. Planning

ANNEX A: PROJECT PROPOSAL

Tripping JIP proposal

Proposal to develop new propeller scale-corrections using boundary layer tripping

CONTENTS

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.

Main idea

Narrow the gap between model tests and CFD predictions

CFD will not be adapted towards model scale results using transition modelling, but model test procedures are adapted towards standard CFD computations.

This approach significantly decreases the uncertainty of both the CFD and the model tests.

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).

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 series

Four work packages

1. Open-water model tests with turbulators
2. Open-water RANS computations
3. Analysis and development of scale corrections
4. Development of full scale polynomials for the Wageningen propeller series

WP1: Model tests with turbulators

New open-water model-tests will be performed with turbulators to trip the flow towards a turbulent boundary layer on model scale to have the flow characteristics representative to the full-scale flow regime.

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: Model tests with turbulators

The focus is on the open water performance of the propellers in the first quadrant until KQ = 0.

No blade force measurements will be done on the C-series propellers. The focus is on open propellers.

Ducted propellers are still challenging in both model tests with turbulators and RANS computations. Therefore, the KA-series and D-series are left outside the scope of work.

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.		

Initial scope will be reduced in view of current number of participants

WP1: Model tests with turbulators

The turbulators are automatically designed and oriented for each propeller and plotted in a sticker for easy and consistent application.

Turbulators are applied on both sides of the propeller, near the leading edge.

Appropriate corrections for the resistance of the turbulators itself will be applied on the results from the model tests.

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.

Further details on the setup are to be discussed tomorrow

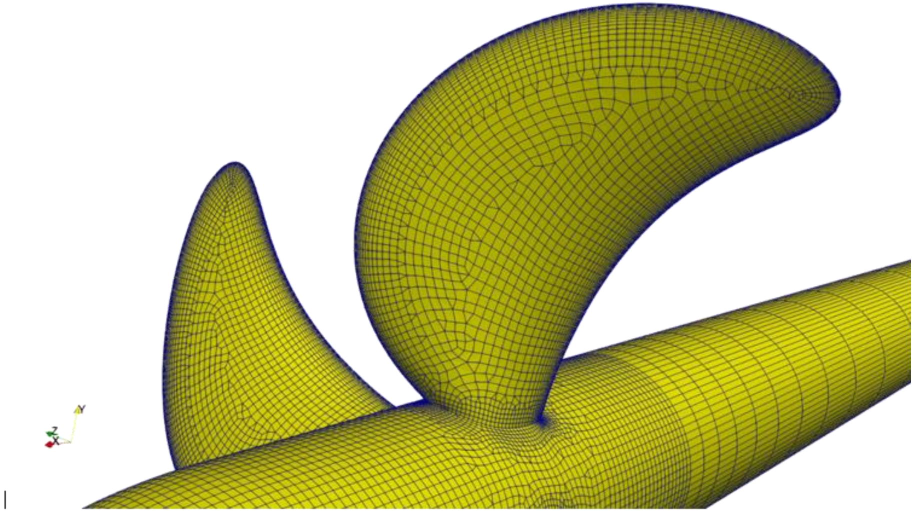


Figure 2-2: Example of Cadence fidelity surface grid

WP2: RANS workshop

- 2024, Wageningen
- To reach for consensus on the RANS approach
- To discuss numerical uncertainty
- Selection of reference propellers
- 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		

Initial scope will be reduced in view of current number of participants

WP3: Generic scale corrections and correlations

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

Both the scale corrections and CFD correlation factors 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 factors: used to match the CFD results with experimental results

WP3: Polynomial of model tests

Fives types polynomial can be derived from the data

1. Model tests
2. RANS computations
3. Difference between model tests and RANS computations
4. Full scale performance of a propeller

WP3: Polynomial type 1

Create a polynomial of model test results as function of Reynolds to be used in the determination of propulsive coefficients from propulsion tests

Each ship speed is analyzed for propulsive coefficients with open water data at equal Reynolds number

- More consistent
- More reliable eta-R

WP3: Polynomial type 2

Create a polynomial of CFD results as function of Reynolds. This gives scale effect at each Reynolds number.

Questions to be investigated using this data:

Is the scale effect as found on model tests similar as computed with CFD? Probably not, due to separation effects which are still present (although to lesser extent as with laminar flow).

WP3: Polynomial type 3

Create a polynomial of the difference between model test and CFD gives at equal Reynolds number a CFD correlation

CFD, albeit very mature, does not capture all physics.

This polynomial provides a correlation between model tests and RANS computations

WP3: Polynomial type 4

Full scale performance of a propeller will be a polynomial based on a tripped model tests at highest achievable rotation rate + the results from usage C

Typical questions that can be answered using this:

- How does the performance vary as function of Reynolds in practice? Is very slow transit more efficient at a slightly smaller diameter?
- How does roughness affect the propeller performance?

WP3: Extent of polynomials

- Per propeller as function of Reynolds model scale, Reynolds full scale and full-scale roughness

- Per propeller series as function of blade number, pitch, blade area, J-value, Reynolds at model scale, Reynolds at full scale and full-scale surface roughness

- Generic baseline method, combining the results from all tested propellers, also being a function of other geometrical parameters, most probably

WP3: generic baseline method

The generic scale correction methodology will serve as a benchmark for future projects. It is envisioned that it will be used as a new standard for propeller scale effects, but it would also serve as quality check on custom computed scale corrections.

WP3: Usage during propulsion tests

During extrapolation of propulsion tests, a combination is used:

- Polynomial type 1: Propulsive coefficients are based on a polynomial from model test data at different 3 different Reynolds number (3POT method)
- Polynomial type 3: Full scale performance is based on the model test at highest Reynolds number + the difference between the CFD computations at the model scale Reynolds and the full-scale Reynolds

WP3: New extrapolation method required

Overall, it is envisaged that this JIP will made a significant step towards a new and widely accepted extrapolation method, which makes the differences between model institutes less prominent. A broad support on this would also serve as incentive for the ITTC to adapt their guidelines in due course.

Model test procedures will need to be adapted, by adopting turbulators on the propeller blades.

New standards and procedures need to be developed, in close collaboration with other model basins

WP4: Full scale polynomial

Based on the results from the model tests and the RANS computations, the polynomials of the Wageningen 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 series polynomial will be implemented in a software package for first phase propeller design.

*the F and FC series will be delivered to the participants of the respective prior JIPs only

Deliverables

1. Full results of the tripped model tests and RANS computations on the public propellers to be used for CFD benchmarking.
2. Dimensionless results in terms of Reynolds scaling of the tripped model tests and RANS computations for the F-series, FC-series and C-series propellers.
3. Generic propeller scale correction polynomial.
4. Generic RANS correlation allowance polynomial.
5. Guidelines for updated model test procedure and extrapolation method.
6. Full scale numerical series polynomial of Wageningen series*.
7. Software package for propeller design using the full-scale numerical Wageningen series polynomial*.

*the F and FC series will be delivered to the participants of the respective prior JIPs only

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

Envisioned 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							■	■	■	■	■	■

Costs and envisioned 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**

Initial scope will be reduced in view of current number of participants (11)

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**

JIP structure

A JIP enables a large-scale research project, while sharing experiences and expertise in co-operation for common understanding and industry standards. Typically, a JIP project bridges the gap between basic R&D activities and full application in commercial projects. The activities are typical pre-competitive co-operation. Therefore, part of the costs is supported by subsidies from the Dutch government.

Acquisition and Promotion

- Website MARIN
  - Promotion video
  - Complete project proposal
  - Leaflet
  - List of participants that have signed
  - Minutes of meeting
  - Papers
- 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 magazine.marin.nl

Scope to be carried out first

The following was decided as plan to work out further for a revised scope in Annex A of the Agreement:

- Take out most of the B-series
  - All current participants are part of the F-series
  - B-series full-scale will be totally different anyhow
  - Take only 1 or 2 existing B-series for reference, B4-70
- Include self-propulsion tests in the scope -> limited scope
- Check one FC-series propeller
- Geosim: only 1 additional propeller instead of 3
- Take the 4-blade C-series only

Additional scope

In case the total funding becomes higher than budgeted due to the participation of more than 21 participants, additional work will be agreed with the participants in an expansion of the scope of work

- Expansion on the scope of propellers. The 3 and 7-bladed F-series may be considered, or different pitch settings for the C-series.
- Expansion of the scope towards ducted propellers and tunnel thrusters. This would also require some more basic R&D to get the tripping on the duct correct.
- Paint tests to visualize the flow phenomena as function of J-value and Reynolds number, on either or both clean blades and blades with turbulators.
- Retests at other basins, towing tanks or cavitation tunnels for benchmarking and correlation.
- Consideration of the power regeneration area in the first and third quadrant.
- Propulsion tests using turbulators on (public) reference ships to study the behavior of the new scale corrections and extrapolation method.
- Ice-class propellers or non-conventional propulsors could be interesting as well.

Most likely extensions discussed on 10 April, priorities to be discussed later

- Off design pitch of C-series, CQ blade to be measured
- Ducted propellers: D-series
  - Face strong scale effects
  - Turbulators would work there as well
  - More research and investigations are required first
  - Many use KA-series, strange scale effects there too.
  - Strong point for other model institute
- Expand dataset of more C-series propellers
- Propeller ice class designs or more generally: investigate the effect of t/c on scale effects

Terms and conditions for participation of model institutes

- We aim to bring together, besides many more propeller manufactures, also the largest and most influential model-testing institutes.
- MARIN proposes to pull them onboard by allowing them to participate with ‘in-kind’ contribution, worth 45k, as participation fee.
- MARIN proposes to have them write a solid proposal, based on terms, conditions and guidelines we decide on today
- MARIN proposes them to present their proposals to us, such that the steering group can decide.

The next two slides on this topic represent the discussion in the steering group from 10 April

Topics of interest from other model institutes

Main focus is experimental work:

- Reference open-water tests
- Towing tank versus cavitation tunnel: influence of turbulence level.
- Standardization of tripping
- Comparison of extrapolation methodologies (strip method!)
- Impact of tripping on propulsion tests -> reference self-propulsion tests
- …

But they could also participate to the CFD workshop

Only partly governmental (public) funded organizations can join as such.
For Europe e.g. HSVA, SINTEF, RISE, SVA, QINETIC, FORCE, CEHIPAR,

Decided way forward for the in-kind contribution for other institutes

- Legally, to manage the risk: pay 45k first, then work is contracted for 45k back
- Additional experimental work should be beneficial / positive for the project
- MARIN to make proposal for certain budget in collaboration with the institutes
- Subcontractor work is always to be approved first by steering group
- Prove their contribution worth of 45k, to be approved by steering group

MARIN will include this proposal in the updated project plan

Registration

New participants are encouraged to sign in onto this project

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