Results of Questionnaire on Analysis Methods for Propulsor

—— Use of Panel Methods and RANS Equation Codes for Propulsion ——

by
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This questionnaire survey was carried out by the authors under the organization of the 21st ITTC Propulsor Committee. The authors consider that the results of the questionnaire show the state of the art of analysis methods for propulsors and that it is significant to record them in this report.

The authors would like to express their gratitude to the other members of the 21st ITTC Propulsor Committee for their cooperation.

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21st ITTC Propulsor Committee
Results of
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Analysis Methods for Propulsor
--- Use of Panel Methods and RANS Equation Codes for Propulsion ---
------ Development and Utilization ------
--- September 1995 ---

1. Introduction

At the 20th ITTC (International Towing Tank Conference) full conference, held in San Francisco (September 1993) , the Propulsor Committee of the 21st ITTC was assigned eight tasks. Task 6 was " Evaluate developments in the use of panel methods and Reynolds Averaged Navier Stokes (RANS) equation codes for propulsion ." The 21st ITTC Propulsor Committee has decided to survey the use and developments of these methods not only by the literature survey but also by the use of a questionnaire, entitled " Questionnaire on analysis methods for propulsor --- use of panel methods and RANS equation codes for propulsion --- "

The 20th ITTC Propulsor Committee carried out comparative calculations and held a workshop for panel methods, Aug. 23, 1992, Seoul, which was reported in the proceedings of the 20th ITTC, Report of the Propulsor Committee. The 21st ITTC Propulsor Committee is investigating the progress in and propagation of panel methods and RANS equation codes by the use of the questionnaire. One of the important points of the questionnaire is to survey the propagation and utilization of the analysis methods for propulsors. The utilization of RANS equation codes for propulsors seems to be few, however, these codes are expected to become a powerful tool for the analysis of propulsors.

The Questionnaire was distributed to 188 organizations including all ITTC member organizations (104) . The Committee had received 82 replies with 66 substantial response to the Questionnaire. The nations of the 66 respondents are as follows :

Canada (3)	China (7)	Finland (2)	France (3)
Germany (5)	Greece (1)	Italy (2)	Japan (19)
Korea (5)	The Netherlands (2)	Poland (1)	Romania (1)
Russia (1)	Spain (1)	Sweden (1)	Turkey (1)
United Kingdom (4)	U.S.A. (7)		

The questionnaire is shown in the Appendix, in which numbers of votes from the respondents are recorded. The results of the questionnaire gives state of the art statement for analysis methods for propulsors as shown in the following sections.

In order to make clear the results of the questionnaire, the responses are categorized into four groups in the analysis;

Group 1: Respondents who have developed (are developing) a panel method for a propulsor
23 responses out of 66

Group 2 : Respondents who have developed (are developing) a RANS equation code for a propulsor
13 responses out of 66

Group 3 : Respondents who are using (will use) panel methods or RANS equation codes for a propulsor and who are not included in the Group 1 nor Group 2
17 responses out of 66

Group 4 : Other respondents
13 responses out of 66

2. Panel Methods

Many researchers (18 respondents out of 66) have developed the panel method for a propulsor and 8 researchers are developing their panel method further.

Potential based panel method with pressure Kutta condition is gaining in popularity. 85% of the methods employ a potential based panel method, whilst the others employ velocity based panel method. 55% of the methods employ a pressure Kutta condition, whilst 24% employ a Morino Kutta condition and a further 7% employ a flow tangency Kutta condition. There is no regular method for the treatment of wake deformation, some are deformed according to calculation, some are deformed according to experimental data, and others are not deformed. There are various methods for viscous correction. Circulation reduction is adopted by very few researchers (15%). Many respondents (39%) use " Sectional drag coefficient by empirical data ". Some (18%) use " Sectional drag coefficient by boundary layer calculation ". Panel methods have been applied widely, for example, analysis of propeller blades with hub (33%), propellers in non-uniform flow (24%), unsteady propellers (21%), propellers with stators (10%), or propellers with rudders (9%).

Recent improvements from a validation point of view included, " panelling ", " Kutta condition " and " wake deformation " which all received the same number of votes (30%). Recent improvements to the application included, " Propeller in non-uniform flow " , " Unsteady propeller" and " Design of a propeller " which obtained almost the same number of votes (20%).

As for further developments, some still claim the importance of the basic subjects such as panelling, Kutta condition, wake deformation, viscous correction, or unsteady analysis. Others expect the development of the application to highly skewed propeller, ducted propeller, stator, propeller with rudder, cavitation analysis, separated flow, or effective wake.

The ITTC Propulsor Committee was requested by 10-12 respondents to " Organize a workshop " and " Organize comparative calculations ". Interesting themes proposed are non-linear Kutta condition; wake deformation calculation; far wake modelling; hydroelastic effects investigation; highly skewed propeller panelling to avoid boundary element distorsion; effective wake; cavitation inception with panel method; prediction of cavitation sheets; leading edge vortex; tip vortex; hub vortex; hull pressure fluctuations.

14 organizations out of the 66 have used panel methods and 14 organizations are using panel methods. Furthermore many organizations (65% respondents of the Group 3) will use the panel method for propulsors in future.

The main application of a panel method is the design of propellers (41%), followed by the estimation of propeller cavitation (26%). Many respondents (45% of Group 1) are satisfied with the results of panel method for pressure distribution on blades or performance KT, KQ. The majority of respondents (35%) regard estimating the pressure distribution on the blade as the main reason for using panel methods with 27% giving performance KT, KQ as the main reason for using panel methods.

The main request to developers of panel methods was for a more suitable computer program for practical utilization. The computer program should be accurate, robust, and applicable to ducted propeller, highly skewed propeller, contra rotating propeller, energy saving devices, or heavily loaded conditions. Care with unsteady Kutta condition; velocity distributions near the intersection of the hub and the blade; a reasonable wake model; and to automate input via file management ; are also in the request.

The ITTC Propulsor Committee received the following requests ; to organize comparative calculations and workshop; to organize them more frequently; to evaluate state of the art of panel methods around the world; validation of the panel codes by using mysterious propulsor; standardization of input / output; to organize comparative computation for a special marine propeller including highly skewed propeller; applications of panel method to the propulsors with appendages, including a propeller and stator; ducted propeller; to investigate quality of cavitation inception prediction; study on the effect of panel numbers and wake deformation on propeller performance. One further comment was " Propulsor generally acts to move a vessel not only straight but to change its course. From this point, we want to know the lateral force acting on propulsor including rudder."

3. RANS equation code

Over the last few years there has been a significant increase in the development and use of RANS equation codes for marine propellers. The 19th and 20th ITTC report provided a review of viscous flow methods used for propellers. In the 20th ITTC report four groups were active in the uses of RANS codes for the study of marine propellers. The results from the 21st ITTC questionnaire show thirteen groups having or developing RANS equation codes and eight groups who have or are using RANS equation codes for marine propellers. There are a further 12 groups who will develop a RANS propeller capability.

Of the RANS equation codes that have been developed, or are under development, there is an even split between finite volume and finite difference methods of which 30% use explicit and 70% use implicit methods. All the methods currently employed on marine propellers use structured mesh grids with 75% of them using multi-block methods. The use of unstructured mesh grids will increase with two groups proposing to use such methods in the future. Mesh adaption to the solutions is used by a third of the methods. The majority of methods use a non-staggered mesh. 60% of the methods use pressure correction whilst the rest use artificial compressibility. Turbulence modelling is split evenly between Baldwin-Lomax and the two equation K-epsilon methods. Maximum mesh sizes varied from 400 to 1,500,000 mesh nodes with the majority number being around 500,000.

The majority of RANS equation codes have been used for KT, KQ and blade pressure predictions. A smaller use is for scale effects and unsteady blade pressure predictions. The RANS equation code has been used in the design of propellers, the study of scale effects, with experimental studies, for the study of cavitation, the interaction between propeller and hull and the effect of skew on propeller performance. Of those expressing an interest in using RANS equation codes, the majority want to use them in the design of propellers, the study of scale effects, propeller hull interactions and cavitation performance.

The areas of concern expressed, were of mesh grid generation and quality, turbulence modelling and higher order methods such as Reynolds Stress Modelling (RSM); boundary conditions; spatial and time accuracy and computational efficiency. Flow field data for validation of RANS equation code is an important area and many workers expressed a need for suitable model and full scale flow data.

Out of the 13 RANS development responses ; 7 requested the organisation of a workshop and 8 requested the organisation of comparative calculations. Also requested was the setting up of a bench mark experimental data base. The view was also expressed that it should include experimental data on skin friction distributions at off-design particularly in the region of the leading edge and near the hub.

Future use of RANS equation codes included; RSM for tip vortex modelling; examination of leading edge laminar separation in model tests and how it influences the scale effect; research on the transition from laminar flow to turbulent flow; leading edge separation prediction of cavitation sheets and the formation of leading edge and tip vortices. Typical requests to the developers of RANS equation code are validation, reliability and providing useful data for extrapolation of model data to full scale.

4. Other analysis methods

Many researchers have developed the lifting surface theory for propellers and some are developing it further. One respondent is developing Navier Stokes solver with a Bubble Two-phase Flow model.

Typical reasons given for not developing a panel method are " Our present methods (Lifting Line and Lifting Surface Method) work reasonably well, if some empirical corrections are included. As we have limited capacity and we believe that empirical corrections have to be included anyhow, we give this work relatively low priority. " and " At present the advantage of panel method over lifting surface does not justify the investment in developing panel method, but we plan to do it in the future. "

Typical reasons given for not developing a RANS equation code are the high cost, performance and reliability. Other comments are " I have not had so many hands, besides I don't think it is worth while." , " Using RANS just for assessing viscosity effect on propeller characteristics is not justified. " , and " Application of RANS for unsteady cavitating flow seems to be too complicated at present."

Many organizations (21 respondents out of 66) have used or are using the method of lifting surface theory.

Reasons of not using a panel method for propulsors are as follows; the accuracy gain compared to lifting surface methods seems to be rather small.; unsatisfactory prediction of KT, KQ and pressure distribution; sensitivity of the panel discretization on the solution; unnecessary for initial design; waiting for practical code.

Reasons of not using a RANS equation code for propulsors are as follows; difficulties in grid generation; large computer capacity and computer time; not reliable enough for the use in a design process of a propeller; waiting for cost effective, reliable, practical correlated system.

5. Conclusions

From the analysis of the results of this Questionnaire and its comparison with the workshop organized by 20th ITTC Propulsor Committee, the current status of analysis methods for propulsors can be derived. Main conclusions are as follows:

Developers and users of the panel method for propulsors are steadily increasing, and application of the panel method is expanding. However there still remain some subjects to be addressed including the treatment of wake deformation and the viscous correction.

Over the last few years there has been a significant increase in the development and use of RANS equation codes for marine propellers.

As higher accuracy is required for the analysis of propellers, so accurate and reliable panel methods and RANS equation codes will become important.

It is important to recognize that almost all propeller designers are working from the basis of the method of lifting line / lifting surface theory. As well as new methods the study of the lifting line / lifting surface theory is also important.

There are more than 10 people who eagerly requested workshop and/or comparative calculations.

The Committee would like to express its gratitude to all participants of the Questionnaire survey for their invaluable contributions.

Appendix
21st ITTC Propulsor Committee
Questionnaire on
Analysis Methods for Propulsor
--- Use of Panel Methods and RANS Equation Codes for Propulsion ---

* Numbers in the parenthesis indicate the numbers of votes obtained in the responses
(Group1+Group2+Group3+Group4 = Total)

1.

Name (Contact person) ____________________
Affiliation ____________________
Postal address ____________________

2. Your standpoint for the questionnaire

2.1 ( ) You will reply to the following questions as a researcher who
(13+8+1+1=23) has developed
(10+8+0+2=20) is developing
(3+1+3+3=10) will develop
the analysis method for propulsor including panel methods and RANS equation codes.

2.2 ( ) You will reply to the following questions as a user who
(5+7+3+1=16) has used
(5+2+6+2=15) is using
(4+2+11+3=20) will use
the analysis method for propulsor including panel methods and RANS equation codes.

3. As a researcher of panel methods

3.1
(16+1+0+1=18) You have developed a panel method for a propulsor.
(8+0+0+0=8) You are developing a panel method for a propulsor.
(2+0+2+2=6) You will develop a panel method for a propulsor.

What is the name of your method? ____________________
What is the title of the paper and the publication of your method?

____

3.2 What is the basic equation of your method?

(20+1+1+0=22) Potential based panel method

(4+0+0+0=4) Velocity based panel method

(0) Others ______

3.3 What is the Kutta condition of your method ?

(16+0+0+0=16) Pressure Kutta condition

(7+0+0+0=7) Morino Kutta condition

(1+0+1+0=2) Flow tangency Kutta condition

(4+0+0+0=4) Others ______

3.4 How do you treat wake deformation in your method ?

(11+0+0+0=11) Non-deformation (constant pitch)

(11+0+1+0=12) Deformed according to calculation

(7+1+0+0=8) Deformed according to experimental data

(0) Others ______

3.5 How do you decide the viscous correction of your method ?

(4+1+1+0=6) Sectional drag coefficient by boundary layer calculation

(4+0+0+0=4) Sectional drag coefficient by experimental data

(13+0+0+0=13) Sectional drag coefficient by empirical data

(1+0+0+0=1) Circulation reduction by boundary layer calculation

(2+1+0+0=3) Circulation reduction by experimental data

(1+0+0+0=1) Circulation reduction by empirical data

(5+0+0+0=5) Others ______

3.6 Applicability of your method

(20+1+1+0=22) Propeller blades with hub can be treated.

(7+0+0+0=7) Propeller with stators can be treated.

(5+0+1+0=6) Propeller with a rudder can be treated.

(15+0+1+0=16) Propeller in non-uniform flow can be treated.

(12+1+1+0=14) Unsteady propeller can be treated.

(2+0+0+0=2) Others ______

3.7 What is the recent improvement to your method from validation point of view ?

(8+0+0+0=8) panelling

(8+0+0+0=8) Kutta condition

(7+1+0+0=8) wake deformation
(2+1+0+0=3) viscous correction
(0) Others ______________________________

3.8 What is the recent improvement to the application of your method ?
(2+0+0+0=2) Propeller blades with hub can be treated.
(2+0+0+0=2) Propeller with stators can be treated.
(2+0+0+0=2) Propeller with a rudder can be treated.
(4+1+0+0=5) Propeller in non-uniform flow can be treated.
(4+1+0+0=5) Unsteady propeller can be treated.
(4+0+0+0=4) The method can be applied to design of a propeller
(2+0+0+0=2) Others ______________________________

What is the title of the recent paper and the publication showing the improvement ?

____

____

3.9 Are there areas and procedures you consider to be incomplete and require further developments and research by your organization or by other organizations ?

____

____

____

____

3.10 Have you any request to the ITTC Propulsor Committee ?
(8+1+1+0=10) Organize workshop
(8+1+2+1=12) Organize comparative calculations
(2+0+0+0=2) Others ______________________________

4. As a researcher of RANS equation codes

4.1
(0+6+1+0=7) You have developed a RANS equation code for a propulsor.
(1+7+0+0=8) You are developing a RANS equation code for a propulsor.
(4+1+1+3=9) You will develop a RANS equation code for a propulsor.

What is the name of your RANS equation code ?

____

What is the title of the paper and the publication of your code ?

____

____

4.2 Which type of flow solver does your code employ ?
(eg. finite difference, implicit approximation factorization, MAC method, finite element etc)

____

____

4.3 Is your code explicit or implicit ?
(2+2+0+0=4) Explicit
(1+10+1+2=14) Implicit
(0) Others ______________________________

4.4 Which turbulence model does your code employ ?
(eg. Baldwin-Lomax, k-epsilon etc)

____

____

4.5 Which type of grid does your code employ ?
(2+11+1+0=14) structured grid
(2+7+0+2=11) multi-block grid
(1+1+0+1=3) unstructured grid
(0+2+0+0=2) others ______________________________

4.6 Does the grid adapt to the solution ?
(1+2+0+1=4) yes
(2+8+1+1=12) no
(0+2+0+0=2) others ______________________________

4.7 Do you use

(2+10+1+0=13)Non staggered meshes (Pressure and velocity values stored at the same location)

(0+3+1+1=5)Staggered meshes (Pressure and velocity values stored at different locations)

4.8 How is the incompressibility of the fluid handled

(0+4+1+0=5) Artificial compressible

(0+6+1+1=8) Pressure correction

(0+3+0+0=3) others ______________________________

4.9 Have you compared the results of your method to that of nonviscous flow theory ?

yes(0+4+0+0=4) ; no(1+2+0+0=3) ; others(0+5+0+0=5)

____

4.10 Have you got reasonable results of the viscous effect from the comparison ?

yes(0+5+0+0=4) ; no(0) ; others(0+2+0+0=5)

____

4.11 Have you compare the results of your method to experiment ?

yes(0+8+0+0=8) ; no(0) ; others(1+3+0+0=4)

____

4.12 Have you got good results from the comparison ?

yes(0+3+0+0=3) ; no(0) ; others(1+7+0+0=8)

____

4.13 What is the range of Reynolds number ($Rn=nD^2/\nu$) your code can be used ?

____

4.14 Are there areas and procedures you consider to be incomplete and require further developments and research by your organization or by other organizations ?

(eg. poor grid, poor turbulence model, boundary condition etc)

____

____

____

____

4.15 Have you any request to the ITTC Propulsor Committee ?

(1+6+0+0=7) Organize workshop

(0+11+1+0=12) Organize comparative calculations

(0+1+0+0=1) Others ______________________________

5. As a researcher of other analysis methods for propulsors (except panel methods and RANS equation codes)

5.1

What method have you developed ? ______________________________

What method are you developing ? ______________________________

What method will you develop ? ______________________________

5.2 Why don't you develop a panel method for propulsor ?

____

____

5.3 Why don't you develop a RANS equation code for propulsor ?

____

____

6. As a user of panel methods

6.1

(8+4+2+0=14) You have used a panel method for propulsor

(7+2+5+0=14) You are using a panel method for propulsor

(2+1+11+1=15) You will use a panel method for propulsor

6.2 What is your purpose of the application of a panel method ?

(10+4+16+1=31) apply to design of propellers

(4+1+6+0=11) use for experimental study

(5+1+2+0=8) use for other study ______________________________

(7+1+11+1=20) use for the estimation of propeller cavitation

(3+0+1+2=6) others ______________________________

6.3 Have you got satisfactory data from the application ?

Performance KT, KQ (10+4+3+0=17) yes, (1+1+1+0=3) no, (2+0+0+0=2) others ___________

Pressure distribution on blades (11+4+4+0=19) yes, (1+1+0+0=2) no, (1+0+0+0=1) others __

Variation of propeller forces and moments (7+2+2+0=11)yes, (1+1+0+0=2)no, (0+0+2+0=2)others

Unsteady pressure distribution on blades (4+1+1+0=6) yes, (1+1+0+0=2) no, (2+1+2+0=5) others

Others (3+0+1+0=4) ____

6.4 What do you want mainly with panel method ?

(11+2+11+2=26) Performance KT, KQ

(15+3+14+2=34) Pressure distribution on blades

(5+0+6+2=13) Variation of propeller forces and moments

(5+2+7+2=16) Unsteady pressure distribution on blades

(3+1+3+2=9) Others ____

6.5 Have you any request to the developers of panel methods ? ________________________

____

____

6.6 Have you any request relating to panel methods to the ITTC Propulsor Committee ? ________

____

____

7. As a user of RANS equation codes

7.1

(0+6+0+0=6) You have used a RANS equation code for propulsor

(1+2+1+0=4) You are using a RANS equation code for propulsor

(1+1+10+0=12) You will use a RANS equation code for propulsor

7.2 What is your purpose of the application of a RANS equation code ?

(0+4+7+0=11) apply to design of propellers

(1+3+6+0=10) use for study on scale effect of propellers

(1+2+3+0=6) use for experimental study

(1+2+0+0=3) use for other study ____________________________________

(1+1+4+0=6) use for the estimation of propeller cavitation

(0+3+5+0=8) use for the study on the propeller hull interactions

(0+1+0+0=1) others ______________________________

7.3 What are the typical number of mesh nodes used during RANS calculation ?

____

____

7.4 What are the maximum number of mesh nodes your solver can handle ?

____

____

7.5 Are you able to mesh the propeller blade passage to allow detailed flow feature capture such as tip vortex, blade wake and blade boundary layer flows ?

____

____

7.6 If you had greater resources (financial and computing) could your method be extended to improve flow feature capture ?

____

____

7.7 How much CPU time does a typical run of your RANS code require ?

____

____

7.8 Is your RANS code capable of allowing accurate mesh definition of the tip and leading edge regions of the propeller blade ?

____

____

7.9 Have you got satisfactory data from the application of your RANS equation code ?
Performance KT, KQ (0+6+0+0=6) yes, (1+0+0+0=1) no, (0) others ______________
Pressure distribution on blades (0+5+0+0=5) yes, (1+1+0+0=2) no, (0) others ______________
Variation of propeller forces and moments (0+3+0+0=3) yes, (1+1+0+0=2) no, (0+1+0+0=1) others
Unsteady pressure distribution on blades (0+1+0+0=1) yes, (1+0+0+0=1) no, (0+3+0+0=3) others

Others (0) ______________________________

7.10 What do you want mainly with RANS equation codes ?

(1+6+7+0=14) Performance KT, KQ
(0+6+7+0=13) Pressure distribution on blades
(0+3+3+0=6) Variation of propeller forces and moments
(0+3+5+0=8) Unsteady pressure distribution on blades
(2+4+3+0=9) Scale effect of propellers
(0+2+2+0=4) Others ______________________________

7.11 Have you any request to the developers of RANS equation codes ? ______________

____

____

7.12 Have you any request relating to RANS equation codes to the ITTC Propulsor Committee ?

____

____

8. As a user of other analysis methods for propulsors (except panel methods and RANS equation codes)

8.1

What method have you used ? ______________________________
What method are you using ? ______________________________
What method will you use ? ______________________________

8.2 Why don't you use a panel method for propulsor ?

____

____

8.3 Why don't you use a RANS equation code for propulsor ?

____

____

9. Request to the ITTC Propulsor Committee

9.1 Have you any request to the ITTC Propulsor Committee ?

(3+4+2+2=11) Organize workshop
(0+5+5+2=12) Organize comparative calculation
Interesting theme for the organization ______________________

Other requests ______________________

10. Do you know of any other organization carrying out work on panel methods that might be applicable to marine propulsors ?

11. Do you know of any other organization carrying out work on RANS equation codes that might be applicable to marine propulsors ?

FINISH

Thank you very much for your cooperation.
Please send your completed questionnaire immediately to

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