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ADDRESS National Research Council Institute for Ocean Technology Arctic Avenue, P. O. Box 12093 St. John's, NL A1B 3T5 TEL. (709) 772-5185, Fax: (709) 772-2462			



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PROCEDURE FOR PODDED PROPULSION SIMULATION

SR-2010-10

Potchara Wongyai and Michael Lau

April 2010

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ABSTRACT

A procedure for podded propulsion simulation using IOT OSIS and Kongsberg Polaris software simulators was developed based on the Mackinaw model test in open water. The data to be simulated in OSIS and Polaris is prepared from the data of static and dynamic model testing. The process to prepare the data involved determining the data that would be appropriate for a certain simulation and preparing the data into the right format. This involved the use of the IOT analysis software SWEET for file conversion and the Pod Analysis program developed prior to the project. The data was then applied to the Data Management program to adjust and modified the data before transferring to OSIS and the Polaris database generator. To ensure the accuracy for both simulators, the results of Mackinaw simulation in OSIS and Polaris were compared. Additional instruction on the Data Management program is also provided.

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PROCEDURE FOR PODDED PROPULSION SIMULATION

1 INTRODUCTION

Podded propulsion simulation is an imitation of podded propulsor behavior of a real ship under various assumptions to predict the character and performance of the propulsion module of the ship. Podded propulsion simulation in this project focuses on determining propulsive forces and shaft power of the podded propellers of the U.S. Coast Guard icebreaker Mackinaw, in which the analysis was based on a model test conducted by the Institute for Ocean Technology (IOT). Torque of the propeller shaft measured from the model test was used to determine power consumed, and forces acting on the ship at location of the podded propulsors were used to determine motion and track made by the ship. The experimental data was incorporated into the IOT simulation software, Ocean Structure Interactions Simulator (OSIS), as well as the Kongsberg Polaris simulation software used in the Center for Marine Simulation (CMS).

The scope of this project was to develop a procedure and the associated tool to analyze pod data for the simulation in OSIS and to generate a database in a useful format for the Polaris software.

Section 2 covers the testing schemes to obtain necessary empirical data and the subsequent data treatments to construct the empirical pod model for simulation. Section 3 details the procedure for simulation. The conclusion and recommendation is given in Section 4.

2 TESTING SCHEMES AND ASSUMPTIONS

This section describes the testing scheme for Mackinaw model test, which was implemented prior to the project. Many assumptions had been made to predict motion of the ship in order to simulate the model in various kinds of maneuvering, such as straight run, and turning circle.

The model was a 1:15.62 scaled model of the Mackinaw icebreaker equipped with two podded propulsors, having pod “A” located on port side and pod “B” on starboard side. The model test took place in IOT’s ice tank. The model was attached to the Planar Motion Mechanism¹ (PMM) connecting to the carriage. More details about the facility in IOT can be found in IOT Standard Environmental Modeling - Ice, 2008. Many experiments were done in both open water and ice; however, only data from static and dynamic testing conducted in open water were used. These tests are further described in this section.

The results achieved from static and dynamic testing could describe the pods behavior at different advance speeds and angles, where pod behavior was indicated by torque of the propeller shafts and planar forces on the ship generated by the pods. In other words, torque, force in x and force in y direction have to be defined as a function of speed and angle, where the directions of x and y are positive toward the bow and starboard, respectively (IOT Standard Model Test Co-ordinate System & Unit of Measure, 2004).

A conventional way to analyze pods is to convert all the parameters into non-dimensional coefficients. For example, K_q , K_{Fx} , and K_{Fy} were used to represent the coefficient of torque, force-x, and force-y. Also J is used as a non-dimensional advance coefficient instead of using advance speed u . The conversional formula is as the following:

$$K_q = \frac{Q}{\rho(rps)^2 D^5}, \quad (2.1)$$

$$K_{Fx} = \frac{F_x}{\rho(rps)^2 D^4}, \quad (2.2)$$

$$K_{Fy} = \frac{F_y}{\rho(rps)^2 D^4}, \text{ and} \quad (2.3)$$

$$J = \frac{u}{(rps)D}, \quad (2.4)$$

where ρ is density of water,

¹ PMM test techniques determine force coefficients for mathematical models of motion

rps is revolution per second of propeller rotation,
 D is diameter of the propeller, and
 u is advance speed.

There are two terms used for describing pod angle: azimuthing angle and rudder angle. Azimuthing angle is zero when a propeller points to the stern, and rudder angle is zero when a propeller is set to make a ship going forward with respect to its heading. Both angles are positive when turning clock-wise, and negative vice versa. The following figure indicates the direction associated with azimuthing and rudder angles.

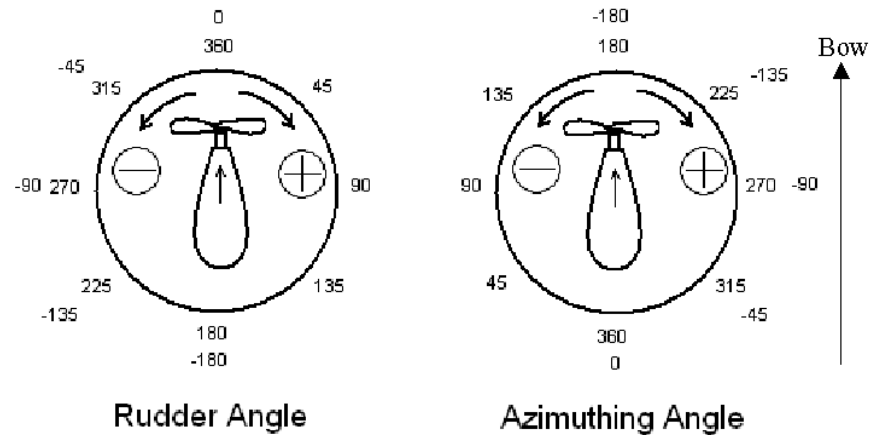


Figure 2.1: Rudder angle and azimuthing angle convention

The static testing consists of several runs of the model with different azimuthing angle, where pod A was fixed at azimuthing angle of 180 degree for every run, and pod B was set to 0, -30, -60, -90, -120, -150, -165, -170, -175, and -180 degrees for respective run. The model was also tested with increasing speed for these runs. Therefore, the relationship of K_q , K_{Fx} , and K_{Fy} as a function of J and azimuthing angle can be obtained.

The result was close to the expected final result, which would describe the three coefficients as in terms of J and azimuthing angle; however the testing only has angles between 0 to -180 degree, where the angle of pod B only pointed outward from the hull.

The character of the pod when pointing inward must also be identified, so a reference testing that has all the angles tested was required. The dynamic testing has pod B fixed at 180 degree but pod A rotated continuously over 360 degree while the model was running straight-ahead at a constant speed. This gave a relationship of the three coefficients as a function of azimuthing angle for all the angles available in pod A.

In this runs the model was towed and allowed to run straightforward only. This means that water-hull interaction was constant as the incoming flow of water or direction of ship velocity was always parallel to the model heading. On the other hand, the simulation might involve turning motion in which the heading of the ship is not necessarily parallel to the ship's velocity, so pod modeling was introduced to explain the behavior of the ship turning in various degrees based on the straightforward runs experimented in static and dynamic testing.

In addition, when a ship turns, resistance between hull and water changes, and therefore, thrust generated by pods might not be as efficient as in a straight motion. Thus, some factors such as wake fraction, rectification coefficient, and

thrust deduction were taken into account where wake fraction is the reduction of the longitudinal speed along x direction, rectification coefficient is the reduction of the transverse speed in y direction, and thrust deduction lowered the thrust produced by pods (Lau and Ni, 2010a). These factors had been built into the OSIS code and the Polaris database generator.

3 PROCEDURE FOR SIMULATION

A standard method to process podded propulsion data to be ready for the simulation in OSIS and Polaris software was developed. The overall process is illustrated in the following Figure 3.1.

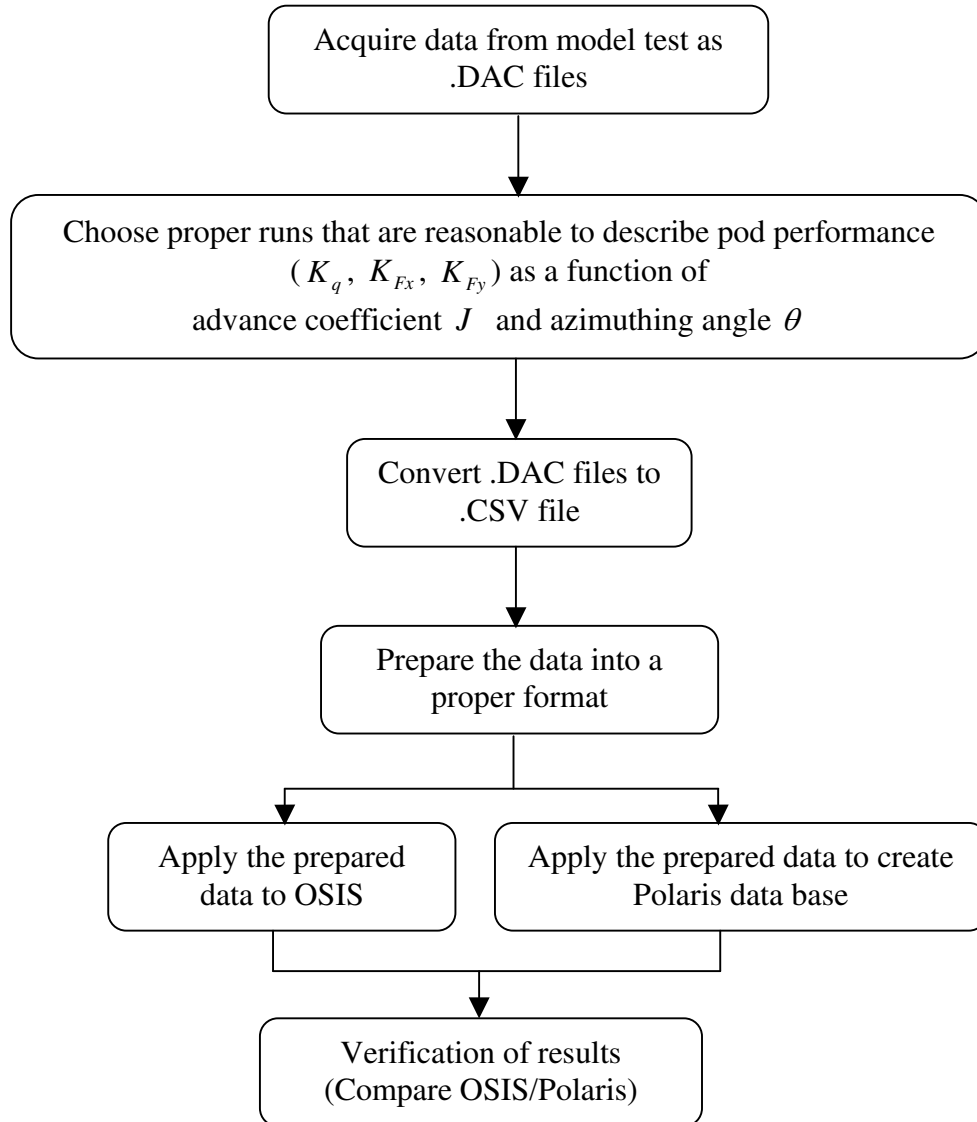


Figure 3.1: Overall process for Mackinaw pod propulsion simulation

The following sections describe the procedure by using examples from Mackinaw.

3.1 Acquiring Data from Model Test and Choosing Runs for the Simulation

In the model test consisted of many testing runs, the data for the testing run was recorded as .DAC files. Table 3.1 summarizes the static and dynamic run used in this analysis. The data was saved in the network share drive at IOT that can be accessed from "lotpc\knarr\project\PJ2200". If the testing condition was known, the proper runs can be determined directly. However, if the test run condition is not known, conversion to .CSV file might be necessary before knowing the condition for each run. For the chosen run, the pods should be tested on different azimuthing angles and different advance speed, so that the relationship of the three coefficients K_q , K_{Fx} , and K_{Fy} can be defined in terms of advance

coefficient J and rudder angle δ . To reduce uncontrollable factors in Mackinaw model test, the chosen runs were on the testing condition where one pod was fixed and the other pod was set to different angles. For Mackinaw simulation, the run 84 to run 97 was chosen. Also reference data from dynamic test was chosen from run 82 and 83, where both run were tested in the same condition.

Combining the data from both runs will improve the accuracy of data. The use of the reference data is to extend the static data from the range $[180, 0]$ to the range $[-180, 180]$; however, run 84 and run 94 had pod B tested on azimuthing angle of 5 degrees, which points inward to the ship body while other runs only have the pod pointing out. This could lead to confusion when extending the data based on dynamic test because the data in region $[0, -180]$ could also be predicted based on the other static runs. As a result, using run 84 and 94 could lead to repetition of data from two difference sources, so they were ignored.

Table 3.1: Static and dynamic run in Mackinaw simulation

Run	Pod A θ_A	Pod B θ_B	Corresponding Rudder Angle δ_B	Speed(m/s)
STATIC_085	-180.00	-175.00	5	0 ~ 1.51
STATIC_086	-180.00	-170.00	10	0 ~ 1.51
STATIC_087	-180.00	-165.00	15	0 ~ 1.51
STATIC_088	-180.00	-150.00	30	0 ~ 1.51
STATIC_089	-180.00	-120.00	60	0 ~ 1.51
STATIC_090	-180.00	-90.00	90	0 ~ 1.51
STATIC_091	-180.00	-60.00	120	0 ~ 1.51
STATIC_092	-180.00	-30.00	150	0 ~ 1.51
STATIC_093	-180.00	0.00	180	0 ~ 1.51
STATIC_095	-180.00	-180.00	0	0 ~ 1.51
STATIC_096	-180.00	-180.00	0	0 ~ 1.51
STATIC_097	-180.00	-180.00	0	0 ~ 1.51
DYNAMIC_082	0 ~ 360	-180.0	0	0.61
DYNAMIC_083	0 ~ 360	-180.0	0	0.61

Generally, choosing an appropriate run depends on the kind of runs done in the model test. For example, if there are more static tests that have pod B runs in the range [0,180] degree, extension based on dynamic test data will not be necessary.

3.2 Conversion from .DAC file

DAC files for each test run can be converted to .CSV (Excel) files through the SWEET program, the software developed by IOT written in the Python programming language.

To convert static or dynamic test data of Mackinaw model test from .DAC file to .CSV, SWEET framework has to be opened. Figure 3.2 shows the template for the conversion of .DAC file to .CSV file. After SWEET is ready, click on “New Run Set File”, and browsed to “PJ2254_PJ2200_Mackinaw_April08_IceTank_v2.py”. This is a template file made specially for converting Mackinaw data. The template shows names of the old runs in red color, which indicates that there is at least one entry that has an error. A new run can be created by duplicating one of the previous runs, and changing the new run name to be the same as the input .DAC file. The new run would also have red name indicating that some inputs are still incomplete, and there are red taps showing where the inputs are missing. Usually the error is because of an empty input or an input that has moved to a different directory. The input file’s directory has to be specified; for example, “C:\Nathan\SWEET\PJ2200\raw complete set\DYNAMIC_083.DAC”. Also, under the Preprocessing/Custom Processor section, browse the processing code “apply_cals_v2.py”. After this, the new run template is ready for conversion. The conversion is executed by clicking on the “Save and Run” button.

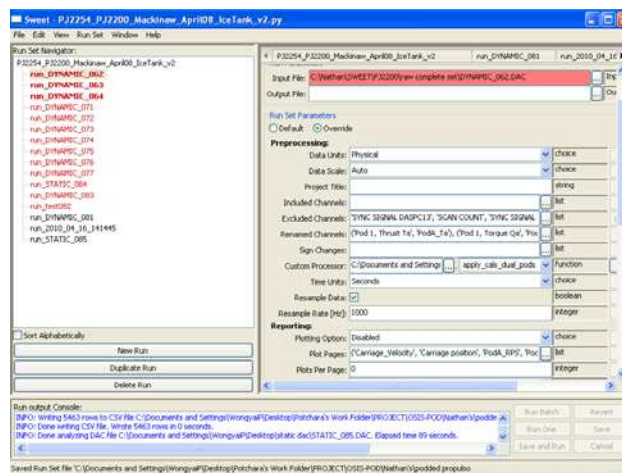


Figure 3.2: A template for the conversion of .DAC file to .CSV file

While SWEET is running, a segment selection screen is displayed (Figures 3.3 and 3.4).

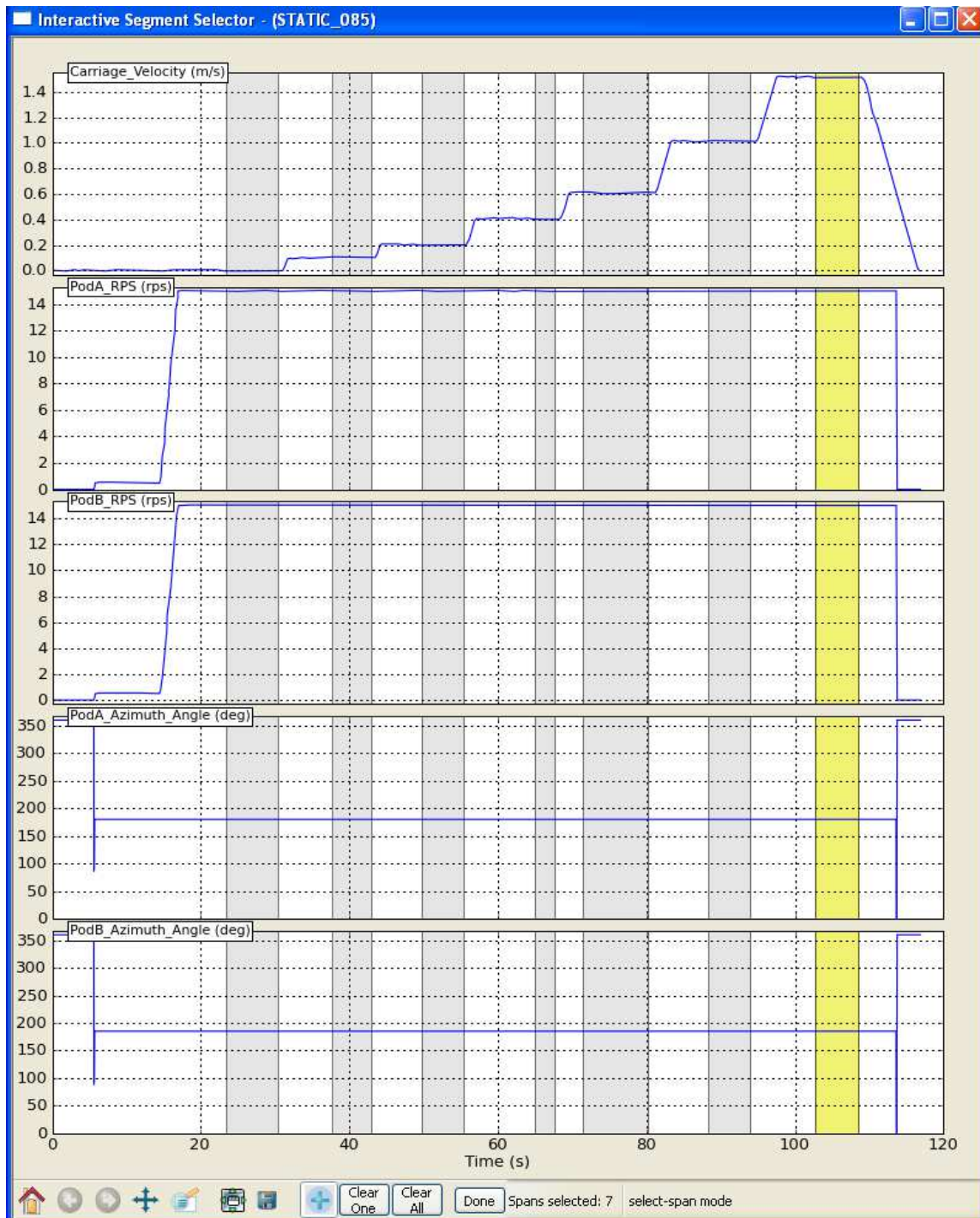


Figure 3.3: Segment selector for static run

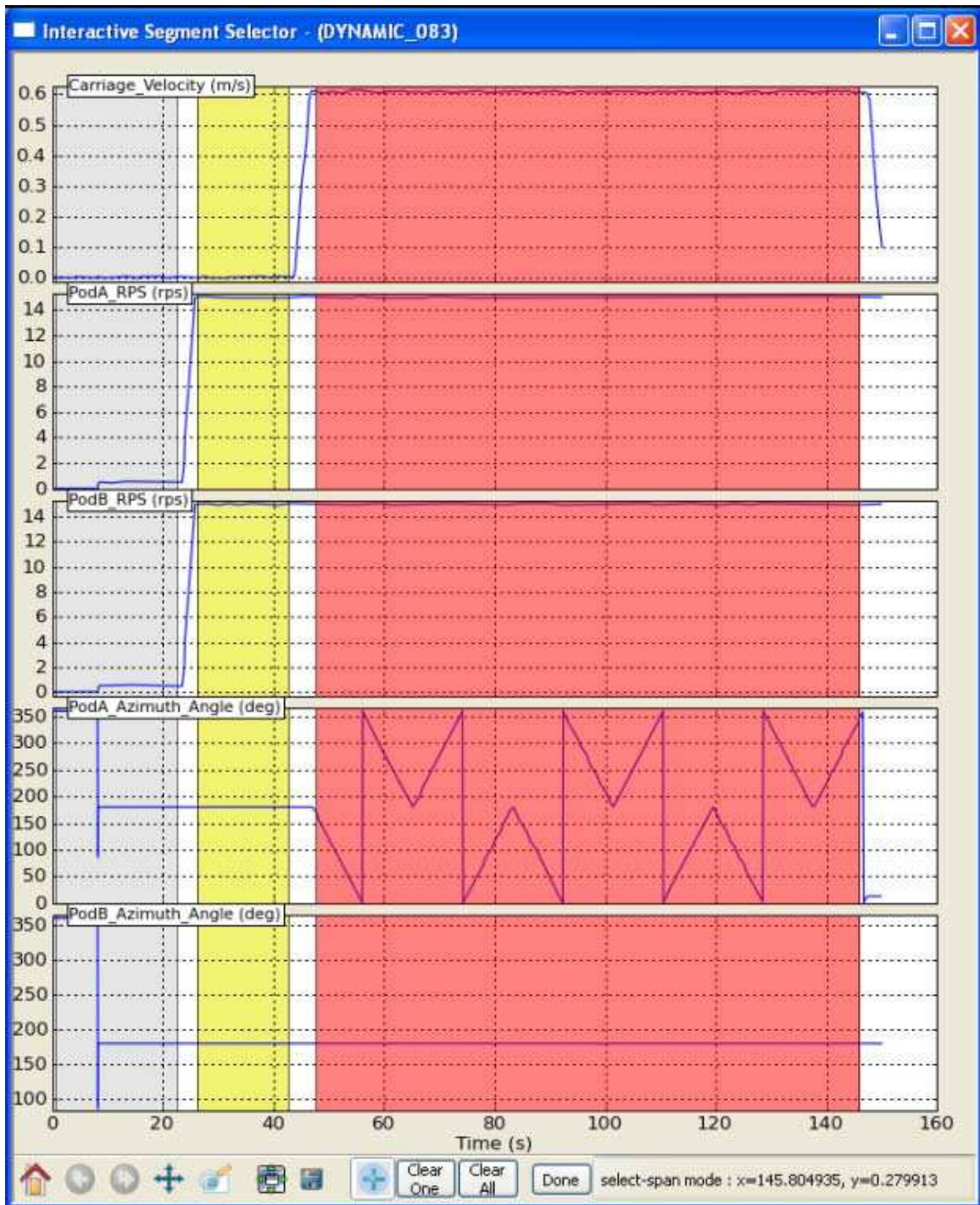


Figure 3.4: Segment selector for dynamic run

SWEET will convert each selected segment to a .CSV file. So, it is necessary that appropriate segments be selected.

For static data, the model was tested with different speeds. Patterns of speed can be observed under "Carriage_Velocity" section. The important segments are

when the speed becomes steady. As in Figure 3.3, seven steady speeds were observed and selected. The output from the program is seven .CSV files saved to the same directory as “PJ2254_PJ2200_Mackinaw_April08_IceTank_v2.py”. This has to be repeated for all the run interested (e.g. runs 85, 86, 87, 88, 89, 90, 91, 92, 93, 95, 96, and 97).

The segment for dynamic runs that is important in the simulation is when the carriage speed becomes steady with azimuthing angle of one pod rotates continuously, or the red section illustrated in Figure 3.4. The .CSV file will be located in the same directory as in static runs. This has to be done for both run 82 and run 83.

More instructions about conversion of .DAC file to .CSV are given in the Analysis of Mackinaw Propulsion Test Data report.

3.3 Preparation for static and dynamic test data

Before the data can be transferred to a simulation, they must be rearranged to a proper format. One file must contain all the information about static data, and another file must contain information about dynamic data.

There are seven .CSV files from each static run. Although each file contains detailed time-series of all data, only carriage velocity, azimuthing angle of pod B, Torque of pod B, Force in x of pod B, force in y of pod B, and RPS were considered with the mean values of these parameters calculated for each .CSV file. Repeating this process for all seven files in all 12 static runs, there will be 7*12 sets of number. Now K_q , K_{Fx} , and K_{Fy} , and advance coefficient J can be calculated where u is equal to carriage velocity, ρ is 1002.2, and D is 0.2 m. Also, round up the numbers of azimuthing angle to integer, and line up the data in to the following format (Table 3.2):

Table 3.2: Static input file format

	A	B	C	D	E
1	Static Run				
2	J	Azimuthing	KQ	KFX	KFY
3	-2.065E-05	175	0.686963	-0.4473422	-0.0289368
4	0.0333456	175	0.678787	-0.4415527	-0.0233766
5	0.0671735	175	0.668869	-0.4347082	-0.0219425
6	0.1353106	175	0.649694	-0.4194323	-0.0201774
7	0.2021931	175	0.628977	-0.3988735	-0.0293397
8	0.3366007	175	0.57954	-0.3468708	-0.0399092
9	0.5043219	175	0.517335	-0.2866815	-0.0480548
10	-2.582E-05	170	0.68453	-0.4411704	-0.0627844
11	0.0333652	170	0.679896	-0.4378347	-0.0583379
12	0.0673284	170	0.670409	-0.4315739	-0.0597546

At this point, Kq, KFx, KFy, or azimuthing angle might have opposite signs than what they suppose to be. However, they can be adjusted later after inputting the data to the Data Management program for pod simulation, a tool developed in this project.

Dynamic data can be prepared by running through the Podded Analysis program, a Matlab program that was developed prior to this project, by running “podded_analysisV1_2openwater.m”. Before running the program, the input command of the code has to be modified for uploading the right file.

```

1 % =====
2 clc
3 clear all
4 format long e;
5 disp('LOADING DATA SET 1');
6 load -ASCII DYNAMIC_082_S3.csv
7 D1= DYNAMIC_082_S3;
8
9
10 % ^ Loads data set ^
11

```

Figure 3.5 Loading file name for the Podded Analysis program

As in Figure 3.5, the loading command on the sixth line loads the file “DYNAMIC_082_S3.csv” to the program. The name has to be changed according to the file that is going to be uploaded, and the file has to be available in the same directory as “podded_analysisV1_2openwater.m”. The program

could generate the relationship of the coefficient based on multiple menus showing on Matlab command-line. In Figure 3.5, only one .CSV file is uploaded, but if there are two dynamic runs that were tested on the same condition such as run 82 and run 83, the data for both runs can be combined. To do that, the code has to be modified to:

```
% % %%=====
clc
clear all
format long e;
disp('LOADING DATA SET 1');
load -ASCII DYNAMIC_082_S3.csv
D_1= DYNAMIC_082_S3;
load -ASCII DYNAMIC_083_S3.csv
D_2= DYNAMIC_083_S3;
D1=[D_1;D_2];
% ^ Loads data set ^
```

While running the program, choose pod A for analysis, and the graphs and equations of K_q , K_{Fx} , and K_{Fy} for the dynamic runs can be obtained. The polynomial order for trend line curve fit is usually set to 6th order. This will make the trend line generated be more accurate. The output graphs show actual data points, smooth data points, and the trend line, where the actual data was measured from the model test, smooth data was generated to remove some extreme outliers in the actual data, and the trend line and its associated equation were based on the smooth data (see Figure 3.6).

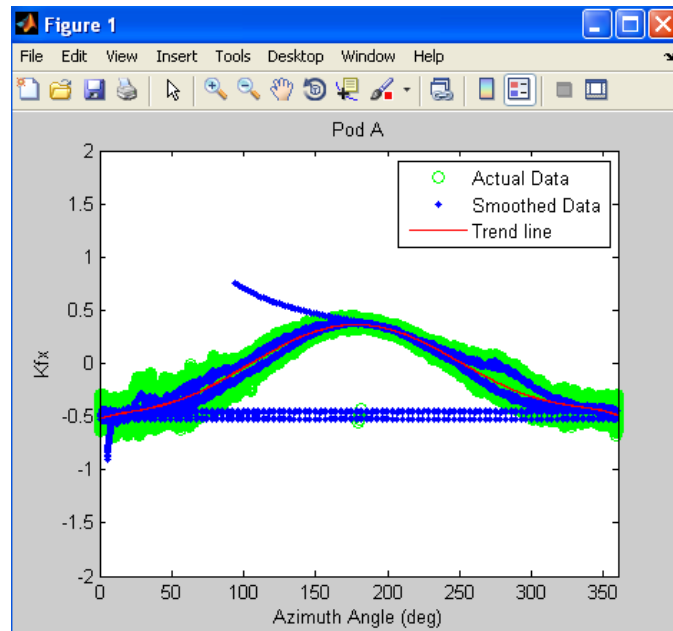
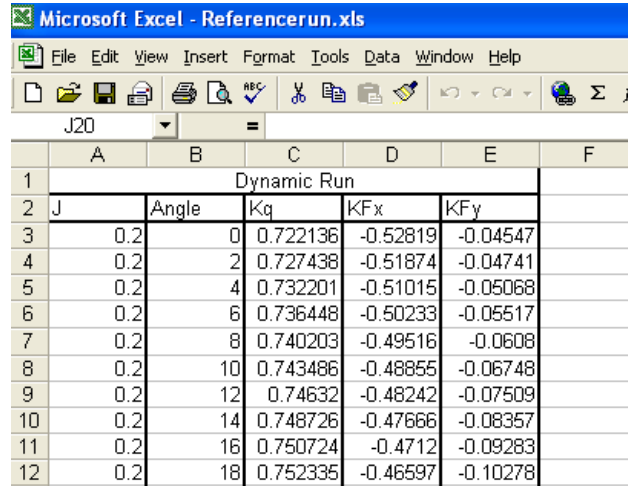


Figure 3.6: Output graph from Podded Analysis program

To prepare the file for pod analysis, an Excel file has to be generated manually based on the equation received as in the following format (Table 3.3).

Table 3.3: Dynamic input file format



	A	B	C	D	E	F
1	Dynamic Run					
2	J	Angle	K _q	K _{Fx}	K _{Fy}	
3	0.2	0	0.722136	-0.52819	-0.04547	
4	0.2	2	0.727438	-0.51874	-0.04741	
5	0.2	4	0.732201	-0.51015	-0.05068	
6	0.2	6	0.736448	-0.50233	-0.05517	
7	0.2	8	0.740203	-0.49516	-0.0608	
8	0.2	10	0.743486	-0.48855	-0.06748	
9	0.2	12	0.74632	-0.48242	-0.07509	
10	0.2	14	0.748726	-0.47666	-0.08357	
11	0.2	16	0.750724	-0.4712	-0.09283	
12	0.2	18	0.752335	-0.46597	-0.10278	

The constant value of J has to be determined from the .CSV file, but this does not affect the simulation. Angles should be uniformly spaced from 0 to 360 by incrementing by 2 degrees. K_q , K_{Fx} , and K_{Fy} for each specific angle are calculated by using the equation generated by the program.

3.4 OSIS simulation for Mackinaw

The prepared data can now be used as input files for OSIS. However, OSIS also has other requirements in order to start the simulation. The readers are referred to the OSIS user's manual (Lau and Ni; 2009) for details.

One requirement for OSIS are three input files that indicates the ship properties, environmental conditions and specifics of various ship maneuvers to be simulated. For instance, the files for Mackinaw are called "Mackinaw55InIce.ocs", "Mackinaw55InIceFree.ocs", and "Mackinaw55InIceNew.ocs". These three files have to be saved under "OSIS Model Settings Files" folder.

In "Mackinaw55InIceNew.ocs", there is an option to initialize the Data Management program within OSIS. Below a section called "Explanations for the input data", there is a list for assigning the running type, which contains "pod_option". (See Figure 3.7.) When pod_option = 0, OSIS will use the default pod data from the Mackinaw, but if pod_option=1, OSIS will initiate the Data Management program, which allows the user to input pod data from a different model test.

```

Ship in Ice Free Motion settings configuration file
This is a settings file for the Ship in Ice Captive Motion in OSIS
Created on 20-Oct-2006
Explanations for the input data:
1)Run Type: 0 straight forward (RPS)
             1 Dieudonne Spiral (RPM, Rudder Angle, Rudder interval,
             2 Zig-Zag Maneuver (RPM, Rudder Angle, Rudder deflecti
             3 Circle Maneuver (RPM, Rudder Angle)
             4 Any Planar Motion
2)Any Planar Motion may be obtained to read input data defined time
   Motion, or start at the Run Type of Straight Forward, and then us
   after advancing speed becomes high enough.
3)Test of ice-propeller interaction: 0, 0.05, 0.1, 0.15
4)pod_option: 0 Mackinaw of 2nd-order regression equation to call ;
               or 1,2... designed by the programmer to extend this p
-----

Run Type                = 00003
Advance Velocity (m/s)  = 7.00000e-001
Ice-propeller interaction = 0.15
pod_option              = 1
Rudder Interval (deg)   = 00005
Rudder Deflecting time (s) = 10
Propeller Starting Time (s) = 00020
Propeller RPM (1/min, Starboard Pod) = 180
Rudder Angle (deg, Starboard Pod) = 30
Propeller2 RPM (1/min, port Pod) = 180
Rudder2 Angle (deg, port Pod) = 0

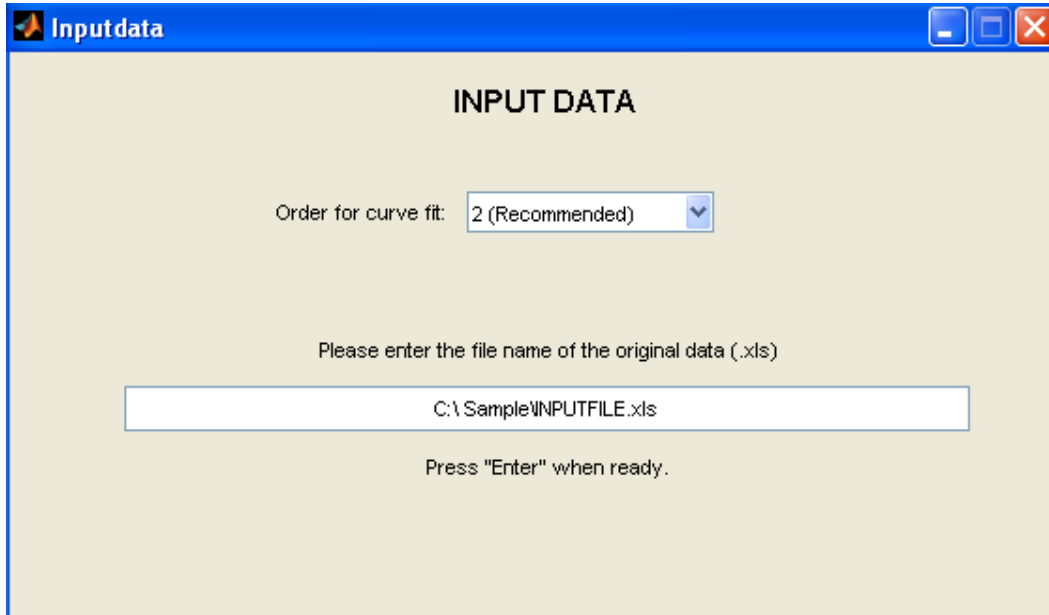
Any planar motion
t(s), RPM, Rudder angle(deg)
Cols = 3
Number = 601
1  140  0
2  140  0
3  140  0
4  140  0
5  140  0
6  140  0

```

Figure 3.7 pod_option in “Mackinaw55InIceNew.ocs”

OSIS starts by running “osis.m”. OSIS menu will then be displayed and the user can create task for “Ship Maneuvering Simulation” by selecting the model for simulation to “Mackinaw55” and setting the environment to open water in free motion mode. The type of maneuvering, pod speed, and pod angle, can be adjusted through “Free Mode button”. The simulation starts when all necessary setting is completed.

Before OSIS starts to simulate, the Data Management program will appear (Figure 3.8). The Data Management program allows the uploading of the prepared data for static test. The directory of the file should be properly addressed. Trend line order of static test data can be specified on this page, where the order is usually set to the 2nd order as it produces stable trend lines.



Inputdata

INPUT DATA

Order for curve fit: 2 (Recommended) ▼

Please enter the file name of the original data (.xls)

C:\Sample\INPUTFILE.xls

Press "Enter" when ready.

Figure 3.8: Input data screen

After finish entering the file name, press enter to proceed to the next screen (Figure 3.9). The performance graphs of K_q , KFx , and KFy versus azimuthing angle are displayed on this screen. Outliers and unexpected data can be removed by clicking “Edit Data”, selecting the coefficient on the edit page (Figure 3.10), typing in the angle that has the outliers and pressing “Enter”. Run 92 of the static test, which was tested at -30 degrees, has a problem and do not gives corresponding results, so angle -30 has been dropped. J values can also be dropped if necessary. K_q , KFx , and KFy also need to be modified.

Understanding the performance graphs and physical effect of K_q , KFx , and KFy is important for the proper editing. Usually, when a ship starts, their podded propellers have azimuthing angle at 180 degrees, as it is in tractor (or pulling) mode. There is no force in y direction acting on the pods; hence, $F_y = 0$. This leads to the first setting rule that KFy must be set to zero at 0 and 180 degrees. In addition, KFy is positive when pod is in the range [180,360], and negative in the range [0,180]. Another rule for the setting is that KFx has to be positive at 180 degrees. Visually, it should be at its peak, as pods at 180 degrees give the best advance motion, due to maximum force achievable in x direction. OSIS would automatically cease when the ship starts to go backward. Sometimes the program will generate negative J values, but OSIS will not work in backward running in this version, so J values on the negative side will not be used in the simulation. Therefore, the existence of the negative J values in OSIS does not affect the simulation. Also, K_q is usually set to positive, but it does not affect the simulation much, as positive or negative is a matter of propeller turning direction.

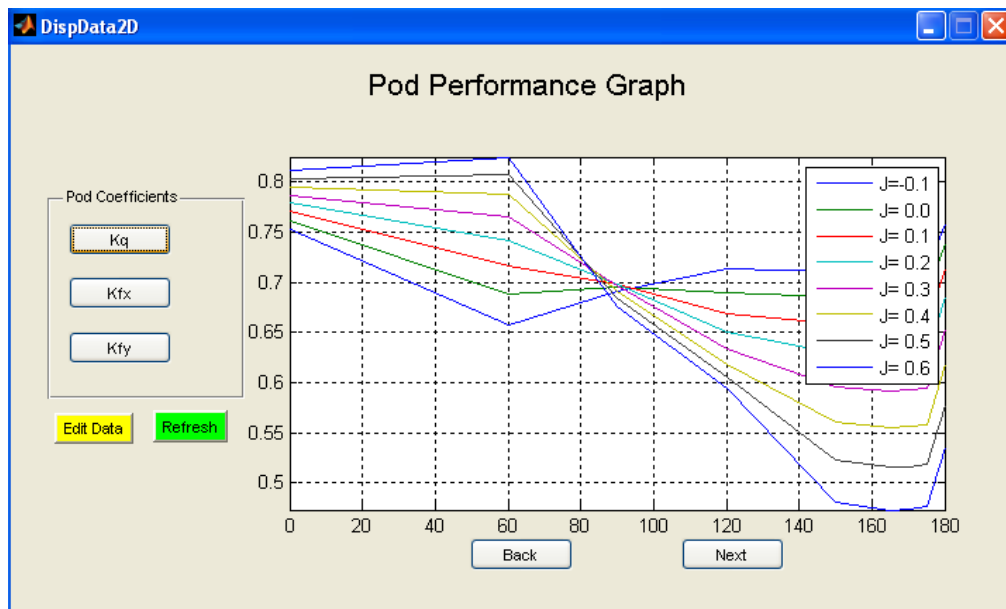


Figure 3.9: Display screen showing the data of K_q , K_{fx} , and K_{fy}

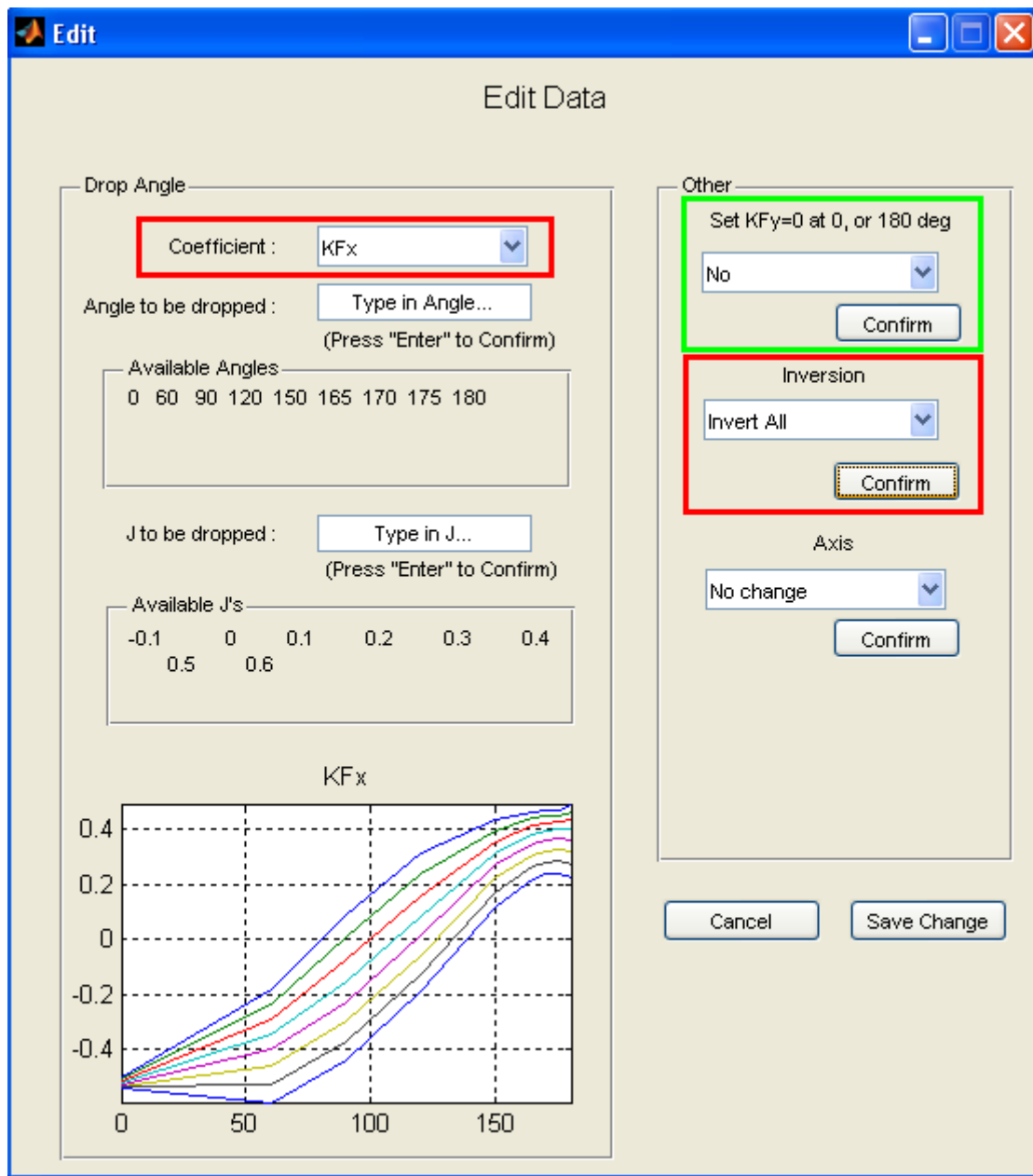


Figure 3.10: Data editing screen

Dynamic data can be uploaded to data extension page (Figure 3.11). The file has to be prepared as described in Section 3.3. Order of the trend line can also be selected here, but it should be referred to the order used in the Pod Analysis program.

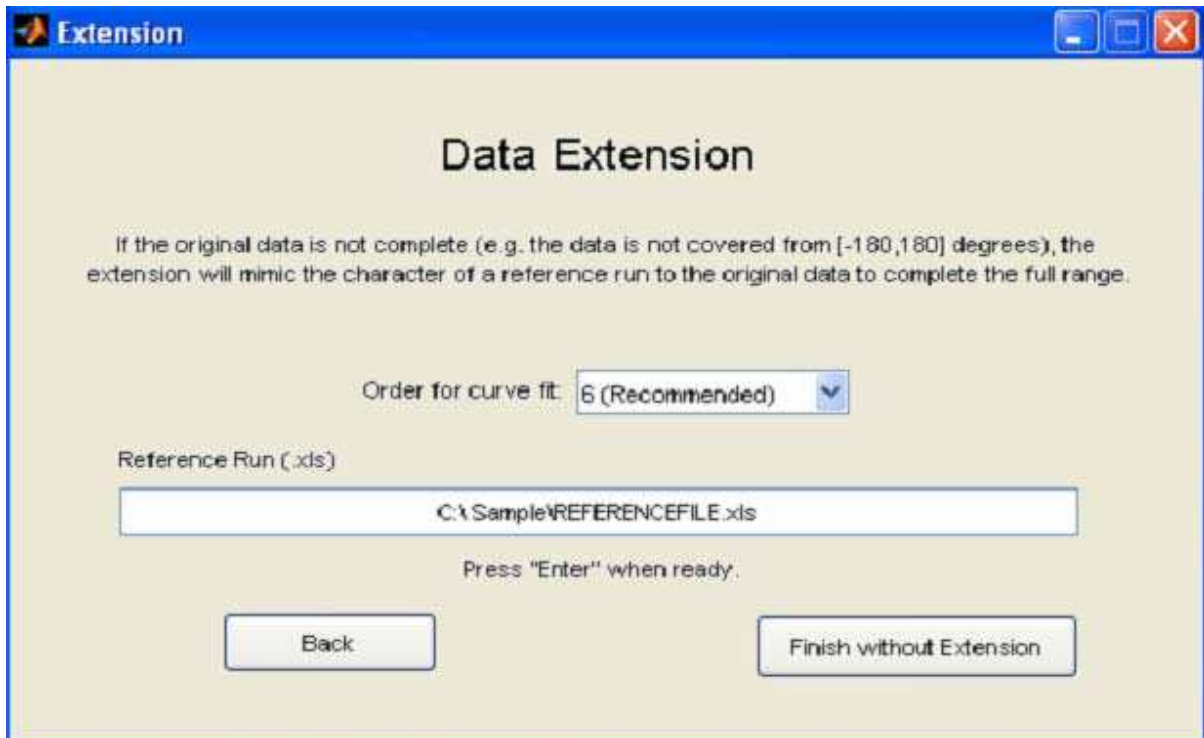


Figure 3.11: Data Extension screen for inputting dynamic test data

The only concern is to make sure that the reference line goes along well with the previous data. If not, the data can be adjusted through the edit page. After they are aligned along the same trend, pressing “Extend All Data” would generate the second half of the data. Nevertheless, there is one limitation in this extending function. This function accepts no more than half of the full angles. For instance, the data to be extended have to be in the range $[0,180]$ and $[180,360]$ only for the simulation in the azimuthing angle range $[0,360]$.

The complete data of Kq , KFx , and KFy should look similar to those given in Figures 3.12 - 3.14, respectively.

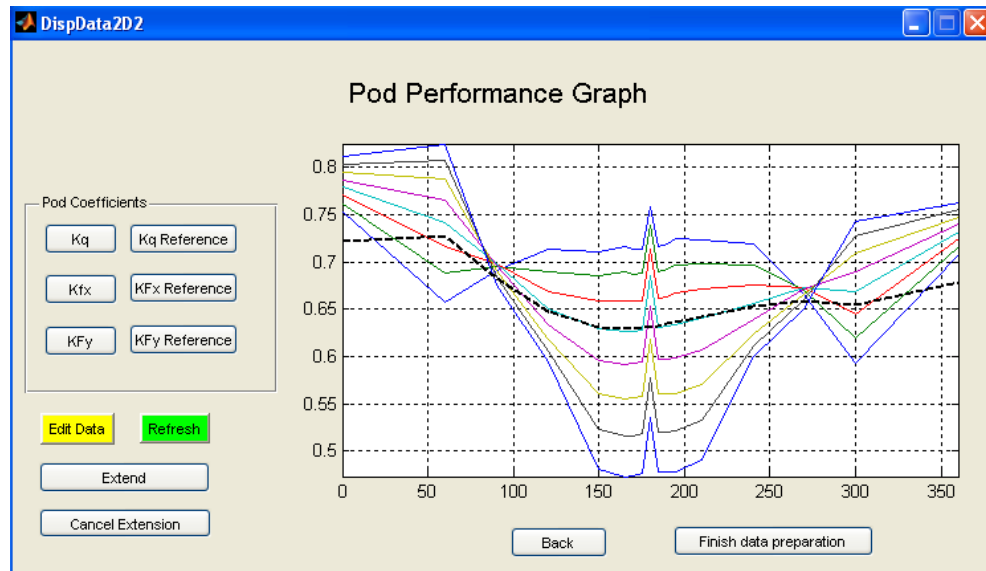


Figure 3.12: Complete data for Kq

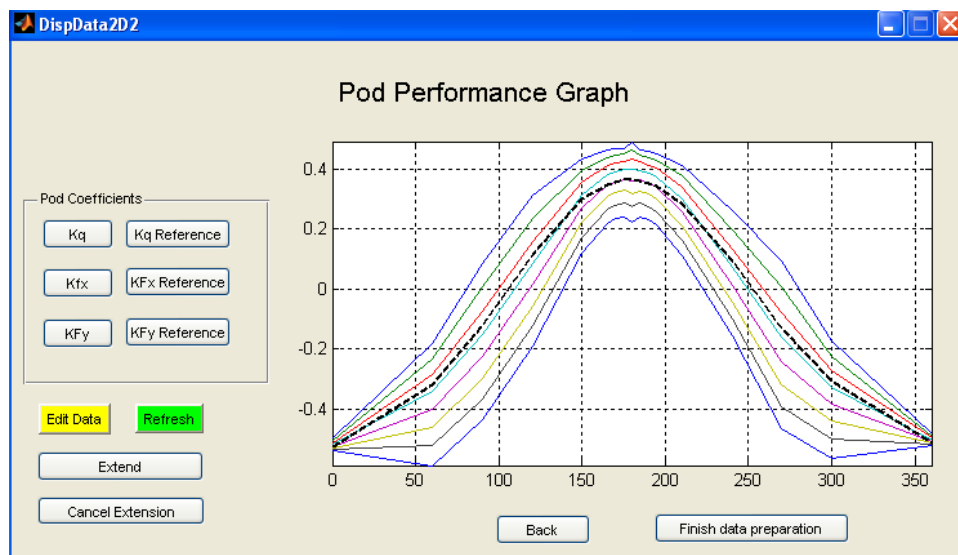


Figure 3.13: Complete data for Kfx

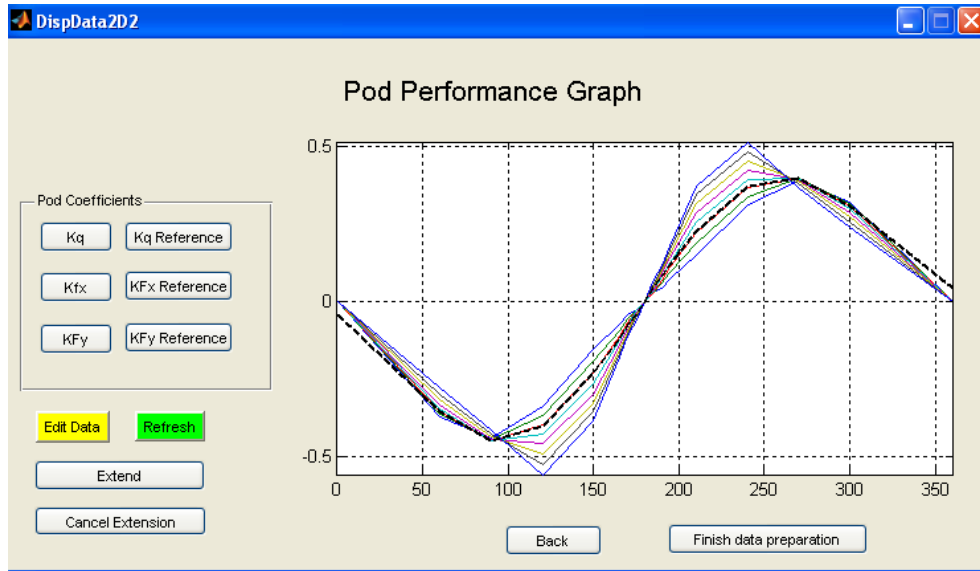


Figure 3.14: Complete data for KF_y

3.5 Generating database for Polaris

The Polaris pod model database is a set of three look-up tables, which is used as an input file for simulation in CMS. The three databases contain coefficients \bar{K}_q , \bar{K}_x , and \bar{K}_y respectively. The K 's (the coefficient of torque, force in x, and force in y) used in OSIS and \bar{K} in Polaris are calculated differently (Lau and Ni, 2010b).

To generate the three Polaris database, run the program "form_databaseApr18.m" from Matlab, and the Data Management program shows up. The data should be modified in the same way described in OSIS, except that K_q , KFx , and KFy have to be shifted back by 180 degree to the range $[-180, 180]$. The program generates eight files in total. Only three files, "Kq_database.ocs", "KFx_database.ocs", and "KFy_database.ocs" are in the right format usable by Polaris.

3.6 Based Calculation for Data Modification with Data Management program

This section summarizes the task of the Data Management program that was used in Mackinaw simulation.

After the prepared static test data are input to Data Management program with 2nd order for polynomial equations, the program would generate 10 equations of

Kq , KFx , and KFy versus J , based on 10 azimuthing angles, i.e., 0, -30, -60, -90, -120, -150, -165, -170, -175, and -180 degrees, that are input. Originally there were 12 runs, but the last three run, Run 95, Run 96, and Run 97, were tested on the same azimuthing angle, so the program automatically combines them. A graphical example of the equation is given in Figure 3.15.

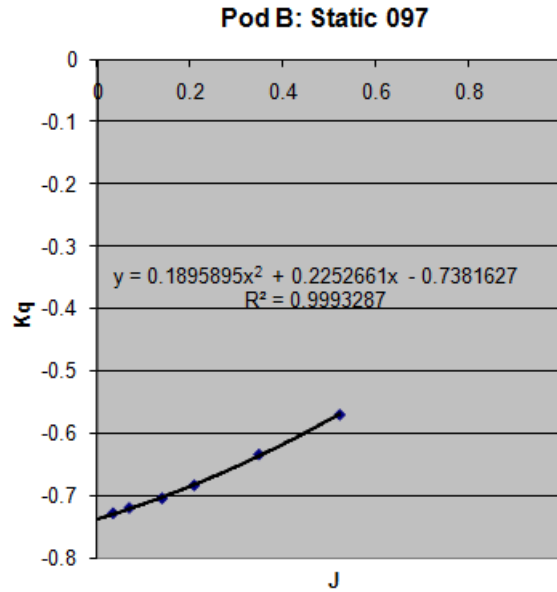


Figure 3.15: Example trend-line of Kq versus J for Run 97

When combining the ten trend-lines together, three 3D surfaces which represent Kq , KFx , and KFy as a function of J and θ could be obtained, where the data in between the ten lines can be estimated based on linear interpolation (see Figure 3.16). Note that in the diagram, the angles have already been converted to positive values.

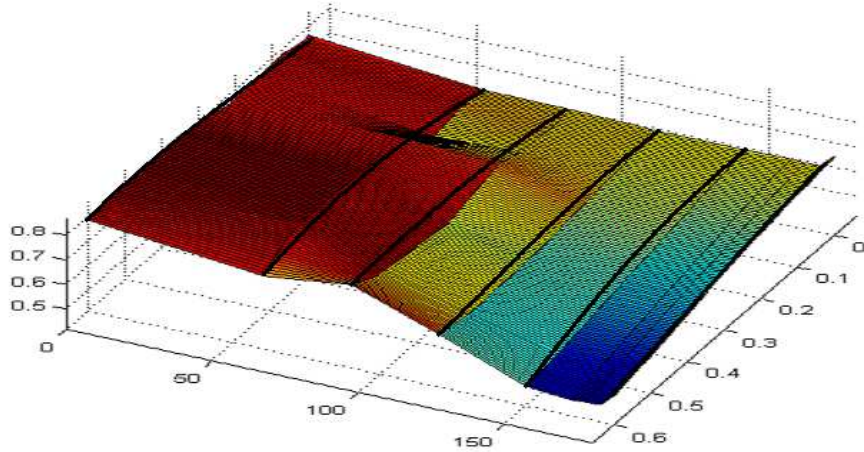


Figure 3.16: Surface representation of Kq as a function of J and θ

This 3D representative can be viewed in 2D for more accuracy in determining the data, as shown in Figure 3.15.

Static test data needs to be extended to cover a full range of pod angle from 0 to 360 degrees based on dynamic test data. Lau and Ni (2010a) has developed a model for data extension using Equation 3.1, where static data are the original points and dynamic data are reference points.

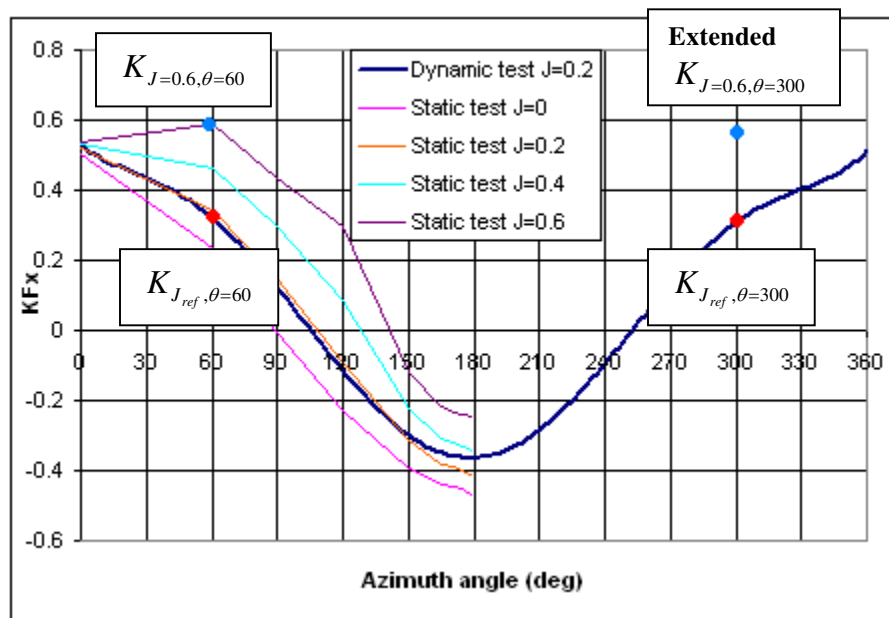


Figure 3.17

Equation 3.1 for data extension is expressed as:

$$K_{J_1, \theta_2} = \frac{K_{J_{ref}, \theta_2}}{K_{J_{ref}, \theta_1}} \cdot K_{J_1, \theta_1}, \quad (3.1)$$

Where K_{J_1, θ_1} is the original point,
 K_{J_1, θ_2} is the extended point which has $\theta_2 = 360 - \theta_1$, and
 K_{J_{ref}, θ_1} and K_{J_{ref}, θ_2} are the reference data at the same
 angles as K_{J_1, θ_1} and K_{J_1, θ_2} respectively.

At this point, any extreme outliers could be removed. As mentioned in Section 3.5, the angle from Run 92, which tested at angle -30 degrees, has to be removed because it gives inconsistency values.

The finished data as shown in Figure 3.18 is ready for the simulation.

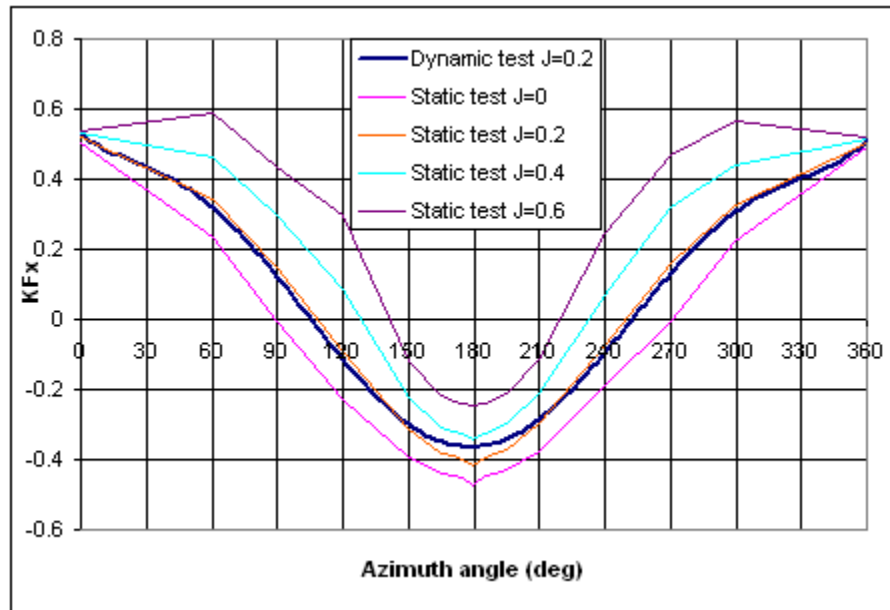


Figure 3.18: Example for K_{Fx} graph with the extended data

3.7 Verification of Results

Preliminary verification of the pod model was performance by comparing the simulated turning diameter and speed during turning maneuvers between OSIS Polaris under same testing condition and ship power. The main purpose of the comparison is to determine whether the data generated from IOT and Polaris using the same pod data agree within an acceptable range.

Figure 3.19 shows the comparison of the turning diameter simulated by OSIS and Polaris, whereas a comparison of ship speed is given in Figure 3.20. Despite the difference in the hydrodynamic model representation of the ship used in OSIS and Polaris, the turning diameter and ship speed predictions agree well in both the OSIS and Polaris simulations. Details of the verification are provided in Lau and Ni (2010b).

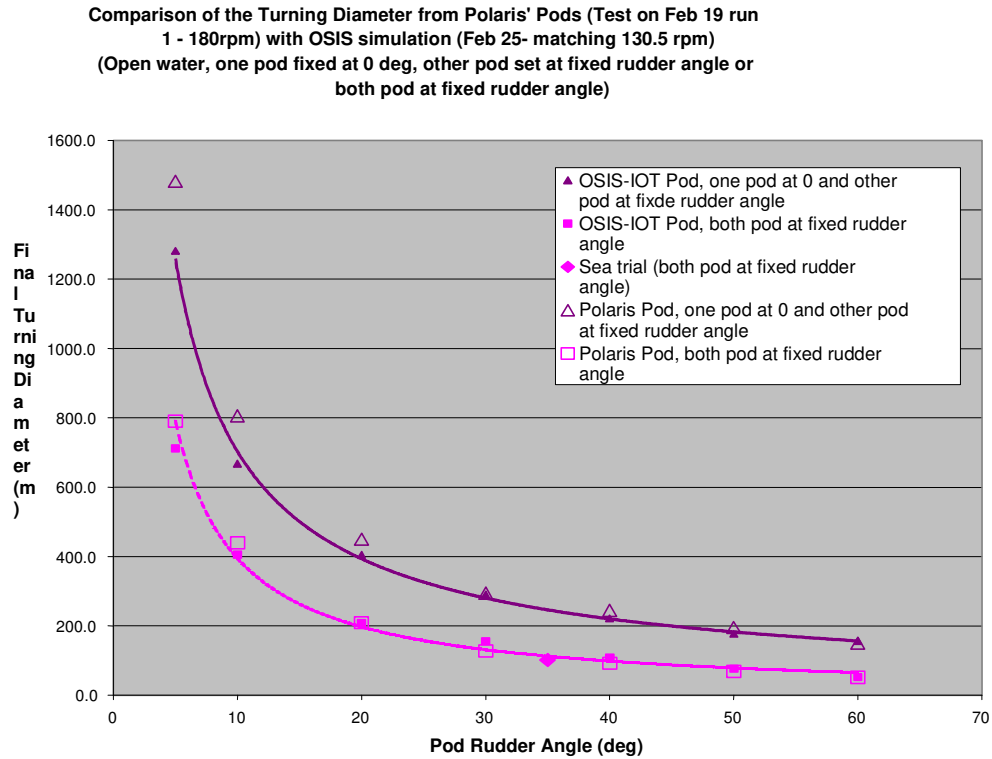


Figure 3.19: Diameter Comparison between OSIS and Polaris

**Comparison of the Ship Speed from Polaris' Pods (Test on Feb 19 run 1 - 180rpm) with OSIS simulation (Feb 25- matching 130.5 rpm)
(Open water, one pod fixed at 0 deg, other pod set at fixed rudder angle or both pod at fixed rudder angle)**

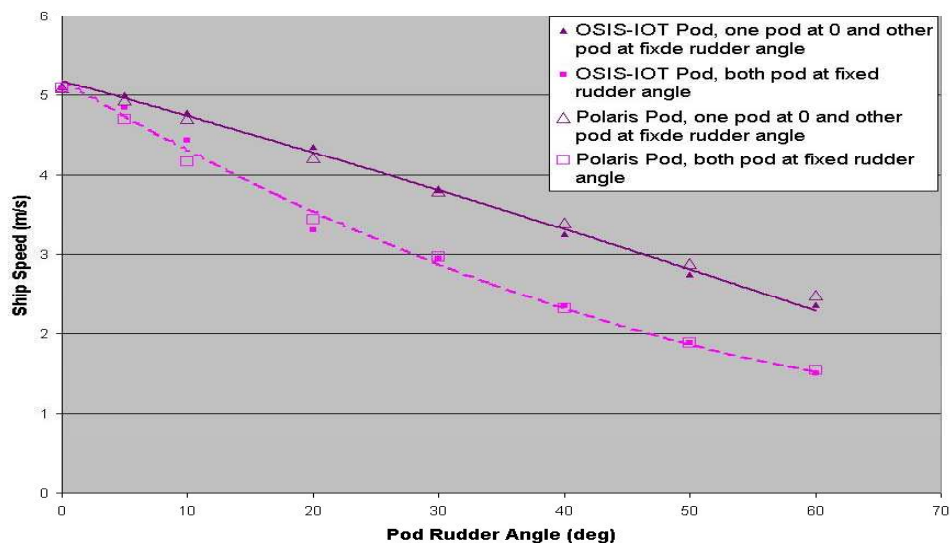


Figure 3.20: Ship speed comparison between OSIS and Polaris

4 CONCLUSION AND RECOMMENDATION

With the procedure for podded propulsion simulation formalized, simple static and dynamic tests can be conducted and empirical model generated automatically for numerical simulation. A tool has been developed to implement the procedure to reduce the manual processes. Nevertheless, the Data Management program still allows for data manipulation, so the final data can still be altered.

In current version for both OSIS and Polaris database generator, wake fraction, rectification coefficient, and trust deduction, are set to some constant function or value. Different ships have different coefficients and they needed to be properly specified. Both programs still do not have any user interface to allow for new inputs of these values yet. Developing a tool to modify these parameters would greatly improve both programs capability to simulate various kinds of data.

5 REFERENCES

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