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Prepared	Approved
HSMV Committee of 22nd ITTC	22nd ITTC 1999
Date	Date

High Speed Marine Vehicles: Dynamic Instability Tests

1. PURPOSE OF PROCEDURE

To measure ship motions due to dynamic instabilities of high speed craft in calm water.

2. TEST TECHNIQUES AND PROCEDURES

2.1 General

The ITTC recommended procedures peculiar to high-speed craft are given as separate procedures for each test type. The procedures are:

- Resistance (Procedure 7.5-02-05-01)
- Propulsion (Procedure 7.5-02-05-02)
- Sea Keeping (Procedure 7.5-02-05-04)
- Manoeuvring (Procedure 7.5-02-05-05)
- Structural Loads (Procedure 7.5-02-05-06)
- Dynamic Instability (Procedure 7.5-05-02-07)

Issues of importance for different types of high speed craft are covered in separate sections in each procedure when needed.

2.2 Dynamic Instability Tests

2.2.1 Motions in calm water due to dynamic instability

High speed stability problems of planing mono-hulls in calm water are very important as pointed out in the HSMV Committee report to the 18th ITTC.

2.2.1.1 Transverse Stability Loss at High Speed

At high speed the transverse stability decreases, and the stability loss causes sudden large heel and chine walking of planing mono-hulls, as stated by Washio et al. (1993), Katayama & Ikeda (1995), and Ibaragi et al. (1996). Katayama & Ikeda (1996) pointed out that the dependency of the transverse stability on running trim causes unstable parametric roll motion when the craft has pitching motion.

2.2.1.2 Longitudinal Instability at High Speed

Porpoising is a typical longitudinal periodic motion due to longitudinal instability. Katayama & Ikeda (1996, 1997, 1998) reported that this pitch and heave combined motion is a kind of self-exciting motion of coupled oscillation system in which coupled restoring coefficients have different signs to each other.

Bow drop is also longitudinal non-periodic motion which can occur for planing mono-hulls running at high speed. The longitudinal stability characteristics at high speed also have an important role in the phenomenon.

2.2.1.3 Course Keeping Ability

The large heel of planing mono-hulls sometimes causes course keeping problems even in calm water, like well known broaching in following seas (Washio et al., 1993, Ibaragi et al., 1996).

2.2.2 Tests

2.2.2.1 Motion Measurements

Motion measurements of a towed model free to move in the relevant degrees of freedom in calm water are commonly carried out to find the inception of, or the region of advanced velocity, and the conditions of ship weight and location of CG where ship motions due to dynamic instability occur. Such experiments can also be carried out in combination with usual resistance tests. A free running radio-controlled propelled model test can provide not only stability information but also manoeuvring information.

The influence of the propulsor and appendages on the ship motion due to dynamic instabilities can be significant, and the model used in the experiment should be with scaled propulsors and appendages or with suitably adapted towing procedures. Furthermore, the effects of cavitation and ventilation, which may be significant for small models, cannot be avoided in tests at atmospheric pressure. Experiments in cavitation facilities may be required when the effect is expected to be significant.

If such effects cannot be avoided in experiments, a computer simulation using measured or predicted hydrodynamic coefficients would be more reliable than the experiments.

2.2.2.2 Force Measurements

In order to check the occurrence of the stability loss at high speed, measurement of the restoring moments is usually carried out. In fully captured or semi-captured model tests, the attitude of the model should be adjusted to the corresponding attitude at each advance speed. To measure the roll restoring moments, inclined tests are carried out. The inclined tests are divided into two kinds which are to measure change of inclination angle using a model free to move in the relevant degree of freedom, or to measure forces acting on a model fixed in the relevant degree of freedom. From the datafile of hydrodynamic forces obtained for a fully captive model test with systematically changing attitudes and speed all restoring forces including cross-coupling restoring forces for arbitrary attitude can also be determined as well as all other forces which are needed to simulate the steady running attitude and resistance. Multi-component balances, multi-component load cells, or equivalent, have been employed. The range of changing attitudes, rise and trim, should be carefully selected on the base of expected attitude.

In order to find the causes of unstable periodic motions of a planing hull due to dynamic instability, it is necessary to know all hydrodynamic forces, static (restoring) and dynamic (damping and added mass) forces, acting on ships. It may be possible to simulate the motions by computers if these hydrodynamic forces are known. To measure dynamic forces, forced oscillation tests are used. The test facilities and procedures are almost the same as that used in sea keeping test, but the mean attitude of the model should be adjusted to the corresponding running attitude. It should be noted that it is very important to know the cross-coupling restoring coefficients between heave and pitch motions accurately.

Some dynamic forces like roll damping can also be measured by simple free decay tests. However the decay of motions at high speed is usually too rapid to measure the forces accurately. Therefore forced oscillation tests are preferable to get accurate results.

An oblique towing test with inclined model may provide manoeuvring information on the model for a course keeping problem in calm water.

3. PARAMETERS

3.1 Parameters to be Taken into Account

- Motion measurements
- Amplitudes and period of motions, phases between motions, mean attitudes
- Force measurements
- Added mass, damping and restoring forces
- Pitch and heave coupled restoring forces
- Froude scaling law
- Location of centre of gravity
- Thrust line
- Running attitudes
- Tow line
- Appendages

3.2 Recommendations of ITTC for Parameters

None

4. VALIDATION

4.1 Uncertainty Analysis

None

4.2 Benchmark Tests

None