 Transactions on the Built Environment vol 11, © 1995 WIT Press, www.witpress.com, ISSN 1743-3509

Calculation of drag characteristics for floating vehicles

S.T. Kaczmarczyk, J. Kulczyk, A. Pieluzek
Military Institute of Engineering, 50-961 Wroclaw 43, Poland

Abstract

The unique methodology used by authors during the calculation of drag characteristics for full sized floating vehicles has been presented in that paper. Test objects were tracked armoured personnel carriers (APCs) used in the army which are adapted to crossing rivers or lakes. Drag characteristic of those untypical floating objects has been calculated by towing them by a vehicle moving on the riverside. It has been described the construction of test stand designed by authors and the equipment used for measurements. Exemplary course of towing force and speed registered during the test and statistic processing principles of test results have been presented in the paper. Drag characteristic of a tracked APC calculated during the test is published. The authors have been presented the track motion effect (tracked propeller) on drag characteristic form. The authors table a motion about the change of characteristic calculating method for tracked vehicles. This change lies in the towing of vehicle in which the speed of track motion is the same like the towing speed. Such calculated characteristic is approximated the reality.

1 Introduction

The drag characteristic i.e. the drag dependence upon speed in the water must be known for every floating object. An amphibious vehicle e.g. an armoured carrier is also called the object. Such vehicles are generally used by army and there is expecting they are able to rivers crossing at once without special preparing. The vehicles must be prepared for floating in respect of construction. The know-how of drag characteristic is required both during propeller designs for floating vehicles in order to obtain of assumed speed in the water and by comparison of different constructed hulls. The calculation of this characteristic by analytical means is now unattainable considering the lack of credible date in scientific publications. It refers to the calculating methodology and drag characteristic of carriers.

The most valuable characteristics are these once which are calculated for real objects in full scale.They are not burdened with model errors which always becoming simplified the structure of tested object and with errors resulting from extrapolation of model test results on real object.

The testing of carriers in full scale creates many problems of technical - organizational nature and its realization is not possible even in the greatest in Poland towing tank with dimensions 250 x 12 x 6 m which is placed in Gdansk-Oliwa [1]. The towing tank is too narrow and in this case must be used very large towing force which is impracticable by towing carriage.

One should take into account the following object parameters at test planning of carriers:
length - 5-8m,
width - 2.8-3.3m,
draught - ~1.5m,
total weight - ~15000kg,
towing speed - ≤3m/s,
towing force - >500daN.

The above - mentioned considerations caused that it has been decided on working out of special methodology for the measurement of armoured carrier drag characteristics in full scale on a test stand which is placed in a natural water reservoir. The methodics takes into account the effect of estimation of tracked propeller on vehicle drag characteristic.

2 Methodics of making investigations

The drag characteristic investigations of real object should be conducted during its towing in the stagnant water with step variable fixed towing speed. During the measurement the vehicle must move with the constant speed (V_h=const). Using the present measuring techniques the measurements need not have done in the determined measuring length. Measured quantities are recorded during the whole towing test and then it can be selected the measuring length after the analyse of recording.

Considering various towing methods of floating vehicle it has been decided for the use of non-typical method described in the paper [2]. It consists in towing of floating vehicle by means of a rope by another vehicle moving on a bank. The 100m long track on which the towing vehicle moves, was hardened and levelled (in order to avoid of travelling speed variations). The towing vehicle is equipped with an additional device for speed measurement so-called „the fifth wheel" with the measuring range 0-4m/s and accuracy 0.01m/s. The force and towing speed were measured from the deck of towing vehicle by use of electronic measuring technique (extensometer and hydrometric current meter). The recording of results of a measurement is made all the time with the help of multichannel recorder placed on tested object. Such arrangement procedure of measuring and recording equipment allows to obtain as less as

possible deformed measurands and record them to later processing when the test is over.

3 Test stand

The water region for experiment should be characterized by following parameters:

a) water lane length not less than 200m,

b) water lane width not less than 100m,

c) water lane depth must meet following requirements:

- first requirement:

$\frac{h}{T} \rangle 3$, where h - water lane depth, T - max draught of vehicle;

for T=1.5m depth h>4.5m;

- second requirement:

$F_n = \frac{V}{\sqrt{gh}} \langle 0.5$, where: V - vehicle towing speed, g - acceleration of gravity

for V=3m/s and g=9,81m/s depth h>3,6m;

d) identical depth for whole water lane length.

The water region which meets such requirements is occured in an arm of the Odra river in Wroclaw and there has been built the measuring position. The construction of measuring position is schematically shown on fig. 1. The terrain configuration in the test place (level difference between water mirror and bank plane is about 3.5m) has been obliged to pull a towing rope through pulleys mounted to dolphin. The hardened track for driving of towing vehicle has been placed perpendiculary with the floating track. The tow-rope pulling through pulleys from the towing vehicle was connected with the floating vehicle and had the extensometer (1). On the bow of tested vehicle on the left and right side were attached two extension arms with hydrometric current meters (2) to measure the speed in the water. On the propeller shaft of tracks was installed a photoelectric probe to measure the track speed. All outputs of measuring devices were connected with multichannel magnetic recorder (3) by means of devices which are monitored the measuring values. The towing vehicle is equipped with the „fifth wheel"(4) with the monitor for projection of present travelling speed. Such prepared test stand allowed to carry out and record the measurements with the continous observation of measuring values.

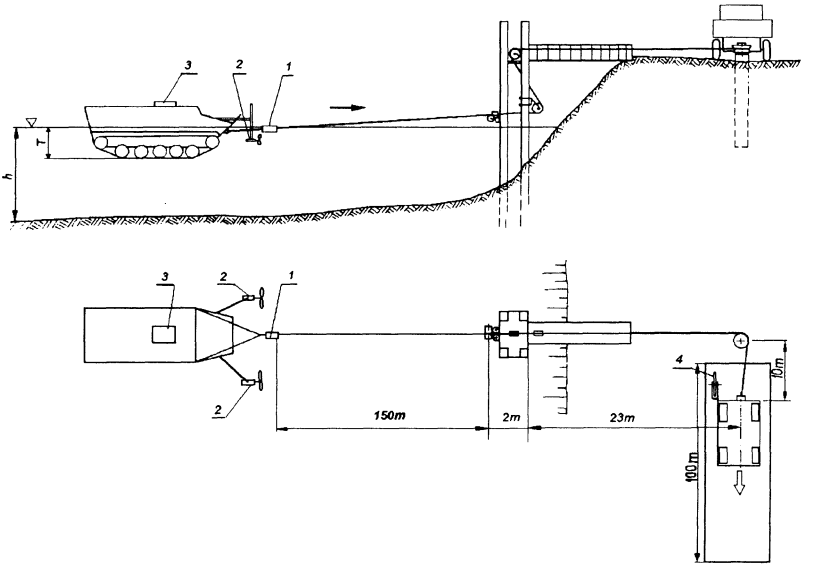

Fig.1. Test stand diagram.
1 - dynamometer, 2- speed in the water meter, 3 - recorder,
4 - towing speed. meter „fifth wheel"

4 Measuring procedure

During the development of system for measuring the drag characteristic of real object was taken into account the specific character of making investigations in field conditions and it was assumed the necessity of continous recording of measuring values: voltage changes generated by three measuring lines: towing force, speed in the water, track speed. Considering the organizational conditions prevailing during the investigations it was decided on use of an analog magnetic system of data logging. This system requires the simplier handling than the digital recording system having greater information capacity. The probability of accidental loss or erasing of storage is minimal the least posible, during the investigations there can be recorded the full acoustic comment relating to the conditions of testing. The recorded data are provided for digital processing in laboratory conditions.
Fig. 2 is shown the diagram of measuring system used in a tracked vehicle [3]. This system contained the following measuring lines:
a) towing force measuring line with electronic extensometer with measuring range to 1500 daN. the signal from voltage output of extensometer amplifier was recorded in a magnetic recorder. As control recorder was used the analog plotter conected to monitor output of magnetic recorder. The force measured error taking into consideration all elements of measuring line and processing system should be estimated at maximum 2.5%.

b) two measuring lines of speed in the water consist of hydrometric current meters (type HEGA 2). On the one of two lines for monitoring of present speed value was used the microprocessor speed meter. There were recorded signals coming from probes of hydrometric current meters. The signals assumed the shape of rectangular voltage with the amplitude of about 5V. The measuring constants for both hydrometric current meters were about 0.08m/pulse. The speed measuring accuracy on the ground of adding up of 10 pulses was about 0.02m/s (max. error about 4% at 0.5m/s min speed).
c) measuring line of track speed included the photoelectric tachometer probe receiving pulses from track propeller shaft and microprocessor speed meter. There was recorded the pulse train from the photoelectric probe similary to the speed in the water. The greatest error of measured track speed was about 3% at 0.5m/2 minimal speed.

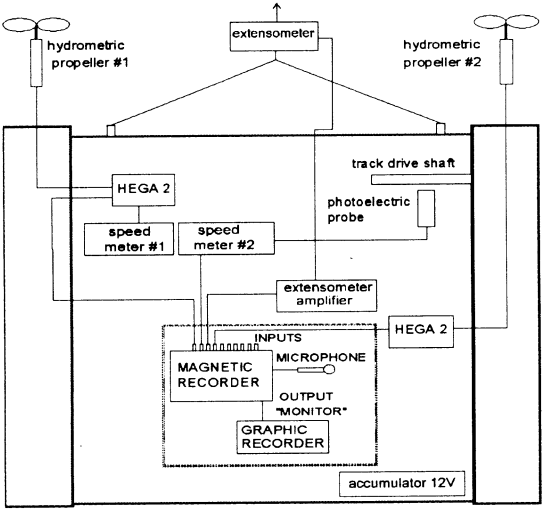

Fig. 2. Diagram of measuring system installed on vehicle.

5 Processing procedure of measured results

The recorded on magnetic recorder results were feeded into a computer PC to process by use of multi channel analog-to- digital converter card. It has the resolution of 4096 quantization levels of input voltage in range from -5V to + 5V. When feeding the signals into a computer was applied the sampling frequency of 500Hz in every channel. There was conditioned by correct conversion of rectangular signals coming from speed meter. The results of every test were recorded on a hard disk in the shape of data file including complete voltage changes in every channel for a given test.

5.1. Selection of measuring lenghts

On the ground of analysis of speed in the water changes and towing force from each data file was selected the lenght for which were met the assumptions for a given test it means the speed value (V=const) and the force value (F=const) were established at a given level. During the selection of the first measuring lenght there was applied the optical analysis (Fig.3). In selected fragment of measuring lenght was analysed the tendency of signal variation. The selected fragments for which the tendency was not less than ± 0.2% were used as a basis for the determination of drag characteristic points. Usually there was corresponded with 10m long distance in the water (125 pulses of the probe placed in hydrometric current meter).

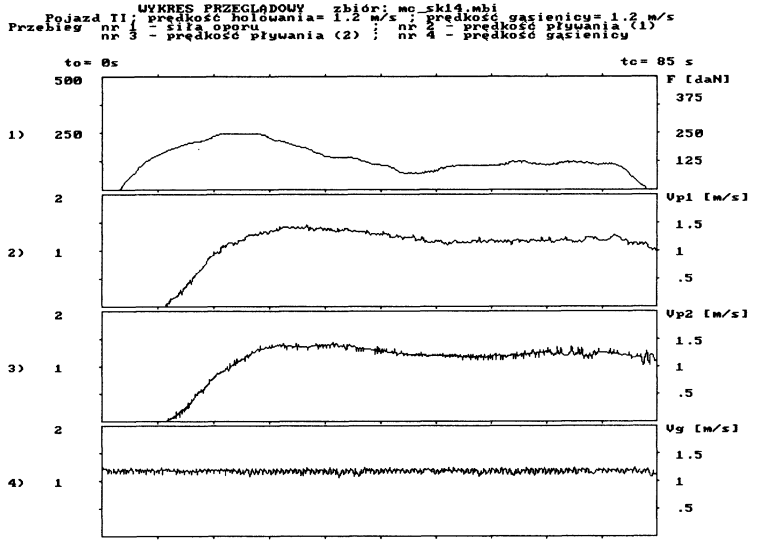

Fig.3. Example reviev diagram of recorded values.
F - towing force, V_{p1} and V_{p2} - towing speeds, V_g - track speed

6 Calculation of drag characteristic

In selected fragments of measuring lenght the towing force and speed after the statistical handling were helpful in the calculation of particular points of empirical drag characteristic. Based on calculated points and by use polynomial regression there were drafted the drag characteristic for every vehicle in the speed range from 0 to 3m/s according to the type of vehicle.The highest correlation coefficent figures out k^2 = 0.97 - 0.99 and it was obtained for following curves:

$$F = a_2V^2 + a_8V^8$$

The square term of an equation describes well the drag characteristic less than 1.5m/s speed. The correction a_8V^8 describes the increased drag of complicated (unstreamlined) hull of a tested vehicle in comparison with the perfect hull. Fig. 4 shows the drag characteristic calculated for a tracked vehicle with a motionless track and the track moving with the towing speed.

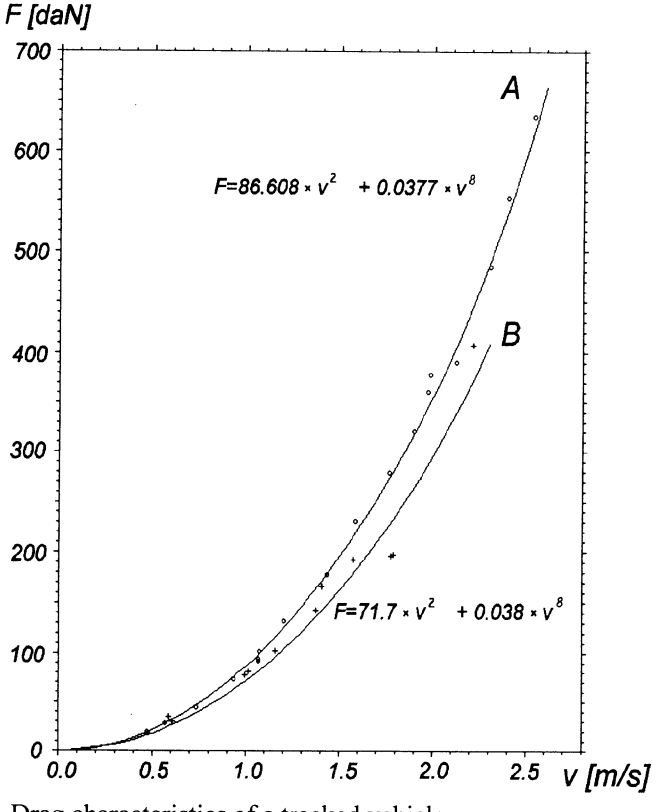

Fig. 4. Drag characteristics of a tracked vehicle.
A - motionless track, B - track in motion (V= V_{towing})

7 Conclusion

The initial analysis of measured results has been showed that the correct course of drag curve has been obtained. That indicates that the measuring methodics has been correctly worked up. The obtained arrangement of drag curve points is enough correct that it can be left out the analysis of polynomial regression (what is anyway commonly used in measuring of ship drag). Measuring procedures, constant recording and monitoring let have confidence in obtained results.

During testing of a tracked vehicle the distinct differences have been shown between the drag characteristics for the vehicle with motionless tracks and tracks in motion. If it assumes initially, the differences can be used for thrust estimation generated by moving tracks and the thrust quantity depends on track speed. This is the linear dependence. The complete analysis of effect of tracks on the drag will be require to calculate the drag at the constant towing speed and various track speeds.
One should be assumed that for a tracked vehicle two drag characteristics should be calculated. The one with motionless tracks and the other with moving tracks with the same speed what the towing speed. It is described in above-mentioned tests and in the paper [3].

This paper has been made as the realization of research desing N° 9360401205 and costs were covered by Komitet Badan Naukowych (Scientific Research Comittee) in the years 1993-1994.

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