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A new modelling arrangement for testing of Catenary Anchoring Leg Mooring (CALM) system behaviour in waves

SUMMARY

Model tests of the Catenary Anchoring Leg Mooring (CALM) systems are often carried out in elongated tanks which makes it necessary to significantly distort catenary of the anchoring chains, and causes a complication when checking test results by numerical models, or alternatively - to reduce the model scale which leads to increasing scale effects.

In the paper a new model testing arragement is presented where all chains are placed in planes parallel to the tank axis which makes numerical calculations easier and modelling the system in a greater scale possible.

INTRODUCTION

Various systems of ship mooring and oil reloading in open sea have appeared concurrently to new mining and production platforms for exploitation of the sea-bed natural energy resources. Devices operating near the shore or harbours are usually of the Single Point Mooring (SPM) type.The reloading of oil take place directly from or to a shuttle tanker moored temporarily to the SPM.

The most often used SPM systems are CALM (as well as SALM - Single Anchor Leg Mooring) systems because of their simplicity and low construction and operation costs.

However, physical and numerical modelling of the systems is difficult due to a large number of possible working states and system configurations as well as loading conditions to be taken into consideration.

From the available literature on SPM model tests it results that only few tests have been conducted in a large scale, i.e. that greater then 1:15. The comparison of the published results of those tests and results of the tests conducted in a scale greater than 1:15 shows significant and basic differences between them. In the case of SPM for example the scale effects can even reach 15% [1], when modelling it in too small scale and in line with the Froude scaling method. The model tests in a greater scale than 1:15 are very seldom performed because of difficulties in physical modelling of SPM . In elongated tanks fitted with a wavemaker, adjusted for ship seaworthiness tests, spacial modelling of a catenary anchoring system is very difficult due to limited width of such tanks. Therefore it is necessary to significantly distort catenary of the anchoring chains. Even experimental tanks of similar width and length, which allow to model the CALM system in a satisfactory scale, do not usually allow to model a CALM system together with a moored tanker, to say nothing of more complex systems.

COMMON WAY OF MODELLING THE CATENARY ANCHORING SYSTEMS

The most often used way of CALM system modelling is to locate a buoy body half-way the tank length and to fix it to the tank walls and bottom with the use of model chains so far as the tank dimensions allow. Such approach makes it possible to model catenary of real chains with satisfactory accuracy only in the direction of wave propagation, i.e. the tank axis. In order to decrease the system's stiffness and nonlinearity the spring with known characteristics is usually inserted between a chain and a fixed point near the tank bottom or wall (Fig.1). Such solution have at least two disadvantages: an additional complication of mathematical model, and completely different behaviour of the buoy in waves.

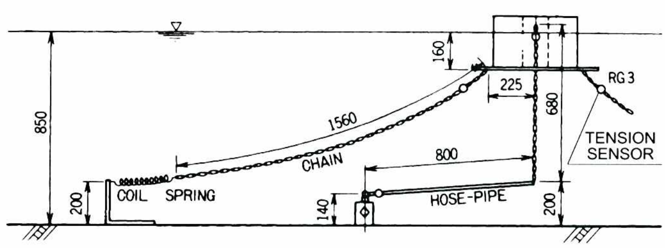

Fig. 1. Example of common modelling arrangement used for CALM buoy testing [3]

Moreover the chains composed of different sections and with hanging masses can be properly modeled only if they are parallel to tank axis and provided that the tank length is sufficient.

A NEW ARRANGEMENT FOR MODELLING THE CATENARY ANCHORING SYSTEMS

A completely other approach to anchoring system modelling was proposed and practically applied. It consists in bringing all anchoring chains to vertical planes which are parallel to the tank axis (i.e. direction of wave propagation). For this purpose a special steel frame was constructed and placed on the tank bottom. The frame was equipped with free running rollers at all extreme points. The chains were hung on horizontally moving beams, parallel to the tank walls (Fig.2). Chain pipes were connected with the beams by means of thin steel cables (ϕ 2.6 mm) and tension sensors fixed to the buoy body. All direction changes of the cables were realized with the help of free-running, low-friction rollers. Inclination angles of the steel cables in the initial state (of no external loads) was set similar to those of the chains near the chain pipes, occurring in real arrangement of the buoy body in question.

The system presented in Fig.2 was applied to testing a symetrical model based on the real CALM system exploited by Petrobaltic Company on the Baltic Sea. Such arrangement can be easily used also for modelling of any unsymmetrical system. Moreover it makes it possible to model any number of chains of different cross-sections. Also, up to 90% of the tank length is accessible for forming the chain catenaries. The wave direction relative to the system position can be easily changed by rotating the frame by an assumed angle.

The arrangement was applied to many model tests of the above mentioned CALM system in regular and irregular waves. The tests were conducted in an experimental tank 60 m long, 7 m wide and of 2.95 m water depth. The scale of the model was assumed 1:13 , and Froude scaling method was applied to buoy, chains, external static loads, etc. Unit weight of the immersed model chain was 7.1 N/m. The cylindrical buoy body was of 0.85 m diameter, 0.41 m height and 725 N weight. The model tests were conducted for two system arrangements, i.e. the CALM system together with and without moored model of a tanker (in ballast and empty condition), at two positions of the steel frame (Fig.2). Special tests with varying bow hawser length were also realized [5].

The basic inconveniences of such modelling arrangement are as follows :

- different influence of waves and currents on chains and hanging masses
- different action of chains due to horizontal displacements of their upper end only.

First disadvantage can be easily taken into consideration in a mathematical model. Besides, if there are no hanging masses on the model chain the wave and current influence on chains is practically negligible [4,6]. Second disadvantage can be considerably reduced by raising the upper ends of the chains in such a way as to obtain the chain characteristics similar, in the predicted ranges of tension and displacement values, to those of the chains directly fixed to the buoy body.

In the particular diagrams of Fig.3 chain reaction changes resulting from buoy displacements : horizontally (along x-axis), vertically (along z-axis) and obliquely (at x=z), are presented. In each diagram two curves are shown in order to compare the reaction changes of the chain working in the presented modelling arrangement and those of the chain considered in the case of the strictly spatial modelling of the system and fixing the chain directly to the buoy body. In the result of applying the cables and rollers in the modelling arrange-

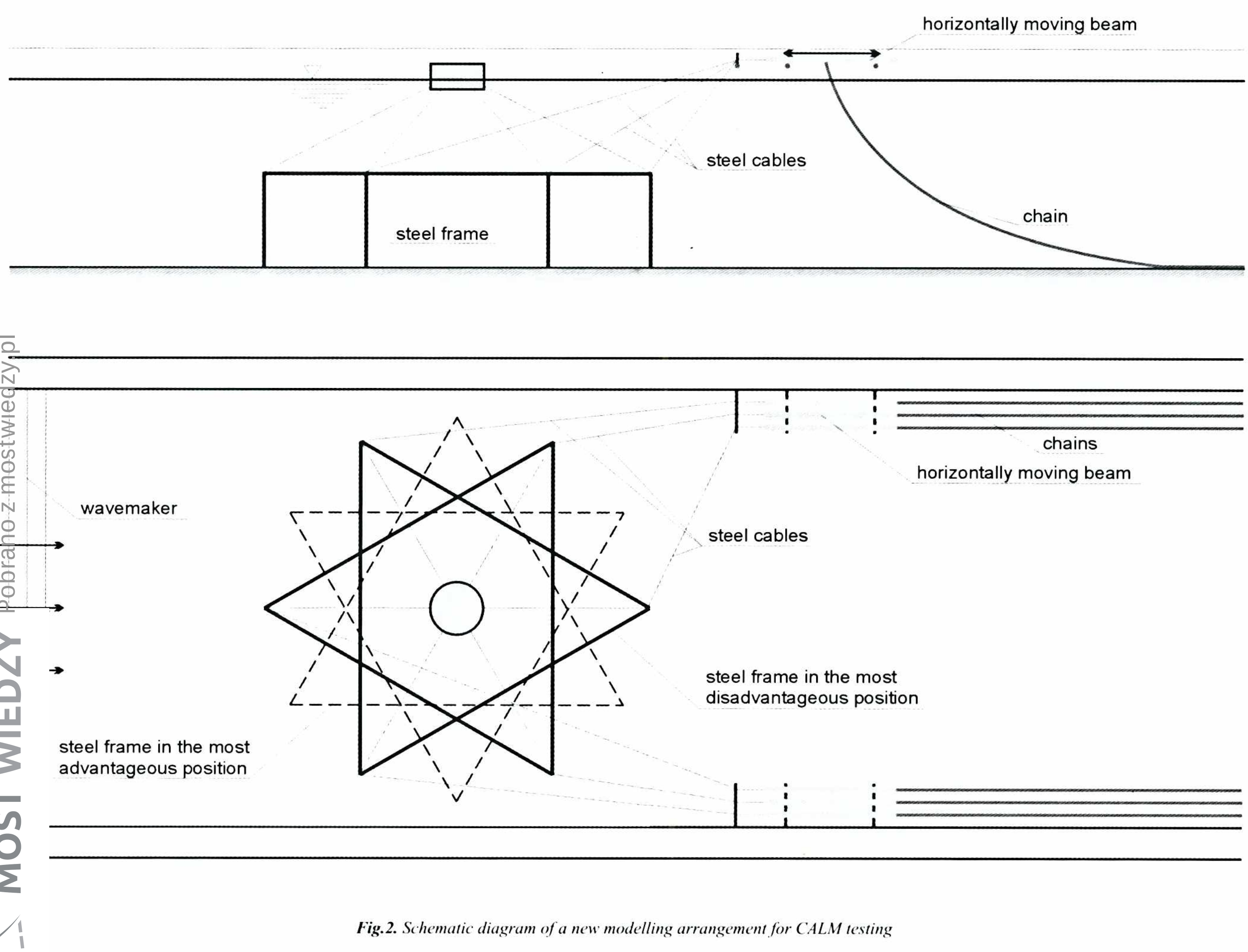

Fig.2. Schematic diagram of a new modelling arrangement for CALM testing

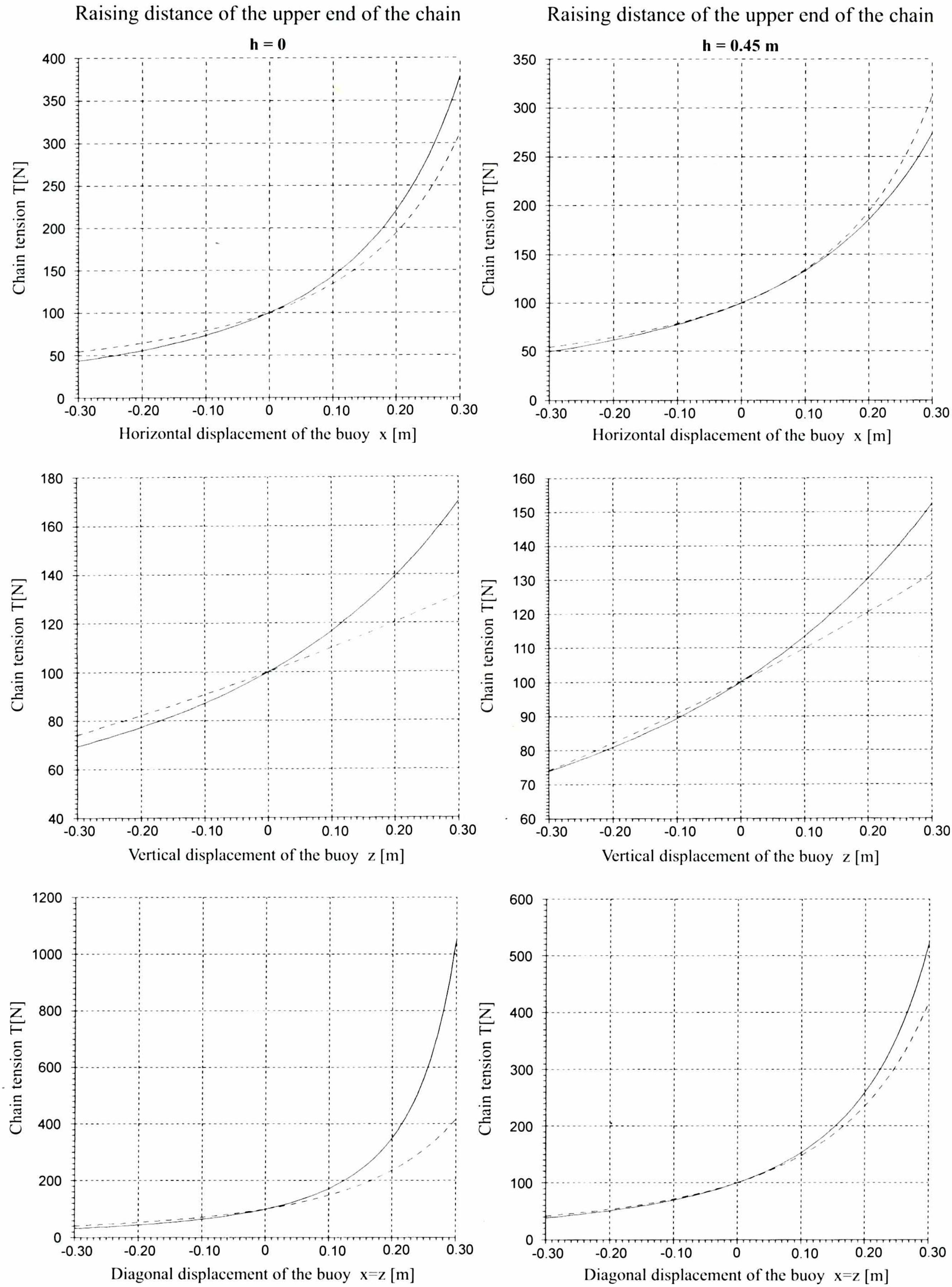

***Fig.3.** The effect of raising the upper end of chain by h=0.45 m*
- - - - - a chain fixed directly to the buoy
——— a chain fixed by means of beam, rollers and steel cable

ment in question, and due to limiting motions of the upper ends of the chains to the horizontal direction only, the chain reaction courses for both above mentioned cases differ to each other.

The differences decrease if the beam level is lifted by *h*. In the realized model testing h=0.45 m was assumed. In the right column diagrams of Fig.3. the reactions of the chain of the lifted upper end and those of the real chain are compared. The left column diagrams concern the situation when the upper end of the modelled chain is not lifted.

From the comparisons it results that - within the predicted ranges of the displacements - the reactions of the modelled chain attached to the lifted beams, are close to those of the real chain.

The influence of raising the upper end of the chain by h=0.45 m, at the initial tension T_o=100 N in the chain placed along the tank axis (in wave direction), i. e. the most disadvantageous position of the whole system, is shown in Fig.3. The predicted range of the horizontal displacement [x] was ± 0.15 m, and of the vertical displacement [z] ± 0.10 m.

CONCLUSIONS

- The presented new modelling arrangement for testing the catenary anchoring systems in elongated experimental tanks can be used for realization of a wide range of tests.
- In contrast to the commonly used way it makes it possible to apply greater model scales and to realistically model dynamic behaviour of anchoring chains.
- By reducing the general displacements of chain pipes to horizontal displacements only it makes a mathematical modelling of the whole system easier.

Appraised by Bolesław Mazurkiewicz, Prof.,D.Sc.

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Miscellanea

The Academic Computer Centre in Gdańsk (CI TASK)

Founded in 1994 by the State Committee for Scientific Research (KBN), Academic Computer Centre (CI TASK) in Gdańsk is an inter-university unit that manages one of the biggest and most modern metropolitan area networks (MAN) in Poland.

The TASK network covers the territory of the whole so-called Tri-City, i.e. Gdańsk-Sopot-Gdynia. It connects 70 LAN networks of various research institutes in which over 6000 computers of PC class, workstations, and servers are installed. The network has about 16000 users (excluding students). The TASK network is connected to the national network thus enabling remote access to the Centre resources, the usage of all networks services, multimedial transmissions, interactive work, teaching and learning through the network.The Centre co-operates closely with four other supercomputer centres in Poland, and participates in creation of national metacomputing system. It also has a link to the TEN-155 panEuropean research network which provides extension of the service to the USA and other overseas regions.

A concise characteristics of the Centre main departments is as follows.

The Network Group serves as the design and supervising centre of the whole Tri-City network. Now the network operates in ATM and FDDI technologies. It consists of three FDDI rings, each with five to eight FDDI nodes connected with links operating in ATM technology. The group maintains all the network services and servers, monitors secure network operation, and gathers network statistics, both within TASK, cooperating MANs, and worldwide transmissions. Network supervising is highly automated with such tools as SUN Net Manager, Cisco Works, and Cisco NetFlow Analyzer. Lately, the Network Group has offered creation of the Virtual LAN facility. A pilot VLAN configuration has been established for the University of Gdańsk.

The Supercomputers Group maintains and manages all the computers (IBM, SGI and SUN) installed in CI TASK equipped with a high-capacity archivisation system (ATL, HP, and EXABYTE). 34 profesional software packages make it possible to perform large scale calculations in various fields of science and technology. The group also delivers expert advice in software application and security of servers . Its latest attainment is the SGI cluster project that resulted in effective supercomputer workload.

The Inter-Disciplinary Group of Mathematical Modelling was established as a group for mathematical modelling of theoretical and applied research. Its main fields of interest include: Quantum Chemistry, Plasma Physics, Atomic Physics, Biomolecular Modelling, Mechanics, Medicine, and Electrodynamics. The Group publishes papers of its interests in the TASK Quarterly Scientific Bulletin. The journal makes it possible to present papers and exchange of views on applied numerical methods for solving a variety of problems in science and engineering by using high performance computers. Contributors are invited to send their proposals to :

quarterly@task.gda.pl

In 1999, in recognition of the Centre's achievements in metacomputing technologies based on SGI servers, a special prize was awarded to it by the KBN (The State Committee for Scientific Research).

Notation :

ATM - Asynchronous Transfer Mode
FDDI - Fiber Distributed Data Interface
LAN - Local Area Network
MAN - Metropolitan Area Network
VLAN - Virtual Local Area Network
ATL, EXABYTE, HP, IBM, SGI, SUN - firm names