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A SIMPLE COMPUTER MODEL OF TRAWL GEAR MOTION

by

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Introduction

The employment of increasingly large capital sums in fishing vessels and the escalating running costs demand ever more efficient catching performance to ensure economic operation.

The efficiency of fish detection techniques may have already overtaken the efficiency of the fishing system to catch the fish.

One of the main areas in which improvement may be possible is in the ability to aim the fishing gear accurately. This requires a knowledge of the location of the gear relative to the vessel, and hence the target, and a knowledge of how the gear will react to a given course of action.

The immediate aim of the present work is to provide a method of predicting the configuration of a trawl gear and its position relative to the towing vessel.

The Model

It was decided to assess the feasibility of modelling pelagic trawl gear motion by using a simplified model. At a later stage it would be possible to increase the model's complexity and accuracy.

From the analysis of steady state measurements of trawl gear geometry and loading, accurate empirical formulae have been developed for the drag, spread and lift forces generated by the net and otterboards. This information allows the gear to be simulated by two point masses at the end of the warps producing drag, spread and lift forces.

A further simplification has been achieved by considering the two dimensional case initially in which the ship travels in a straight line and the gear is represented by one flexible, extensible wire in the plane of the ship's velocity with a single point mass generating only a drag and lift force at the lower end.

The system of forces acting on the vessel and gear in this two dimensional case is shown in Figure 1.

Normally VZ2 is assumed to be equal to W1TZ although a forcing function could be inserted for VZ2 to simulate wave motion.

The Equation System

Empirical equations have been used for the propeller thrust (VT2), the vessel resistance (VR) the gear resistance (UR) and the gear vertical force (UZ2) which includes the gear weight. The form of each relationship is given below.

1. $VT2 = C1 \cdot VN4^2$

2. $VR = E1 \cdot VV^2$

3. $UR = C2 \cdot UV^{E2}$

4. $UZ2 = UW + C3 \cdot UV^{E3}$

E1, E2 and E3 are empirical constants whose values are obtained from analysis of actual measurements during sea trials.

C1, C2 and C3 are constants which are calculated within the program.

The important link in the system is the modelling of the warp connecting the vessel and the gear. In this simple case it has been argued that the acceleration forces acting on the wire are negligible compared to those on the gear and vessel. A routine has therefore been employed which computes the static equilibrium shape and loading of the warp assuming the velocity at all points along its length is equal to the average of the velocities of its ends at any instant. Knowledge of distances between its ends in the X and Z directions is sufficient to compute the tension and shape of the wire along its length.

A flow diagram of the program is shown in Figure 2. It will be seen that a set of data for one steady state case is required initially, comprising values for propeller rpm, towing speed, gear depth and warp upper end tension, from these data the constants C1, C2 and C3 are calculated for use during all future time intervals.

After the initial input it is required to input only the present value of propeller rpm in order to predict the geometry, loading and motion of the system.

Using a computer with software floating point routines the program simulates a given time interval in three quarters of real time. Using one of the new generation of computers with hardware floating point routines, very substantial improvements in running time could be achieved.

Accuracy

A limited number of comparisons have been made between trials measurements and the computer predictions.

The trial hauls were of approximately two hours duration divided into eight periods of fifteen minutes during which the propeller rpm was held constant. At the end of each 15 minute period the gear had settled nearly enough to an equilibrium depth.

Between the 4th and 5th periods the ship was turned through 180° and the gear then towed back along a straight reciprocal course for the second half of the haul. This manoeuvre allows the effect of tide to be determined.

The computer program was run for each half of each of seven hauls in which two nets of considerably different construction were tested. The steady state values attained at the end of the 1st and 5th fifteen minutes periods were used to calculate the constants C1, C2 and C3 for use in the prediction of the motion during the succeeding three 15 minute periods. It is clear that the accuracy of the predictions will be dependent on these initial measurements.

The empirical constants E1, E2 and E3 were unchanged for all the hauls.

Figure 3 shows, for one haul, the measured and predicted depths at the end of each 15 minute period plotted against time.

The program computes values for successive times between those actually plotted but at this stage in development it is the ability to compute final steady state values after each rpm change which is of importance. Prediction of the behaviour of the system during the acceleration phase is dependent on the values chosen for the virtual masses of the vessel and gear.

Figure 4, 5 and 6 demonstrate the accuracy of the predicted speed, gear depth and warp tension for all the cases run. The absolute error is plotted against the predicted value with the 5 and 10 per cent error lines indicated. There is no evidence of any systematic variation of error with the predicted value which indicates perhaps that the errors are of a random nature due eg to the trials data rather than the inaccuracy of the model.

Further comparisons will be made with measurements from trials on different ships.

Refinement of Model

Work has already been done on the three dimensional case which allows simulation of vessel manoeuvring and change of gear horizontal geometry. More complex equations are being developed to model propeller performance more accurately than the simple relation used here and to allow for transverse components of velocity.

A warp routine which takes into account acceleration forces has been developed but the necessity of building this complexity into the model has yet to be demonstrated. The disadvantage of such a refinement is that the improvement in accuracy may not justify the greatly increased program running time.

Summary

The present program has demonstrated the feasibility of modelling trawl gear motion in two dimensions.

The next stage in development may help to answer important questions concerning, for instance, the configuration of a gear during manoeuvres the minimum turning radius permitted before either gear collapse or damage occurs, the ability of a gear to intercept a shoal of fish in a given position and the most appropriate action to take to intercept such a shoal.

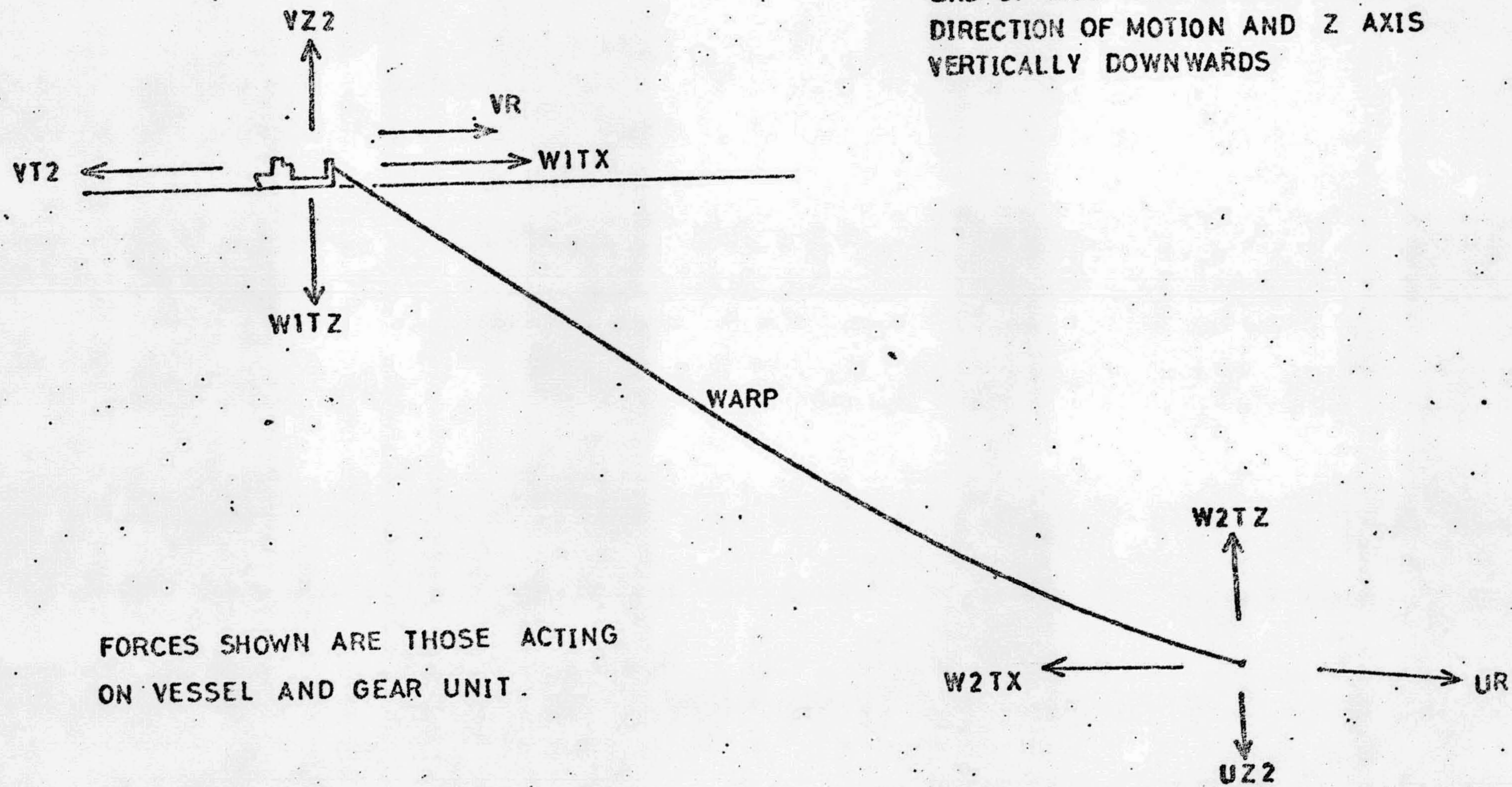
The availability of such information on board a trawler need not be dependent on the presence of a computer. Simple graphical presentation of results from the model for a given gear and vessel may be sufficient.

NOTATION

Symbol	Description
C1, C2, C3	Constants in model equations which are calculated within the program.
DT	Time interval.
E1, E2, E3	Empirical constants required to be input to program.
UA6X, UA6Z	Gear acceleration in the X and Z direction.
UM	Virtual mass of gear unit.
UR (URX, URZ)	Gear resistance (X and Z components).
UV (UVX, UVZ)	Gear velocity relative to water (X and Z components).
UW	Gear weight in water.
UX, UZ	Distances in X and Z directions of gear from vessel.
UZ2	Resultant vertical force generated by gear.
VA6	Vessel acceleration.
VM	Virtual mass of vessel.
VN4	Propeller rpm.
VR	Vessel resistance.
VT2	Propeller thrust.

FORCE DIAGRAM FOR TWO DIMENSIONAL MODEL

THE AXIS SYSTEM HAS ORIGIN AT UPPER END OF WARP WITH X AXIS OPPOSITE TO DIRECTION OF MOTION AND Z AXIS VERTICALLY DOWNWARDS



FORCES SHOWN ARE THOSE ACTING ON VESSEL AND GEAR UNIT.

FIGURE 1

FLOW DIAGRAM

I Input initial steady state values for: VN4, VV, WIT, UZ and empirical constants E1, E2, E3.

II Warp routine for steady state case to determine warp tension components W1TX, W2TX, W2TZ.

III Calculate constants $C1 = (E1 . VV^{2} + W1TX)/VN4^{2}$

$$C2 = W2TX/UV^{E2}$$

$$C3 = (W2TZ - UW)/UV^{E3}$$

(Note that these are the equations of step VI below with accelerations equal to zero),

IV Input present value of rpm.

V Empirical Force Equations

$$VT2 = C1 . VN4^{2}$$
$$VR = E1 . VV^{2}$$
$$UR = C2 . UV^{E2}$$
$$UZ2 = UW + C3 . UV^{E3}$$

VI Acceleration Equations

$$VA6 = (VT2 - VR - W1TX)/VM$$
$$UA6X = (W2TX - URX)/UM$$
$$UA6Z = (UZ2 - W2TZ - URZ)/UM$$

VII Velocity Equations

$$VV = VV + VA6 . DT$$
$$UVX = UVX + UA6X . DT$$
$$UVZ = UVZ + UA6Z . DT$$

VIII Distance Equations

$$UX = UX + UVX . DT - 0.5 . UA6X . DT^{2}$$
$$UZ = UZ + UVZ . DT - 0.5 . UA6Z . DT^{2}$$

IX Warp Routine: Input UX, UZ
Output W1TX, W2TX, W2TZ.

X Return to step IV for next interval of time.

FIGURE 2

COMPARISON OF MEASURED AND PREDICTED DEPTH FOR ONE HAUL

o predicted } value at end of 15 minute period
x measured }

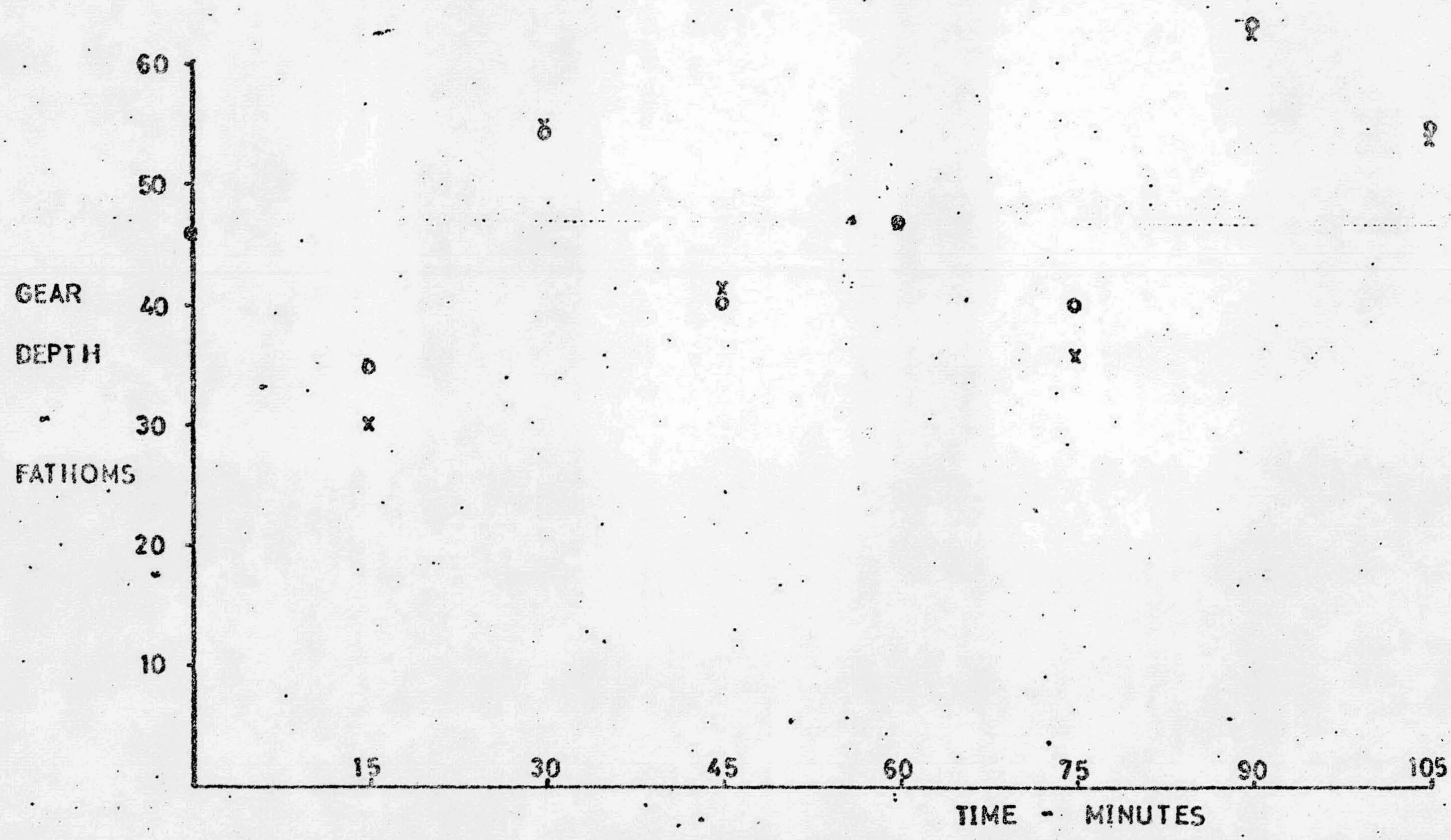
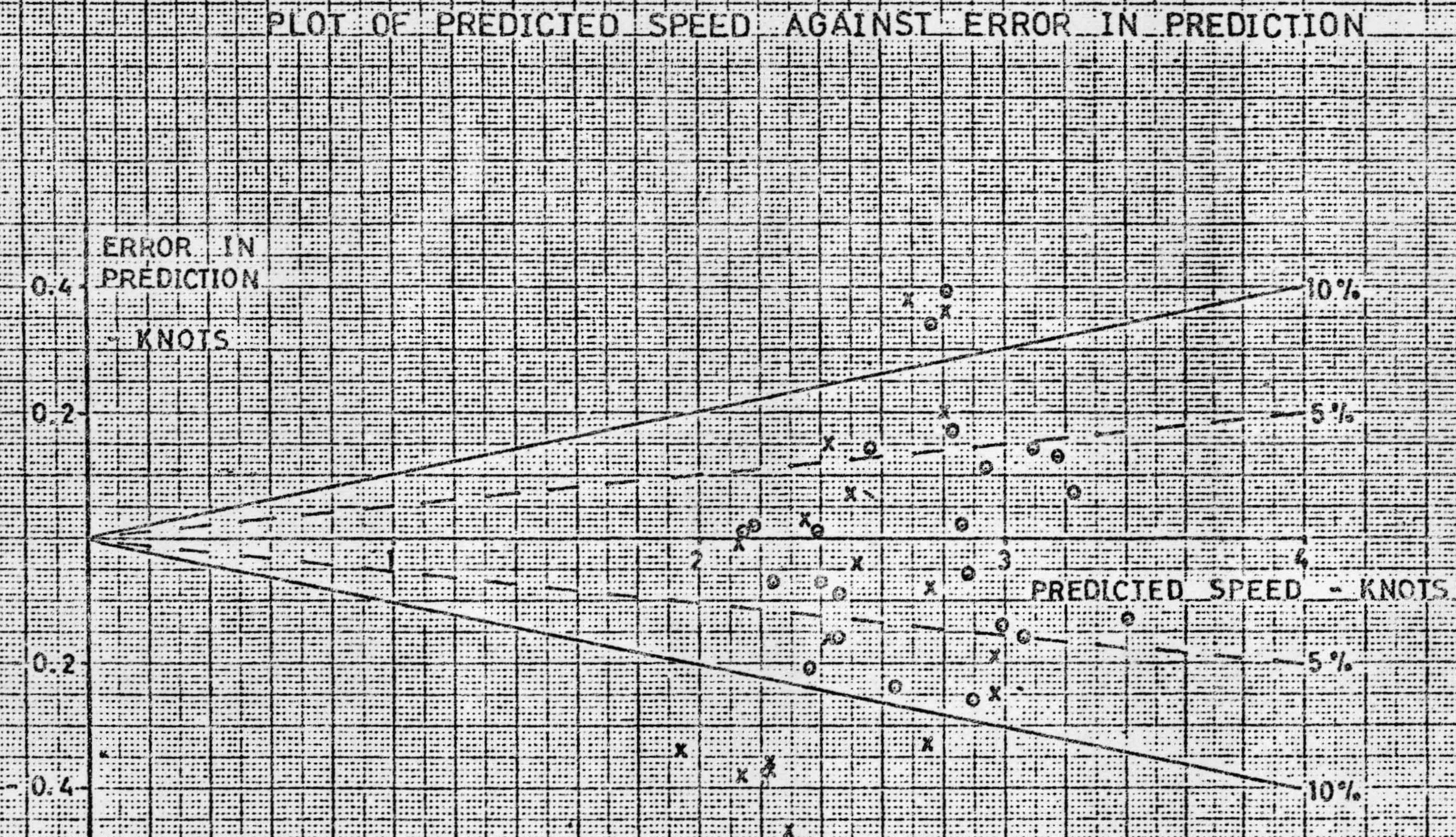


FIGURE 3



PLOT OF PREDICTED SPEED AGAINST ERROR IN PREDICTION
ERROR IN PREDICTION - KNOTS
0.4
0.2
0.2
0.4
1
2
3
4
PREDICTED SPEED - KNOTS
10%
5%
5%
10%

FIGURE 4

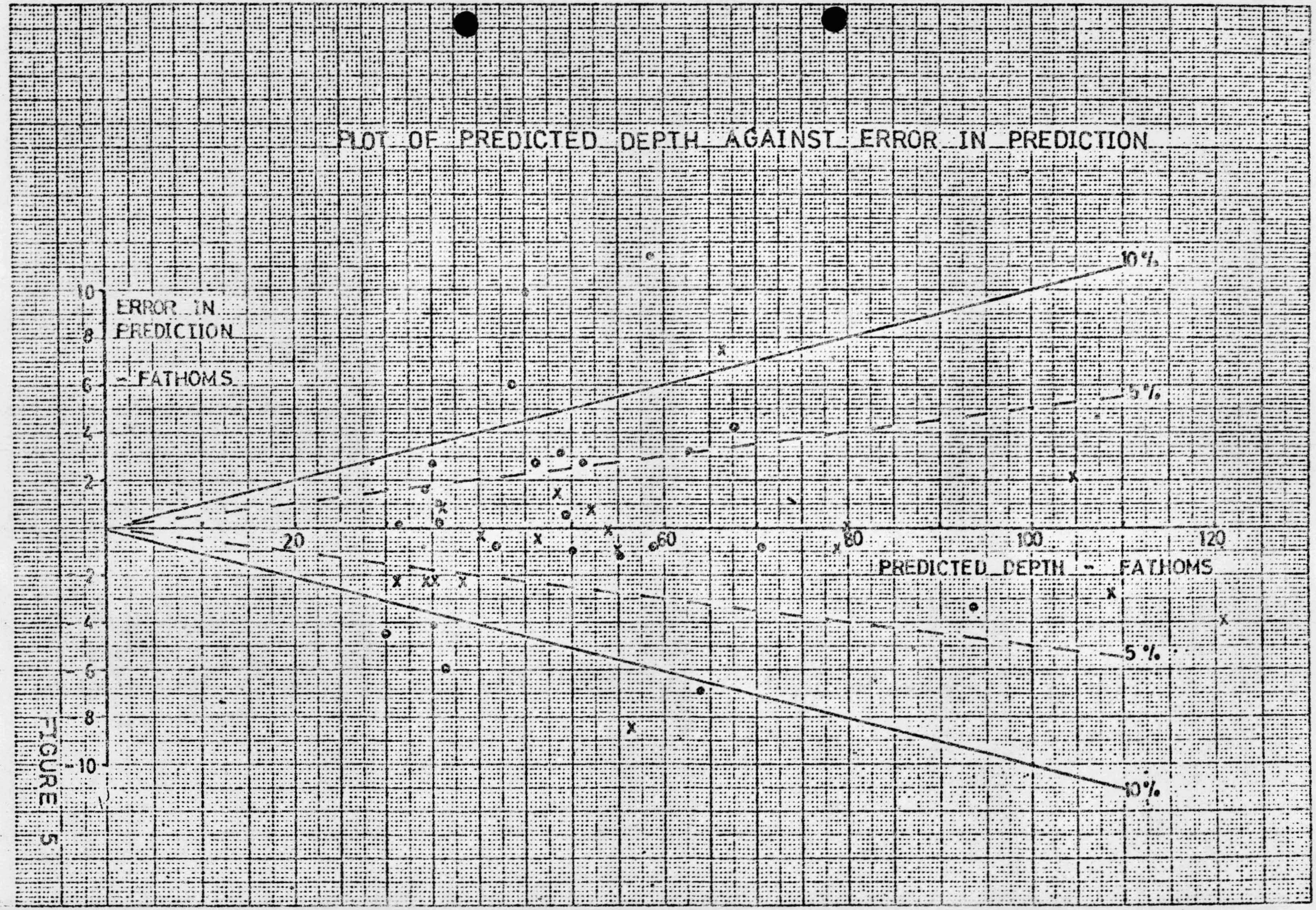

PLOT OF PREDICTED DEPTH AGAINST ERROR IN PREDICTION
ERROR IN PREDICTION - FATHOMS
PREDICTED DEPTH - FATHOMS
10
8
6
4
2
-2
-4
-6
-8
-10
20
60
80
100
120
10 %
5 %
5 %
10 %

FIGURE 5

PLOT OF PREDICTED TENSION AGAINST ERROR IN PREDICTION

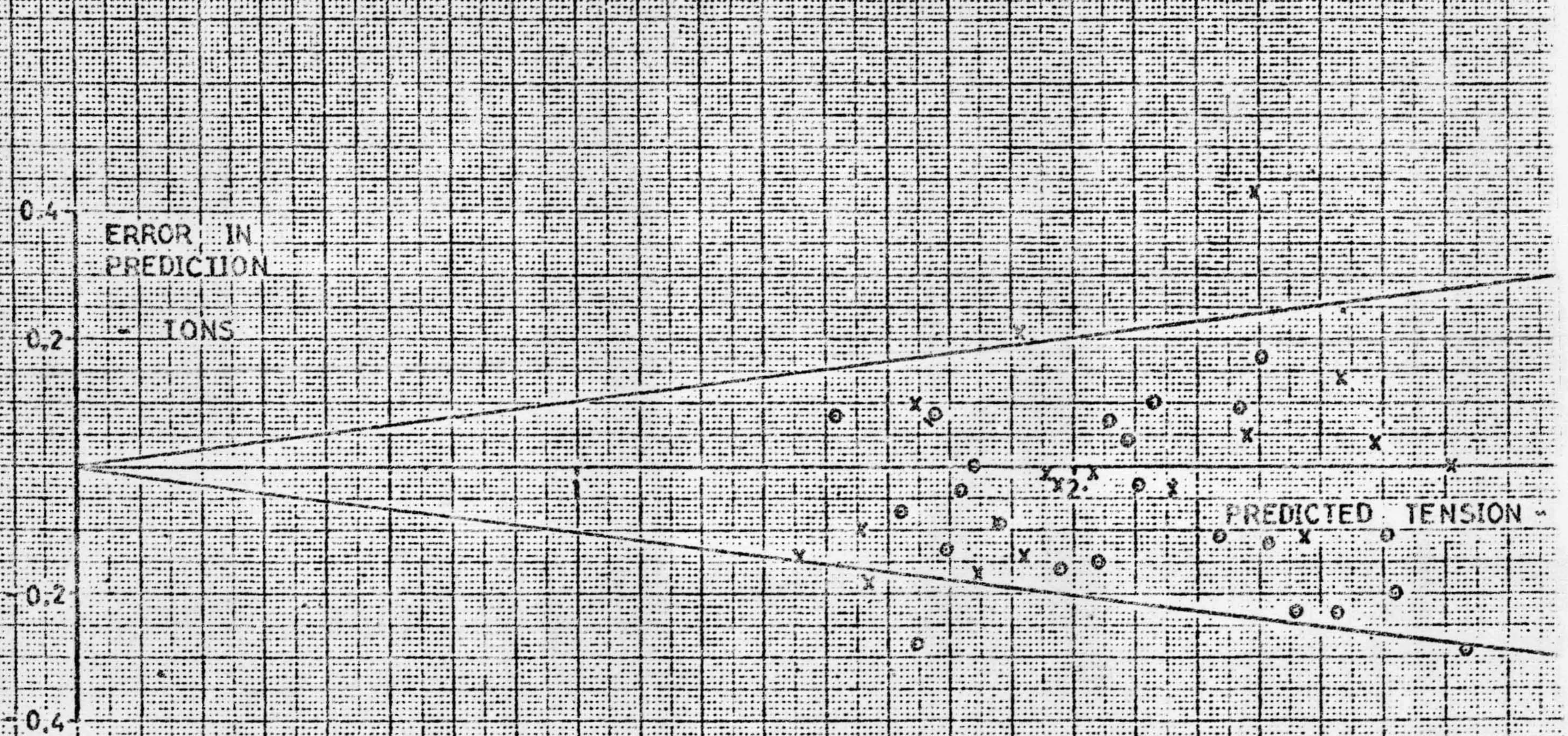


FIGURE 6