SØE-LIEUTENANT-SELSKABET.

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Wire guided torpedoes.

The present status in the Danish Navy on wire-guided torpedoes used for FPBs is the subject about which some remarks should be made.

Since the lay-out af the weapon.system, as it is going to be onboard a FPB, has come from many considerations on single matters the best way of presentation probably is to go through the problems, as we have seen them from the beginning of this development till now.

1. Let us start by looking at a situation as outlined on the first fig. where schematically a FPB is shown firing a torpedo against a target using a sight (or a fire control system) as it is found onboard a Danish FPB to-day.

In order to sent the torpedo in the proper direction, values for the target speed and course has to be estimated either from the visual impression of the target (by day) or measured on a plot (by night). The obtained values is put into the sight together with the relative bearing to the target, and the torpedo-gyro will then automatically get the angle with which the torpedo has to leave the FPB in order to hit the target.

In practice, however, there will always be an error varying from one situation to the next being bigger or smaller attached to the estimated values of the course and the speed of the target, even the measured target-bearing has error. Also the torpedo is not ideal it has tolerances as well on its speed as on its course. So whether a hit is obtained or not in a particular situation is a question, which can only be fully answered by means of statistics, and the answer will be a figure giving that relative number of torpedoes, which fired in many situations like the one in question, will hit the target.

2. An example of the results of such an analysis of a number of situations assuming the same distance of firing is shown on the second fig. As may be indicated from what was said a moment ago the result (the hitting probability) depends on many factors:

1) the size of the target
2) the speed of the target
3) the target angle
4) the assumed torpedo tolerances
5) the errors when estimating the target values
6) the firing distance

The figures given assume the estimated values on the target course to be inside $\pm 10^{\circ}$ from the actual value in 70% of the cases and the estimated values on the target speed independently thereof to be inside $\pm$ "one seventh" of the actual target speed in 70% cases. Figures drawn out of exercise reports shows bigger errors particulary for the target course obtained from the plot. The firing distance is 4000 m, the target speed is 20 kn. A comparison of the calculated percentage with actully obtained result shows a reasonable agreement allthough it is difficult to obtain at sufficient number of similar situations.

As you may see the maximum obtainable hitting probability is to be about 8%, and here it should be born in mind, that the target is assumed to proceed with the same speed and course as when the torpedo was fired. If the target carried out avoiding manoeuvres, what may often be the case in real situations, the values will decrease very much. So what is shown is an optimum of what can be reached under the conditions assumed.

It is the general opinion, that this result is pretty poor compared with the effort necessary to obtain it. More than one torpedo can of course be fired, but then firstly the effort is increased and secondly if the target turns off the result will not be much better.

Allthough the assumed firing distance 4000 m is towards the upper limit of distance used in danish exercises today it is the general opinion on the tactical side, that this distance should be increased appreciable, which would mean a further decrease in the hitting probability.

So something should be done, and we will now look through different possibilities.

1. Decreasing the torpedotolerances. From the table it may seen, that even an ideal torpedo would not do much better since the main error come from the estimate of the target values.
2. Equipment to generate more accurate target values. This of course could give much better results. Still however an accumuzation of the error during the torpedo-run will take place. This is part of what is done in the weapon system, which will go into the coming Danish FPBs, and we will look at this part later. But even if this is done the chances for a hit will be destroyed if the target carries out avoiding manoeuvres.

The use of homing torpedoes.

As a general remark about homing torpedoes it can be said, that homing always introduces the transmission of signal either from the target to the torpedo in the case of passive torpedoes or from the torpedo to the target and back again in the case of active torpedoes. This means transmission through the ocean which can

be a very unrealiable factor. It is an particular the case in the Baltic entrances with its rapidly varying and complicated oceanographic properties.

In most existing types of homing torpedoes the torpedo obtain its ability to home on the target by means of acoustic transmission and the following discussion will be limited here to, looking at the general characteristics of as well the passive as the active acoustic torpedoes.

For the passive acoustic torpedo it is characteristic that its speed is pretty low since it must be balanced against the homing range. This is because increasing speed means increasing selfnoise. The speed of such torpedoes will in general be about 20 kn., which is considered pretty low for use against surface targets.

The influence of the oceanographic conditions may cause very with the speed of the target. This type of torpedoe will narmally not be affected very much by the bottom and they may be used on water depht down to 15 m's.

For the active acoustic torpedo it is characteristic that it may respond to echoes reflected by the bottom if this is not sufficiently far away. The minimum depht will vary from one type of torpedo to the other, being from 60 up till 150 m.

The homing range for this type will also vary with the oceanographic conditions. The speed may go up to 30 kn. for this type of torpedo. From what has been said, you may see, that the introduction of homing torpedoes, as they are available to-day, would mean the introduction of a weapon with a pretty impredictable performance in particular if it should be used in the Baltic entrances and it would be necessary to make restrictions on the areas, where it could be used.

Finally it may be added that most of the existing types of homing torpedoes being developed primarily as ASW-weapons carry pretty small explosive charges.

Remote controlled torpedoes.

As it was mentioned earlier the introduction of an equipment generating accurate values for the course and speed of the target would increase the hitting probability appreciably, the disadvantage being that avoiding manoeuvers carried out by the target again would destroy the chances for at hit.

This brings forward the idea of a remote control of the torpedo since by such a controlarrangement it would be possible to maintain the high hitting probability by turning the torpedo to the collisioncourse corresponding to the target data obtained at any moment after the torpedo has been fired.

To realize this, it is necessary to consider a solution of two main problems.

1. Firstly how to transmit the orders to the torpedo.
2. Secondly how to determine the position of the torpedo since this obviously has to be known in order to steer it properly.

ad 1) The transmission of orders to the torpedoes can theoretically be carried out in a number og different ways and we will look upon some of them.

a) Acoustic transmission through the water could be used, this however would again introduce the unreliable properties of the ocean and the range would probably be too small, and in any case an expensive development of a proper sonar would be necessary. Furthermore the possibility of jamming would exist.

b) Radiotransmission could be used, but in this case either long waves and a great power output would be necessary or the torpedo would have to carry an antenna in or above the water surface which probably would mean great technical difficulties. Also in this case an expensive development would be necessary of as well a proper transmitter on board the FPB as a receiver in torpedo. Also in this case the possibility of jamming exists.

c) Transmission through a wire could be used and this possibility seems immediately to have many advantages because the transmission of orders through a wire is technically a very simple problem. Furthermore since there is no influence to expect from the environment the wire will be a very well-defined transmission-link. And finally there seems not to be any possibilities for jamming but cutting the wire. Using wire-guidance another problem comes up, namely that of paying out the wire from as well the torpedo as from the ship that fired it. Paying out wire from a running torpedo is not a serious problem, since it has been done before, it is however difficult to say very much on beforehand about the difficulties which may arise when a guidance wire has to be paid out from an FPB manoeuvring as its fastest speed. The best way of looking into this problem probably would be to start with as simply an arrangement as possible in order not to let theoretical considerations bring forward more sophisticated constructions than necessary. Finally such trials would be relative simple.

ad 2) The determination of the position was the other main problem. Here one could think of letting the torpedo send out some sort of signals to tell its position, but in this case as in the case of signalling to the torpedo many technical difficulties would be introduced.

Another possibility would be to let the torpedo tell back by a proper arrangement speed and course through the wire. It would then be possible to determine its position by an integration. In practice this would have to be done automatically and such constructions exist to-day.

A third and extremely simple way of determining the position of the torpedo is to calculate what it should be assuming its speed to have the nominal value for the type in question and when the torpedo has to change its course then to change it stepwise counting up the number of steps given.

If in this case the rate of change of the course of the torpedo is kept well above what it would be with a "hard-over" rudder furthermore the turning radii can be expected to be very well defined. This way of determining the torpedo-position may be called dead-rekoning. One price for this simplicity may be a loss in that rapidity with which the torpedo can be turned into a new attack if its fails to hit the first time.

Another factor which will have to be taken into consideration is the certainty with which it is possible to determine the position of the firing ship relative to the position where the torpedo was fired.

This determination is necessary since it is the position of the torpedo relative to the position of the guiding FPB at any moment, which is wanted in order to carry out the steering.

3 This is illustrated on the fig. 3.

In order to estimate the outcome of weapon-system using wire-guided torpedoes and determining the position of the torpedo by dead-rekoning the hitting probability may be calculated. The errors which can cause failure are now mainly the accuracy with which the target position can be determined and the tolerances of the torpedo.

4 The results of such a calculation are given on the fourth table. Again this calculation has been carried out for different tolerances of the torpedo properties and as you may see these properties play a much greater role because of the more accurate target data. The influence of the uncertainties of the navigation is

5 illustrated on the 5. fig. which shows the hitting probabilities for different tolerances of the log.

With that variety of possibilities outlined until now the choise of the Danish Navy has been to work out wire-guided torpedoes as a weapon for the FPBs. Using dead-rekoning as the method for determining the position of the torpedo.

It may be reasonable to sum-up shortly the reasons for that choise.

a) Problems with the oceanographic conditions are avoided
b) An appreciable increase in hitting probability may be expected being independent of target manoeuvers carried out after the torpedo has been fired.
c) The existing torpedoes in the Danish Navy (ex german 67 a's) could be changed for a relatively low price into wire-guided torpedoes. This presume determination of the torpedo-position by dead-rekoning.

6 On the 6. fig. the hitting probabilities for as well the wire-guided torpedo as the torpedo as it is used to-day are given to allow a comparison.

It should be remembered here, that the curve showing the performance of the wire-guided torpedo is independent of target manoeuvers carried out after the torpedo has been fired, while the other curve represent an optimum.

Now let us look upon some details of how the things are going to be worked out in practice.

7 First a sketch on fig. 7 may show you which parts will have to be put into the torpedo,

These are:

1) A receiver amplyfying the steering pulses to the gyro
2) A battery-box
3) A gyro that has the possibility that its reference base can be turned, while it is running. In this case it is the original gyro of the torpedo which has been redesigned.

   The base is turned stepwise by pulses coming through the wire. The step being 1° each and the turning rate 5°/sec.
4) A space for a coil of wire carried by the torpedo together with a proper arrangement for paying out the wire, in this case a tube going to the upper part of the tail. It may be added that the room for the coil is in connection with the sea, so the wire has to be introduced in the torpedo by a watertight plug.
5) The coil of wire. The length of wire will be 13000 m. The wire is paid out from inside. The wire has only one core, the ocean being the other one.

Onboard the ship you will have another coil of wire which will have a lengtn of 18000 m. This coil will probably be put on the deck being in connection with the aft part of the torpedo-tube through a flexible tube. The wire will then, when the torpedo has been fired be pulled out of the front end of the tube by the hydrodynamic force of the water.

A simple guiding arrangement is put on the front end of the tube in order to avoid the wire to be cut by sharp corners.

Secondly: Let us look at the arrangements which will have to be made anboard the firing ship in order to carry out the steering:

1) When the torpedo is fired a calculation of the position of the FPB relative to the firing point must be stated the data given by a gyro and the log.
2) The target data course and speed and position must continously be generated.

3) The relative position of the torpedo must be determined at any moment.

4) The collision course for the torpedo from the position where it may be, must be determined and steering pulses must be transmitted. This would be very difficult to carry out in practice by hand, if a high accuracy is wanted.

So the coming danish FPBs will be equipped with a fire control system, which is designed to carry out the wanted calculations automatically. This fire control system will consist of a number of units and a block-scheme drawn on fig. 8 may be a help here.

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1) It will consist of a target tracker fig. 9 generating the target course, speed, distance and bearing by means of the radar.

2) A computer will belong to the system being able to calculate the torpedo position and the collisioncourse for the torpedo.
The steering pulses to the torpedoes will also be transmitted from the computer to the torpedoes. This computer will have to use the values given by the log.

3) The fire control gyro, which must be a free (not northseeking) gyro in order to avoid errors from the speed and accelerations of the FPB. Furthermore this gyro-assembly is combined with a vertical gyro which serves the purpose af reducing the radar information to a horizontal plane, the reduction itself being carried out by computer.

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4) Finally the system will consist of a torpedo-panel fig. 10, presenting the necessary data on scales to the control officer, who will have this panel in front of him.
This torpedo-panel will be put in a convenient position relative to the PPI on which the torpedoposition will be presented synthetically.
Some details in connection with the fire control may be mentioned.

1) When the torpedo is close to the target even small changes in target data may cause an appreciable change in the torpedo course when the steering is carried out automatically. This is considered inconvenient and unimportant in order to hit. Therefore the automatic steering is blocked, when the distance between the torpedo and the target is calculated to have prefixed value.

2) Because of the tolerances in the real torpedoposition relative to the theoretical position the automatic steering cannot be switch on again before the torpedo has passed on to a certain distance on the other side of the target if it has not hit it.

3) It is at any other moment possible to block the automatic steering and switch it on again. If the steering is blocked the torpedo will proceed on a straight course. Manual steering may then be carried out,

11 fig. 11, this can be of advantage in order to obtain a better angle of hit.

4) If the radar cannot be used it is possible to guide the torpedo automatically along a bearing line to the target. In Danish FPBs this bearing may be given by the optical sight, which is kept as a reserve. An infrared detecting device could be used, when available. The weight of the total fire control system will be approx. 350 kg. and the power consumption will be 0,7 kVA. The system is fully transistorized.

5) More than one torpedo may be fired. In this case the calculated position of the torpedo will be a midpoint of the multiple of torpedoes and the multiple will be guided as a whole.

6) When the torpedoes are fired, they will leave the firing ship at an angle corresponding to the angle between the tube and ship. After a certain time when the torpedoes has obtained a certain distance between each other, they will be taken on parallel courses, whereafter they will be turned against the target.

12 This arrangement, fig. 12, is expected to allow free manoeuvers at any moment during and after the firing for the FPB.