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NAVY DEPARTMENT
DAVID TAYLOR MODEL BASIN
WASHINGTON, D. C.

A PRESENTATION OF THE PROBLEM
OF RUDDER-TRAVEL RATES

by



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UNRESTRICTED

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U.S. Navy Regulations, 1920, Art. 76(11).

August 1947

Report C-7

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INTRODUCTION

Vessels of the United States Navy are provided with steering gears which in general, are designed to move the rudders at a rate of $2 \frac{1}{3}$ degrees per second. This rate is an arbitrary one which does not take into account the differences in the sizes or forms of the vessels.

In the belief that the turning characteristics of the various vessels might be improved by employing a rate of rudder movement different from the standard one, the Bureau of Ships requested (1)* that the David Taylor Model Basin comment on methods of studying the problem of determining the optimum rate of rudder travel for the various classes of naval vessels in service, with a view to establishing design criteria.

DISCUSSION OF PROBLEM

To begin a study of the problem it is instructive to attack it by considering the time relationships between corresponding events on a ship and its model.

The rate of rudder movement on a ship model which is undergoing turning tests should compare with that of the ship directly as the square root of the linear ratio of ship to model. If it is assumed that $2 \frac{1}{3}$ degrees per second is the optimum rate of rudder movement for an aircraft carrier, for example CVB41, then the proper rate for any geometrically similar vessel between 20 feet and 900 feet in length is given by Curve 1 of Figure 1. On this curve have been spotted, in addition to the 900-foot aircraft carrier, a 660-foot cruiser, a 369-foot destroyer, and a 20-foot model, whose basic hull coefficients are sufficiently similar so that each of the smaller hulls may be considered to be a scale model of the largest vessel as far as turning characteristics are concerned. A 163-foot sub-chaser is also included. The sub-chaser has a somewhat larger beam-length ratio than the others but is similar enough for the purposes of this study.

If it is assumed that $2 \frac{1}{3}$ degrees per second is the optimum rate of rudder movement for a destroyer, for example DD692, then the procedure outlined above will give Curve 2 of Figure 1. Curves 1 and 2 show an anomaly in that a 20-foot model, which by a change of appendages can roughly represent either the destroyer or the aircraft carrier, requires a rudder rate of 10 degrees per second in one case and almost 16 degrees per second in the other. Presumably there should be an optimum rate for a particular model regardless of which ship it represents. That is, the rudder rate for the prototype of a model should be a function of the optimum rate for the model and the linear ratio between model and prototype.

* Numbers in parentheses indicate references on page 4 of this report.

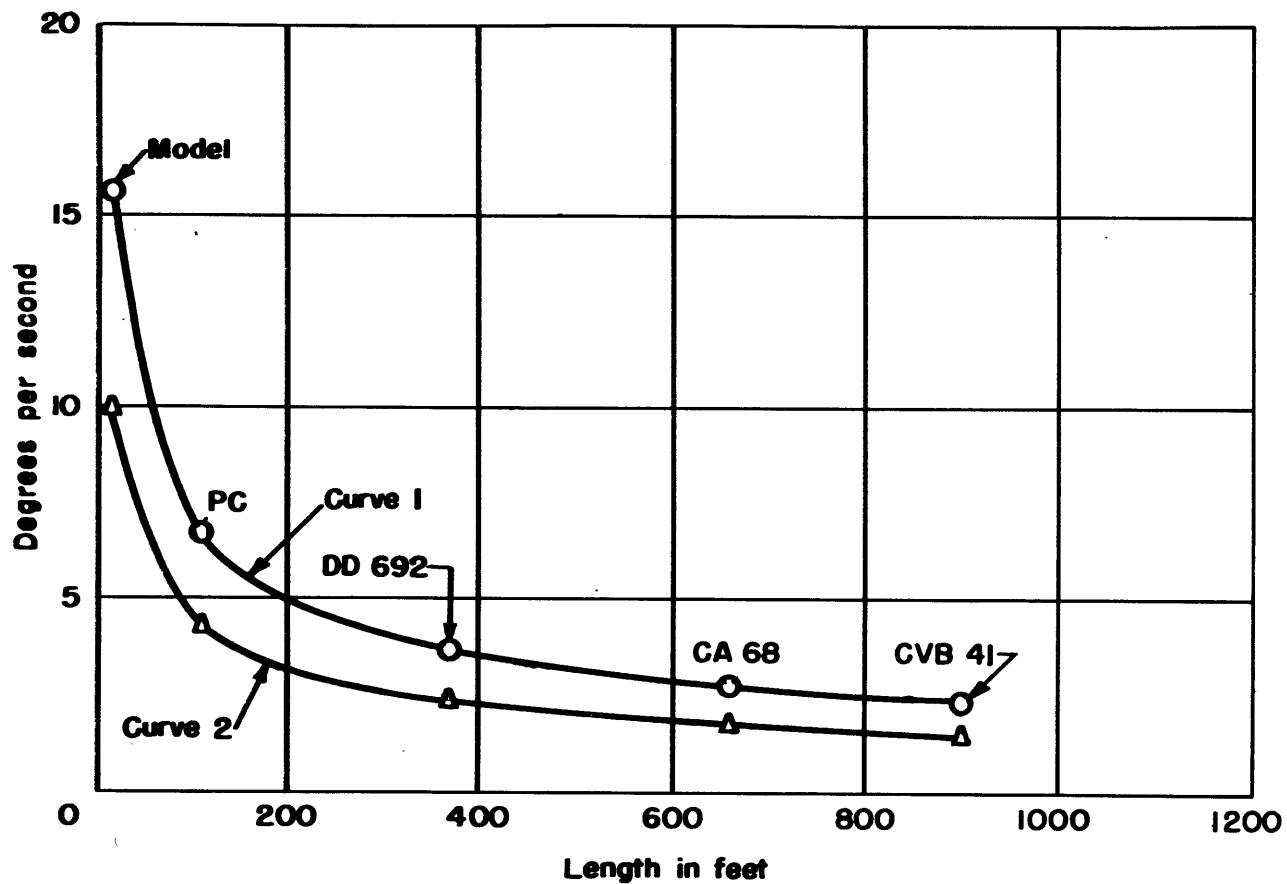


Figure 1 - Variation of Theoretical Rudder Rates with Size of Ship

Curve 1 - Based on nominal rate of 2 1/2 degrees per second for CVB 41

Curve 2 - Based on nominal rate of 2 1/3 degrees per second for DD692

A logical approach to this problem would be to select a representative destroyer model and conduct a series of maneuvering and turning tests in which the rudder rate is varied through as wide a range as might be considered to be of practical value. The optimum rudder rate could easily be determined for that particular type of vessel. The tests should be repeated using a CVB-type aircraft carrier model. A comparison of the optimum rates as determined by these tests would give an indication of the effect of different appendage arrangements on the most effective rudder rate.

In either case the proper full-scale rudder rate could be obtained by a simple expansion of the model rudder rate. If the two models, being of about the same size, show similar optimum rudder rates, then the proper rate for the full-scale ship, be it a destroyer or a carrier, would be a function of its absolute size. If, however, the two models require widely different rudder rates, then it would seem that an extensive series of tests on models of varying hull form and appendage arrangements would be required for the determination of the proper rate for the various types of vessels.

Another variable is introduced when considering the destroyer as the basic type. Since the tactical diameter increases materially at high speed-length ratios it will be necessary to repeat the rudder-rate tests at various speeds in order to bracket any practical combination of speeds and rudder rates. A further extension of the program should be made to compare single- and twin-rudder performances. The full-scale data from the trials of the USS WEST VIRGINIA (BB48) and the USS YORKTOWN (CV5) indicate that a slower than normal rudder rate produced a more rapid change of heading than the normal rate but, in each case there is evidence that the ship was swinging at the time the rudder movement started. Additional full-scale data are considered necessary in order to establish definitely whether the slow rate was more effective than the normal rate.

RECOMMENDATIONS

Rudder-rate tests are now scheduled for a CVL-type aircraft carrier and a destroyer. If the results of these tests prove of value it is recommended that rudder-rate tests be included in the agenda for the BB61 Class battleship tactical trials which probably will be held next year.

A recommended program for rudder-rate tests is outlined in Table 1. This program includes maneuvering model tests for qualitative comparisons in the preliminary exploration. Presumably the effect of varying rudder rates on turning characteristics would be reflected primarily in the initial turning movements rather than in the steady turning circles. Consequently, a comparison of the initial turning movements of the models being maneuvered at various rudder rates would provide a good index of the effect of this variable on turning characteristics. Instrumentation is being developed so that the necessary data may be recorded during maneuvering model tests.



TABLE 1

Recommended Program for Rudder-Rate Tests

Ship	Number of Rudders	Rudder Rate, degrees per second
Full-Scale Tests		
DD849	2	3/4, 1 1/4, 1 3/4, and 2 1/3
CVL48	1	3/4, 1 1/4, 1 3/4, and 2 1/3
BB61 Class	2	3/4, 1 1/4, 1 3/4, and 2 1/3
Model Tests		
DD692 Class	2	5, 10, 15, and 20
DD445 Class	1	5, 10, 15, and 20
CA68 Class	1	5, 10, 15, and 20
CVB41 Class	2	5, 10, 15, and 20

REFERENCES

- (1) BuShips ltr S22-(2)(442-440) of 6 March 1947 to TMB.

