TECHNICAL NOTES

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS.

No. 110

THE EFFECT ON RUDDER CONTROL OF SLIP STREAM BODY, AND GROUND INTERFERENCE.

By H. I. Hoot and D. L. Bacon.

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This investigation was undertaken to determine the relative effects of those factors which may interfere with the rudder control of an airplane, with especial reference to the process of landing. It shows that ground interference is negligible, but that the effects of a large rounded body and of the slip stream may combine to interfere seriously with rudder control at low flying speeds and when taxiing.

Pilots have reported that certain airplanes, particularly those intended for commercial use and having therefore an enclosed cabin of relatively large dimensions, do not respond readily to the rudder when gliding in close proximity to the ground preparatory to landing, and furthermore, were extremely difficult to control while taxiing.

A wind tunnel investigation was therefore undertaken in which the turning moments about the center of gravity of a model biplane produced by rudder angles from -15 to +15 degrees were measured under conditions simulating those encountered in the maneuver of landing an airplane, viz., slow speed flight and gliding at several distances above the ground, in the attitude of a three-point landing, and taxiing.

Three models were used, the first being a 1/15 scale JN4h. No.2 was modified by increasing the depth of the body, maintaining the original width and flat sides, while No.3 was increased in both depth and breadth to a full elliptical section. The relative cross-sectional areas are in the proportion 1 : 1.4 : 2.6. Outlines of these airplanes are given in Fig. 1.

All tests except those for taxiing were made in an air velocity of 20 m/sec (45 m.p.h.) and the propeller speed, except for the glide case, was 16,500 r.p.m. or equivalent to 1100 r.p.m. on an actual airplane. The propeller was an accurate model of that usually used on the JN4h and was driven by a shaft running upstream from the model. The ground was represented by a smooth, varnished wooden surface supported parallel to the air stream and at appropriate distances below the model, measured from the leading edge of the lower wing. The general arrangement of the model, propeller and ground plane may be seen in Fig. 2. The propeller drive shaft extends about 50 chord lengths upstream and there enters a motor-driven gear box.

Numerous tests were required to cover fully the field of the investigation, but of these many showed only the absence of interference, rather than its presence. For this reason only a small portion of the experimental data is reproduced. The entire list of tests is tabulated below in Table I and the data obtained are plotted in Figs. 3 to 6. Tables II and III give the results in a condensed form.

TABLE I.

LIST OF TESTS - INTERFERENCE OF RUDDER CONTROL.

Model No.		1				2				3			
Height above Ground	Angle of Attack	Conditions of Tests.											
7 chord lengths	0°	glide	yaw										
7 " "	15°	"	"										
2 " "	0°	"	"	flight	taxi								
2 " "	15°	"	"	"	"	glide		flight	taxi	glide		flight	taxi
1 " "	0°	"	"	"	"								
1 " "	15°	"	"	"	"								
3 pt. landing	$12\ 1/2^{\circ}$	"	"	"	"	glide	yaw	flight	taxi	glide		flight	taxi

<u>Glide</u> tests are those made without propeller slip stream or yaw.
<u>Yawing</u> tests are without slip stream.
<u>Flight</u> tests are those in which the propeller is turned at a $\frac{V}{ND}$ appropriate for horizontal flight.
<u>Taxi</u> conditions are represented by the use of slip stream corresponding to 1100 r.p.m. of the engine, but without air speed.

CONCLUSIONS.

Angle of Attack.

As a preliminary test, yawing moments N, were measured on model No.1 without ground or slip stream interferences, for different rudder angles, angles of yaw, and angles of attack. Except at extreme yaw the moment was unaffected by a change in angle of attack from 0 to 15 degrees.

Ground Interference.

In the attitude of a three-point landing, with wheels and tail skid just clearing the ground the maximum control moment was 10% less than that without ground interference. The ground effect on rudder control is barely noticeable when the leading edge of the lower plane is two-chord lengths above the ground.

Slip Stream and Body Interference.

The slip stream affects rudder control in two distinct ways. First, it acts unsymmetrically on the rudder and fin, thus causing an initial turning moment when the rudder is in the zero position. Second, it increases the moment because of the additional air velocity past the control surfaces. The former is of course an unpleasant characteristic, the latter on the contrary, is highly desirable.

The extent to which the slip stream affects the empennage is governed by the size and shape of the fuselage and the relative positions of the wings, thrust line, and tail surfaces. Our models varied only in size and shape of body.

The turning moment caused by the slip stream, and the rudder angle required to neutralize it, may be read directly from the intersections of the moment curves with the axes of Fig. 6. The rudder angles required for a straight course, and the slopes of the moment curves are also given in Table II.

TABLE II.

	Angle of Rudder for Straight Course.			Slope of Moment Curve		
Model No.	1	2	3	1	2	3
Gliding at 45 m.p.h.	0	0	0	155	140	140
Flying at 45 m.p.h.	1.6	1.6	2.6	355	350	335
Taxiing at 1100 r.p.m.	5	6	12	90	55	55

In a straight glide the rudder angle on a symmetrically trussed airplane is of course zero. For model No.1 the rudder control in a slow glide is less than one-half, and in taxiing only one-quarter as sensitive as in slow horizontal flight. The maximum control when under power is with a right-hand propeller somewhat less in right-hand than for left-hand turns.

It is noteworthy that a 12° right rudder is required to maintain a straight course when taxiing the No.3 airplane, leaving very little reserve rudder angle for making a voluntary turn toward the right, or for counteracting extraneous disturbances. The narrow, flat-sided body of model No.2 does not give rise to such objectionable control features as does the more rounded body.

Recommendations.

The tests show that it is necessary to consider carefully the rudder and fin design on large-bodied airplanes in order to avoid the probability of poor rudder control.

It is essential that the slip stream should have a sufficient velocity in the neighborhood of the tail surfaces and if, due to the form of the body, this is not readily attainable, the rudder should be increased in size or preferably replaced by two small rudders placed on either side of the center line of the body in order to avoid its shielding effect. The unsymmetrical action of the slip stream may to some extent be compensated for by slightly offsetting the vertical fin, or by placing a sufficient proportion of fin area below the thrust line of the propeller.

TABLE III.

Model No.	1			2			3		
Condition of Test	Flight	Glide	Taxi	Flight	Glide	Taxi	Flight	Glide	Taxi
Rudder at -15°	-6050	-2400	-1850	-5750	-2020	+1230	-5900	-1960	-2700
" " 0°	- 550	0	- 420	- 400	0	- 350	- 400	0	- 650
" " $+15^\circ$	4750	2350	900	4450	2130	490	3800	2000	+ 160

Effect of slip stream and body interference on turning moments.

Angle of attack 12 1/2°, air speed 20 m/sec (except for taxi), propeller speed 16,500 (except for glide), area of rudder, 48.5 cm², distance from C.G. to rudder post - 36.5 cm.

Taxi conditions are represented by the use of slip stream corresponding to 1100 r.p.m. of the engine, but without air speed.

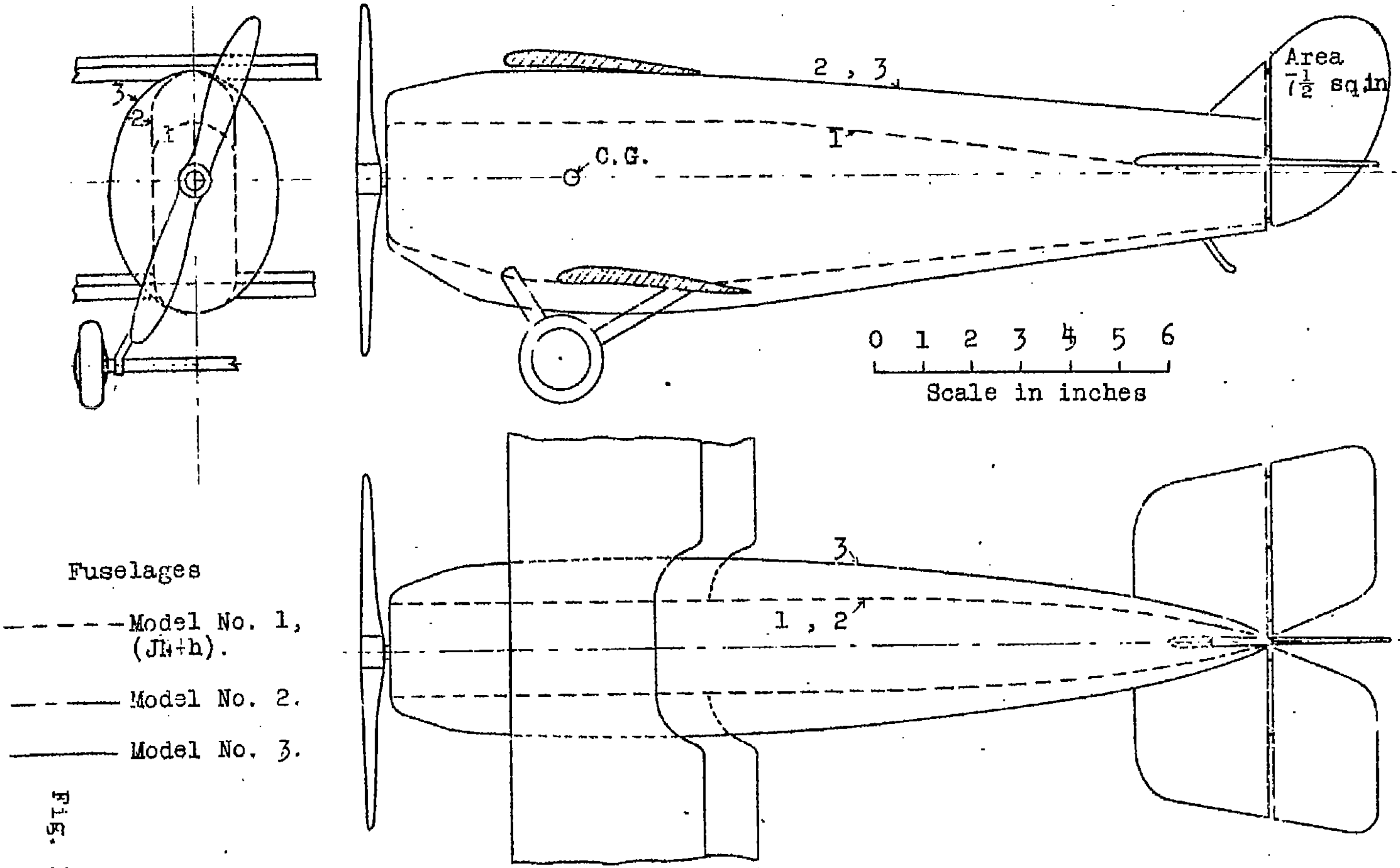

Fig. 1.

Fig. 1 - Outline of Models.

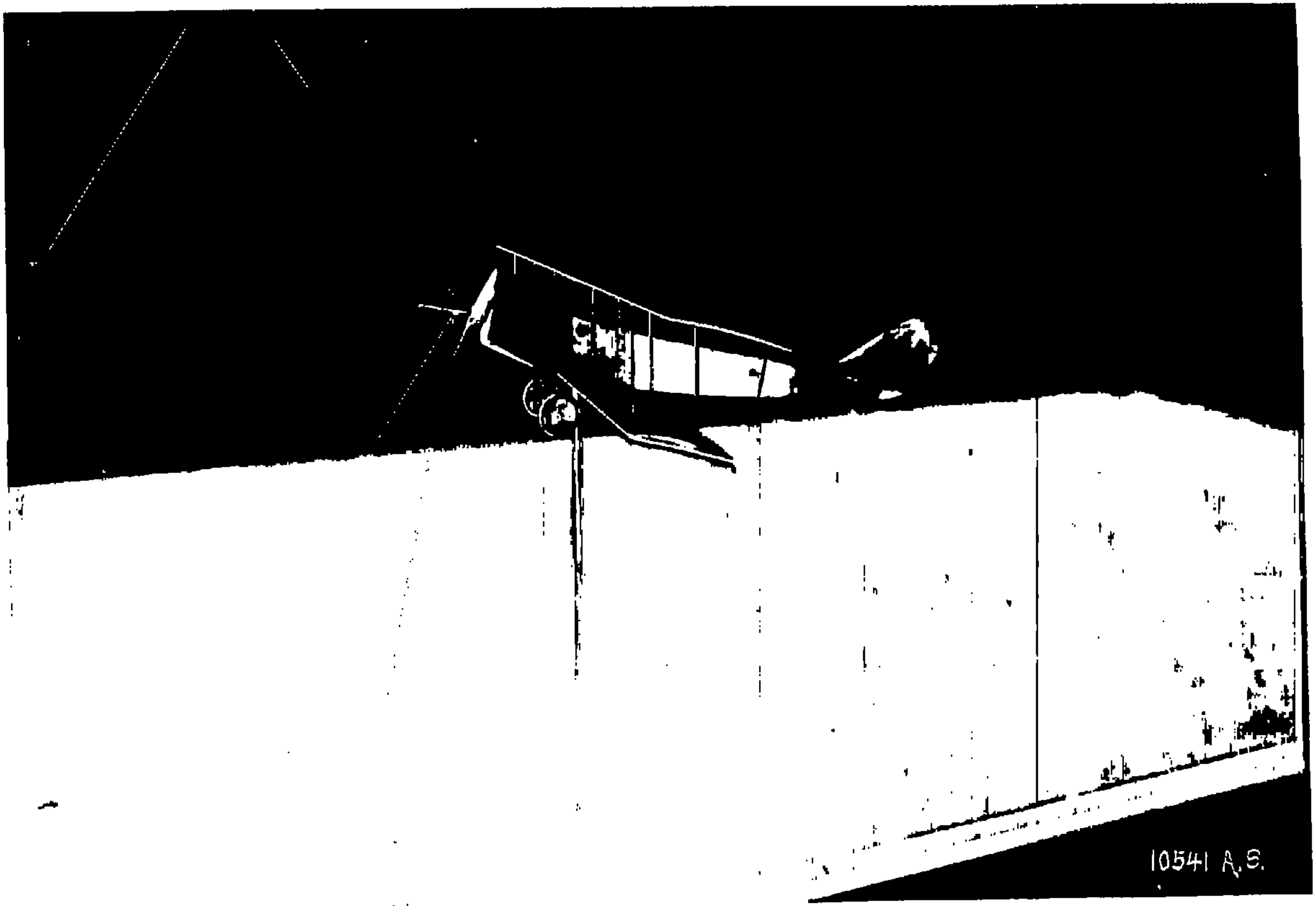

Fig.3. ARRANGEMENT OF MODEL, PROPELLER, AND GROUND PLANE.

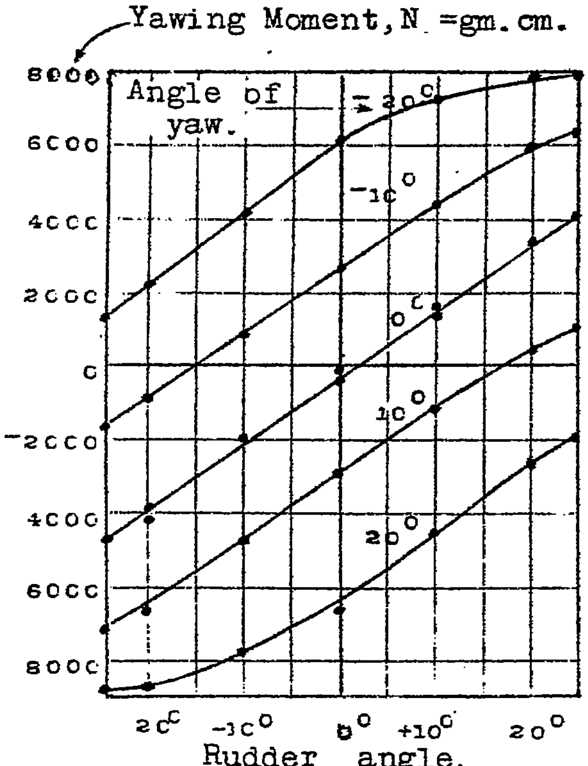

Fig. 3 - No. 1 model without interference. No slip-stream. 15° angle of attack.

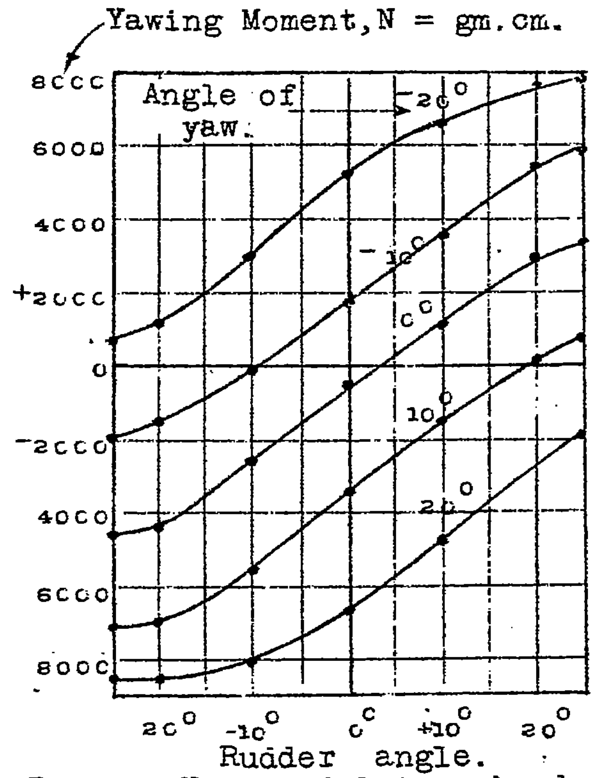

Fig. 4 - No. 1 model two chord lengths above ground. No slip-stream. 15° angle of attack.

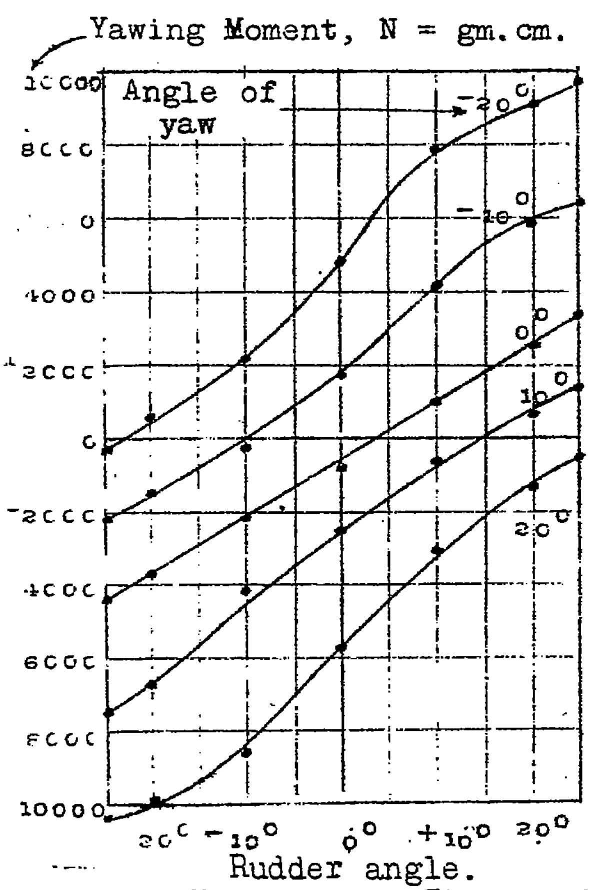

Fig. 5- No. 2 model. Three point landing. No slip-stream. 12.5° angle of attack.

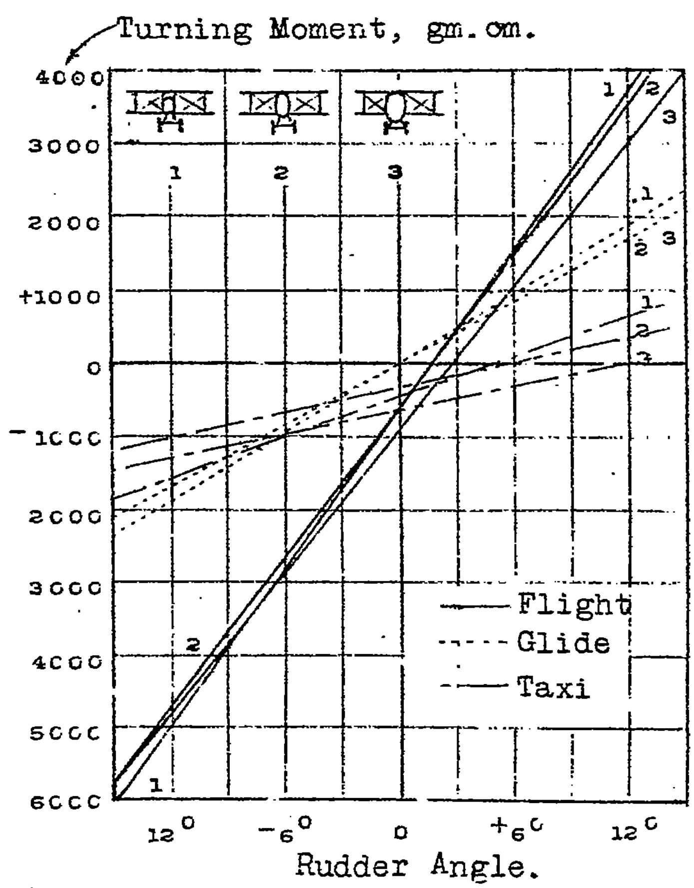

Fig. 6- Comparison of rudder control for different bodies and slip-strea[m] conditions. 12.5° angle of attack.