attempted to answer by discussing fundamental but unsophisticated mathematical models that highlight all essential features (Ref. 1 of Dzung's comment). I have exposed the statement (Ref. 2 of Dzung's comment) that this material is the same as found in the countless applications of routine classical procedures. In addition, the false impression has been created that Dzung's Ref. 1 deals only with this subject. It contains many other items, including a variational approach to boundary-layer heat transfer which is of drastic simplicity and remarkable accuracy. This is in contrast with the extremely elaborate procedure of Dzung's Refs. 3 and 4, which are more suitable for dealing with the Schroedinger equation than with engineering problems.

This paper (Dzung's Ref. 1) also prepared the ground for a companion paper that follows and deals with the more difficult problem of coupling between a solid and a moving fluid in transient heat flow.

Spontaneous Ignitability of Nonhypergolic Propellants under Suitable Conditions

N. L. Munjal*
Gorakhpur University, Gorakhpur, India

BIPROPELLANTS used in rockets are classified as hypergolic (self-igniting) and nonhypergolic (non-self-igniting). Ignition usually is preceded by exothermic chemical reactions. If the heat generated is not enough to raise the temperature of the vapor or gaseous reaction mixture to the ignition temperature, the flame will not be produced. Ignition will not take place if the vapor is intrinsically nonignitable. In general, the former factor is responsible for the inability of several bipropellants to ignite spontaneously. It appears, therefore, that, if the chemical reaction preceding ignition can be accelerated, spontaneous ignition can occur. Suitable additives can be employed for this purpose. It is the purpose of this comment to report the role of such additives.

The nonhypergolic fuels used in the investigation were m-cresol, furfural, cyclohexanol, anisole, and triethanolamine, which were of laboratory grade. For oxidizer, red-fuming nitric acid (density 1.5 g/cm^3) containing 6% nitrogen oxides was used. These fuels did not ignite with it, but in few cases red-fuming nitric acid containing 5% potassium permanganate was used to make the fuel self-igniting. The ignition delay was measured by the cup-test method, as described earlier.[1] The fuel and the oxidizer were taken by volume. The volume of the oxidizer taken was 1.1 ml, and the volumes of m-cresol, furfural, cyclohexanol, anisole, and triethanolamine were taken as 0.6, 0.6, 0.6, 0.6, and 0.8 ml each time, respectively.

The results given in Table 1 show that the forementioned fuels become hypergolic when red-fuming nitric acid containing potassium permanganate is used. Similar behavior of potassium permanganate is known for the gasoline/red-fuming nitric acid system.[2] The mechanism of action of potassium permanganate is under investigation.

Table 1 Average ignition delay using red-fuming nitric acid

Fuel	With $KMnO_4$, sec
m-cresol	0.30
furfural	10.0
cyclohexanol	8.0
anisole	erratic
triethanolamine	3.0

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* Research Fellow, Chemistry Department.

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Comments on "Wing-Tail Interference as a Cause of 'Magnus' Effects on a Finned Missile"

A. S. Platou*
Ballistic Research Laboratories, Aberdeen Proving Ground, Md.

HAVING read Benton's paper[1] recently, the author finds that an additional description of the flow over a rotating wing is necessary in order to understand it. The author agrees with Benton's conclusions concerning wing-tail interference creating a side force but does not agree with his picture of the mechanism involved.

The angle of attack on a rotating wing varies linearly along the span of the wing according to $\alpha = \omega r/U$. Here ω is the spin rate, r is the spanwise distance from the centerline of rotation, and U is the freestream velocity. In turn, the spanwise lift distribution is not only a function of the stationary wing factors but also the variation of angle of attack along the span. The spin changes the lift distribution on the wing and makes it necessary to integrate along the span in order to determine the resultant lift force and its center of pressure. The forementioned alters the flow and force pattern present on a stationary wing and must be considered in analyzing the conditions existing on a rotating wing.

It also is interesting to note that when free spin conditions exist on a cruciform wing plus body ($\delta \neq 0$, $\alpha = 0$), such as in Benton's paper, the resulting rolling moment on each wing must be zero ($\int r dL = 0$). However, the lift force is not zero on all sections of the wing but varies from positive values (tends to increase spin) on inboard sections to negative values on outboard sections. Under free spin conditions the resultant lift on each wing, which must be located on the body centerline, is in the direction of the inboard lift. However, the resultant lift on a symmetrical configuration at $\alpha = 0°$ will be zero, for the lift on opposing wings will cancel.

From Benton's paper it is seen that, when the wing-tail configuration reaches $\alpha = 10.5°$, the upper tail fin (fin d) is clear of the wing vortices and is subject only to freestream conditions. In this case the lift (side) force on the fin can be computed from

$$L = q \frac{dC_L}{d\alpha} \frac{P_{WBT}}{U} \int_{r_1}^{r_2} r \, ds$$

Here r is the span distance from the body axis, r_1 and r_2 are the span distances to the root and tip chord, and ds is the incremental wing area. However, fin b at the same time is immersed fully in the vortex pattern so that it is no longer subject to freestream conditions. Instead, its lift (side)

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* Research Engineer, Supersonic Wind Tunnels.

force distribution will be modified by the vortex pattern, and the modification will be a function of the fin location in the vortex pattern. If the forces on fins b and d are different, then a resultant lift (side) force exists. In general, it has been found that the resultant side force acts opposite to the body magnus force. (The forementioned reasoning has assumed a roll position where fins b and d are in the angle-of-attack plane. Similar reasoning using all four fins can be used at other roll positions.)

If η_d and η_b are considered to be due only to the influence of the wing-vortex pattern, then an additional term must be added to Eqs. (27) and (29) of Ref. 1 to account for the lift (side) forces due to rotation of the fins. Also, when a fin is immersed completely in the vortex pattern, its lift need not be equal to the wing lift as stipulated in Eq. (32) of Ref. 1 $[\eta_b(\alpha_d) = 1]$. Its lift will be a function of the fin position in the vortex pattern. Since the details of the wing-body vortex or wake pattern have not been computed, it appears that the fin forces cannot be computed easily.

During the past year a series of wind tunnel tests on a finned spinning missile have been run in the Ballistic Research Laboratories' tunnels with the objective of obtaining magnus forces and moments. This configuration does not have wings, and the fins are the same diameter as the major body diameter. The configuration depends on the body-fin interference to produce the magnus forces and moments. Sufficient room is not available here to describe these tests, but the results have been published in Ref. 2.

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Reply by Author to A. S. Platou

EDWARD R. BENTON*
National Center for Atmospheric Research, Boulder, Colo.

THE author of Ref. 1 wishes to thank Platou for his instructive comments.[2] However, they do not basically disagree with the original paper but rather lead to some higher-order corrections to the theory. The main implication of Ref. 2 is that the effects of roll rate were not properly accounted for in Ref. 1 when the forces and moments on rotating wing and tail panels were dealt with. Actually, these effects were considered, but they were found to be much smaller than the main effects described.

In his second paragraph, Platou correctly points out that the rotation of a wing panel produces a distribution of effective angle of attack that varies linearly with spanwise distance from the axis of rotation. The loading that accompanies this distribution is also proportional to roll rate, and it must be added to that arising from wing stationary factors. Consequently, there is a force and a moment "due to roll rate." This was discussed in Sec. 5 of Ref. 1 (see pp. 1362–1363). The moment, of course, is just the well-known roll damping moment. When it is added to the rolling moment due to wing deflection, the total rolling moment on each panel is found to be zero, as it must be under free spin conditions (refer to last paragraph on p. 1362, Ref. 1).

The real point raised by Platou is that, even though the rolling moment is zero, there is a net lift force on each wing panel. This is correct, but, as implied in Ref. 1 (top of p. 1363), this net force is, to a first approximation, negligible. In fact, it can be shown to be considerably smaller than either of the component forces (due to panel deflection and roll rate), which make up the net panel force. References 3 and 4 imply that the spanwise centers of pressure for the forces due to deflection and roll rate are at about 0.76 and 0.60 of the exposed semispan, respectively. Together with the fact that the net moment on each panel is zero, this implies that, for the present missile, the net lift force is less than $\frac{1}{5}$ of the force due to panel deflection. Moreover, the net forces on panels 2 and 4 are directed oppositely, so the total side force is indeed small. This net side force is zero at $\alpha = 0$, by symmetry. Furthermore, Fig. 4 of Ref. 1 shows that experimentally, it remained zero for all α up to 8°. This further confirms the belief that these net side forces on each panel are considerably smaller than the primary forces dealt with. Whereas such forces are unimportant for the wing-body combination, a more accurate theory than that of Ref. 1 would attempt to take into account the influence of these forces in determining tail loads.

The rest of Platou's comment is quite correct, but it applies to a range of interest deliberately excluded from Ref. 1. The tail interference factors used in Eqs. (27) and (29) of Ref. 1 do not include the effects of roll rate. This should involve no appreciable error so long as all four tail panels mostly are immersed in the vortex wake. This condition holds for the range of α between 0 and 8°, which is the only range discussed in Ref. 1. For higher α, the forces and moments become nonlinear with angle of attack. Certainly, one of the nonlinear effects to be expected is the one surmised by Platou, which occurs when one panel experiences free-stream conditions while the other one still is immersed in the wake.

Finally, it should be pointed out that the condition expressed in Eq. (32) of Ref. 1 is not a stipulation, as stated in Ref. 2, but rather an assumption of the theory which is plausible (at least to the author), and whose ultimate justification is that it predicts results of the right magnitude. Actually, as mentioned in the paragraph immediately following Eq. (32), it is not assumed that the lift of one tail panel is the same as on one wing panel but only that the total side load developed on the two relevant tail panels is equal in magnitude to the lift on one wing panel.

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* Staff Scientist. Member AIAA.

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Motion in a Soap Film

C. A. M. VAN DER LINDEN* AND A. RIETDIJK†
Werkspoor N.V., Amsterdam, Netherlands

Nomenclature

h = thickness
σ = specific weight
T = surface tension
r,φ,x = coordinates

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* Mathematician, Department for Engineering Research.

† Mechanical Engineer, Department for Engineering Research