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Lifting Surfaces and Bodies with a Sliding Skin

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Synopsis: The working principle of lift production by a 'sliding skin' is explained. Preliminary experimental results are promising. More development work is needed for specific applications in airplanes, ships and flow engines.

Introduction

It is well-known to aerodynamicists and other physicists that a lift force can be produced by rotating a circular cylinder and by placing it roughly perpendicular to a free fluid stream(Fig. 1). Although the magnitude of the lift force is attractive at the higher rotational speeds, the drag force remains rather great in comparison with the lift and so prevents the successful application of rotating cylinders as lift-producing components for airplanes, ships, flow engines, etc. [1].

The drag force can be lowered to an acceptable value by decreasing the frontal area and by otherwise reshaping this lifting surface (Fig. 2 and 3 respectively). The device of Fig. 3 was tested in the 1930's and the lift and drag measurements were encouraging [2]. However, the surface in Fig. 3 as well as that in Fig. 2 has rollers carrying and driving endless moving belts. This is a complicating design feature and prevents their successful application as lift-producing components.

An alternative, less complicating design feature is shown in Fig. 4. Here, the lifting surfaces are enveloped by an endless belt that is loose, flexible, thin and movable. A gas film is interposed between belt and surface. The fluid enters continuously at high pressure through inlet restrictions at the smaller radii of curvature. The laminar film flow is directed mainly in circumferential direction towards the greater radii of curvature where pressures are much lower. Here, the fluid is bled via rather wide outlet restrictions. The cross-section shown in Fig. 4 is elliptical. This is one of the shapes that makes it possible to balance the local pressure in the fluid film and the stresses in the flexible belt and so completely separate belt and surface. Sliding of the belt is possible by locally cutting grooves and so creating a favourable shear stress distribution acting on the inner side of the belt. Indeed, the shear stress distribution can be so designed that its resultant may drive the belt up to great sliding speeds [3].

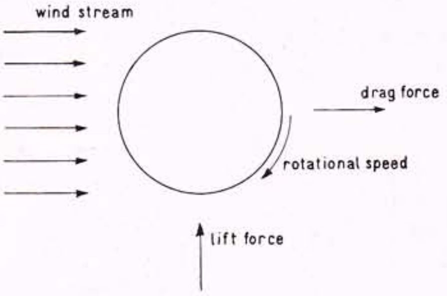

Fig. 1. Forces acting on a long rotating cylinder in a free stream.

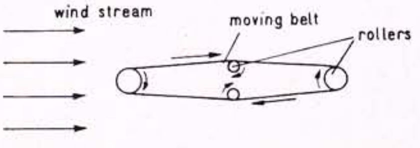

Fig. 2. Rollers carrying and driving on endless moving belt.

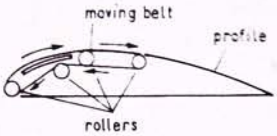

Fig. 3. Lifting body.

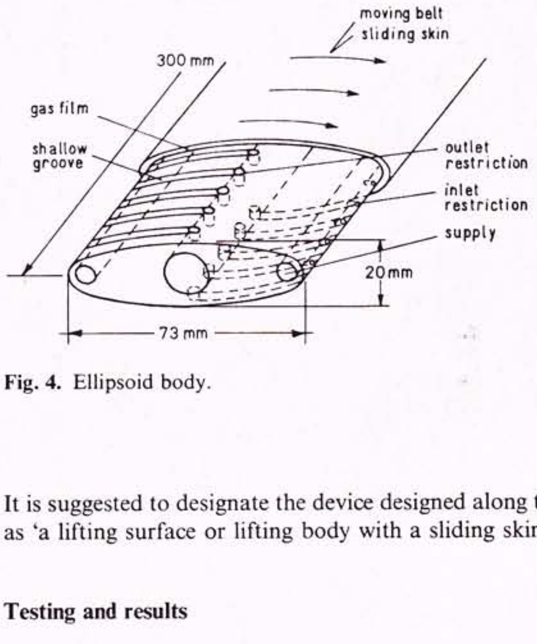

Fig. 4. Ellipsoid body.

It is suggested to designate the device designed along these lines as 'a lifting surface or lifting body with a sliding skin'[1]).

Testing and results

The elliptical body with a sliding skin shown in Fig. 4 has been tested in a wind tunnel of 0.3 m diameter. The ellipsoid was placed close to the end in the midplane perpendicular to the rotational axis of the tunnel. Three angles of attack (i.e. the angle between the midplane and the chord of the ellipsoid) were used: −10, 0, and + 10 degrees. Windspeed could be varied between 0 and 20 m/s. The speed of the sliding skin was either 0 or 2500

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[1]) Patent applied for.

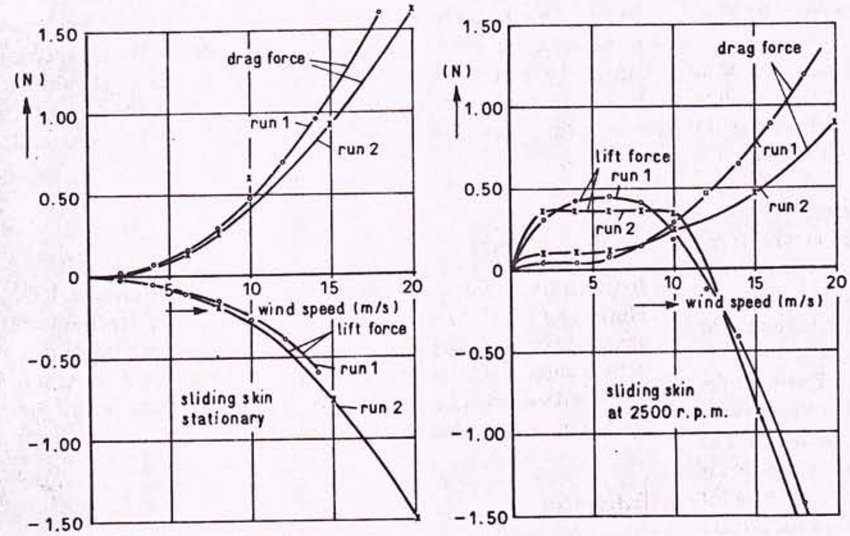

Fig. 5. Experimental results for a *negative* angle of attack.

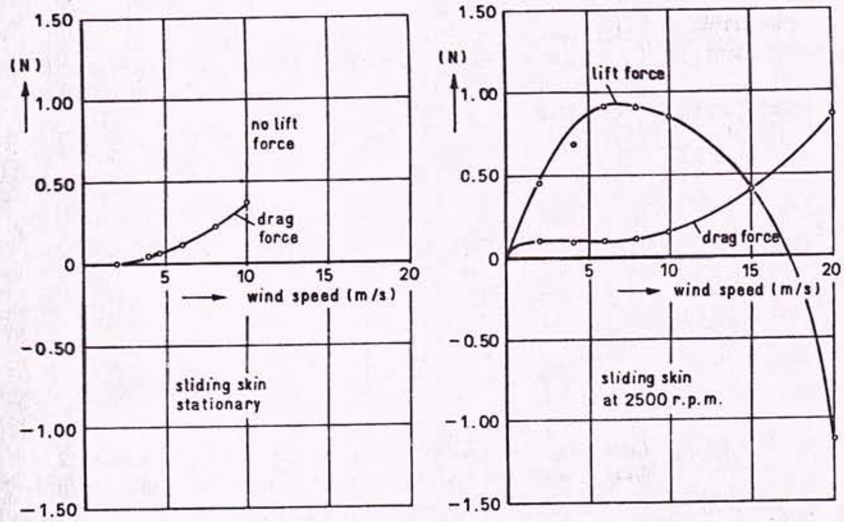

Fig. 6. Experimental results for a *zero* angle of attack.

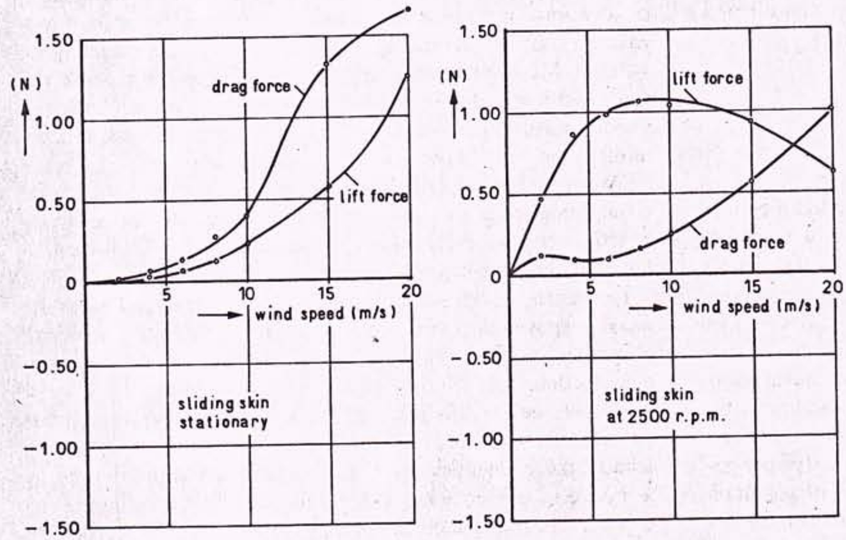

Fig. 7. Experimental results for a *positive* angle of attack.

r.p.m. A dimensional presentation of the tests is given in Figs. 5, 6 and 7.

In Fig. 5 the angle of attack is negative: −10 degrees. With the skin stationary the lift force is negative and the absolute value of the drag force is slightly greater than that of the lift force. The direction of sliding of the skin is such that the lift force becomes positive for a speed of 2500 r.p.m. (linear skin-surface speed ~ 7 m/s) at moderate wind speeds. For wind speeds much greater than the linear sliding speeds, the lift turns negative again. The magnitude of the lift is maximum in a regime where the wind speed is roughly equal to the linear sliding speed. Fig. 5 gives graphs from two runs: the difference between the data from both runs shows that the repeatability is poor. No differences of this magnitude were encountered with angles of attack of 0 and +10 degrees (Figs. 6 and 7 respectively).

In Fig. 6 the actual angle of attack may differ ± 1 degree. The criterion that was used for a zero angle of attack to be reached is a zero lift force. Anyhow, by sliding the skin at 2500 r.p.m. a lift force could be produced of almost 1 N. This lift is much greater than the value obtained with a negative angle of attack. In Fig. 7 the angle of attack is +10 degrees. The lift is only slightly greater than in the previous case. However, the region with a maximum lift extends up to higher wind speeds.

The three Figures 5, 6 and 7 clearly show that an appreciable lift force can be produced by the sliding skin and that the drag force is hardly affected by the sliding motion.

A comparison with existing methods for producing more lift and less drag would show that the sliding skin needs more development work. For making sliding skins competitive, sliding speeds should be in the order of 50 m/s and cross-sections should be more slender than the one depicted in Fig. 4. Also, the power for supporting and driving the skin should be determined and minized.

Acknowledgement

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[3] HIRS, G. G.: Externally pressurized bearings with inherent friction compensation. Trans. ASME Series E, Journal of Applied Mechanics, June 1965, p. 285.