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A POSSIBILITY OF AVOIDING SURFACE ROUGHNESS DUE TO INSECTS

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16. Abstract

Discussion of a method for eliminating turbulence caused by the formation of "insect roughness" upon the leading edges and fuselage, particularly in aircraft using BLC. The proposed technique foresees the use of elastic surfaces on which insect roughness cannot form. The operational characteristics of highly elastic rubber surface fastened to the wing leading edges and fuselage edges are examined. Some preliminary test results are presented. The technique is seen to be advantageous primarily for short-haul operations.

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A POSSIBILITY OF AVOIDING SURFACE ROUGHNESS DUE TO INSECTS

F.X. Wortmann

1. Overview

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Upon collision of insects with fuselage and leading wing edges a roughness is produced which is normally great enough to generate an immediate turbulence. Thus, the insect-roughness considerably deteriorates the aerodynamic performance of an aircraft. A premature turbulence is undesirable especially in those cases where a significant reduction in resistance could be achieved on aerodynamically smooth surfaces by keeping the boundary layer laminar. This insect problem will only be solved by taking into account that the boundary layer is to be kept completely laminar through suction. The methods proposed heretofore to eliminate insect roughness are relatively complicated. They are all aimed more or less at protecting the leading wing edges with protective coatings before take-off; these coatings would then be jettisoned or washed off at greater altitude, i.e. above the insect zone. Such methods and pertinent questions about them are reported in detail in [1].

It is instructive that cumbersome take-off preparations can however, also include a suction step for long-range aircraft. For short-range aircraft which do not even leave the insect zone, or for aircraft which only partly desire a laminar flow, e.g. through laminar profiles, the solution to the insect problem should rely on simpler methods. In the author's opinion, elastic surfaces offer one such possibility, since they do not allow the generation of insect roughness in the first place.

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*Numbers in the margin refer to pagination in the original text.

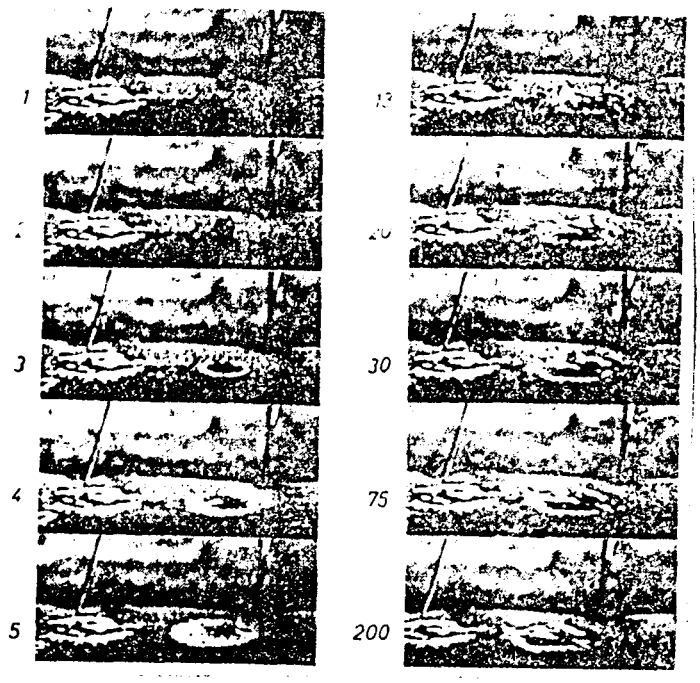

Fig. 1: Impact of a Drop of Water on a Foam Rubber Surface on the Right Side of the Photo. On the left, a similar drop at the end of the Impact. Impact velocity about 5 m/s. Picture sequence: 6000 exposures per second. The numbers indicate the picture numbers of the film.

2. Action of Elastic Surfaces

At higher impact velocities even small insects have a kinetic energy sufficient to cause disintegration of the insect shell and distribution of the viscous body fluid upon impact on solid surfaces.[1] If the second process can be prevented, then the first process can be viewed as insignificant. Thus below, the insect will be viewed as a viscous drop of liquid. Now it is suggested to store the impact energy for a brief time in an elastic "spring" and to use it to decelerate the drop of liquid. Whether this will succeed will depend primarily on the following parameters--as one can easily see.

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[1] If one's hand is held in an air stream moving at about 150 km/h and filled with fruit flies, then each impact is felt as a small pain.

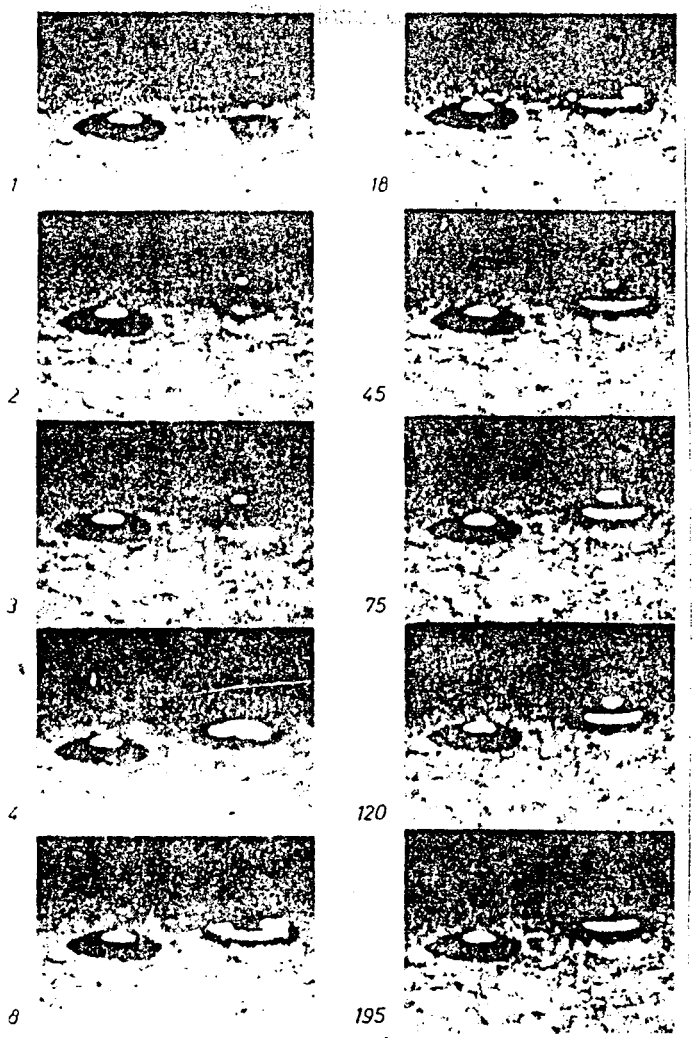

Fig. 2: Impact of a Drop of Oil on a Foam Rubber Surface. Left: A drop at the end of the impact Process. Impact Velocity about 7 m/s. Image frequency: 6000 exposures per second.

1. The mass of the spring must be sufficiently small, otherwise the spring will not be compressed.
2. The vibration period of the system must be so small that the viscous drop is not distorted too much during this time.
3. The spring damping should also remain sufficiently small, even at high frequencies, in order for sufficient energy to be available to separate the drop from the wetted surface.
4. The separation process should be promoted by poorly wettable surfaces.

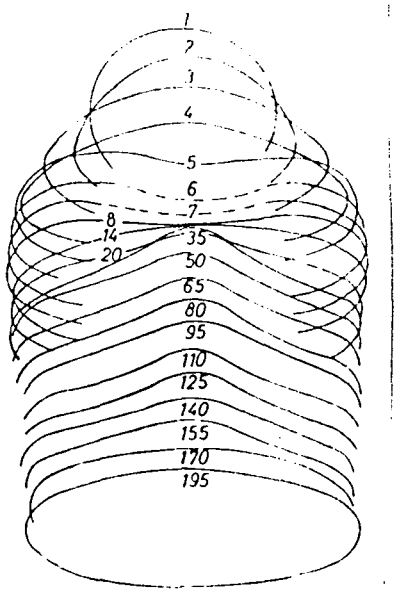

Fig. 3: Contour of the Oil Drop upon Impact on a Foam Rubber Surface. The numbers denote the picture numbers of the film. Image frequency: 6000 exposures per second.

Figure 1 shows the impact of a droplet of water at low velocity. The droplet has such low viscosity that it splits apart before any reflection occurs.

Figure 2 shows the same process with a drop of oil. Now we clearly see the vibration shape of the droplet, which is shown enlarged in figure 3. The impact energy is not sufficient however, to separate the droplet from the surface.

Figure 4 shows several photos of a water droplet impacting a silicon rubber surface at a speed of 150 m/s.[2] Now we clearly see the reflection and separation of the drop from the elastic surface. A small part of the drop evidently adheres to the surface.

3. Tests With Insects

Naturally these few tests simulating insects by a drop of fluid and using only perpendicular impact, will permit only a few basic findings on the effectiveness of elastic surfaces. Thus, additional tests with real insects were conducted in summer 1961 and 1962 using various elastic surfaces under different types of conditions.

[2]These photos were taken by Mr. E. Wieland of Dornier-System Co. using a high-frequency camera developed by G. Hahn [2].

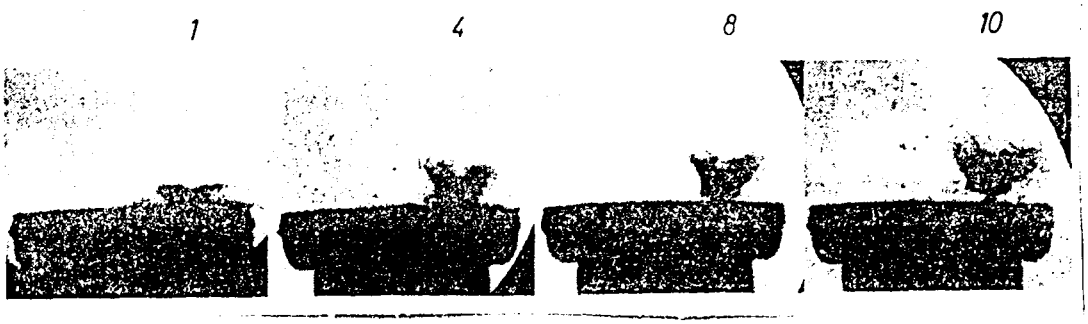

Figure 4: Reflection of a Water Drop upon Impact on a Silicon Rubber Layer. Impact speed about 150 m/s. Image frequency: 85,000 per second. The numbers denote the picture numbers of the film.

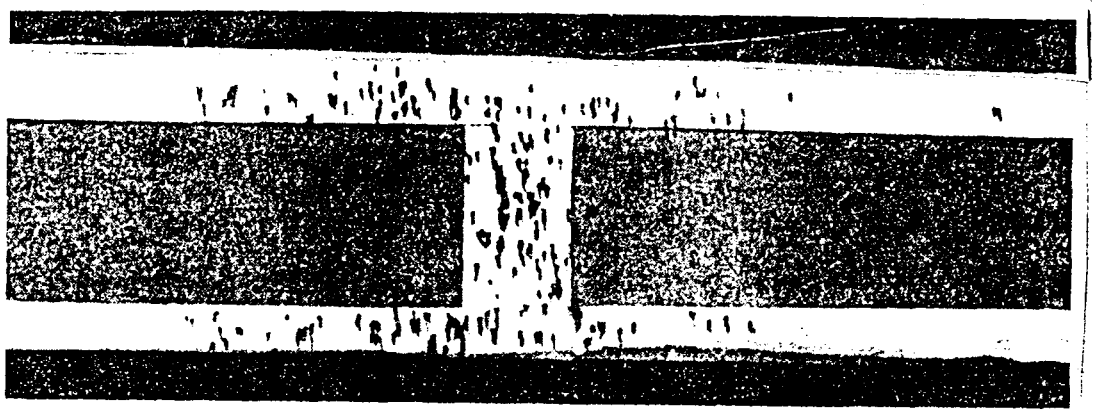

Figure 5: Fruit Flies in Perpendicular Impact on a 3 mm-thick Silicon Rubber Plate. Impact speed about 50 m/s. The dark spots on the rubber are points impact. The white adhesive strip is used to attach the rubber.

The tests were concentrated on solid rubber and foam rubber surfaces of 1 - 3 mm thickness with Shore-hardnesses of 10 - 35. Figure 5 shows a typical result of a wind tunnel test with perpendicular impact of fruit flies on a 3 mm-thick solid rubber surface.[3] Figure 6 shows the result of another wind tunnel test with various rubber samples and variable angles of impact.

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[3]My thanks go to Mr. Hamma for his untiring assistance in these tests.

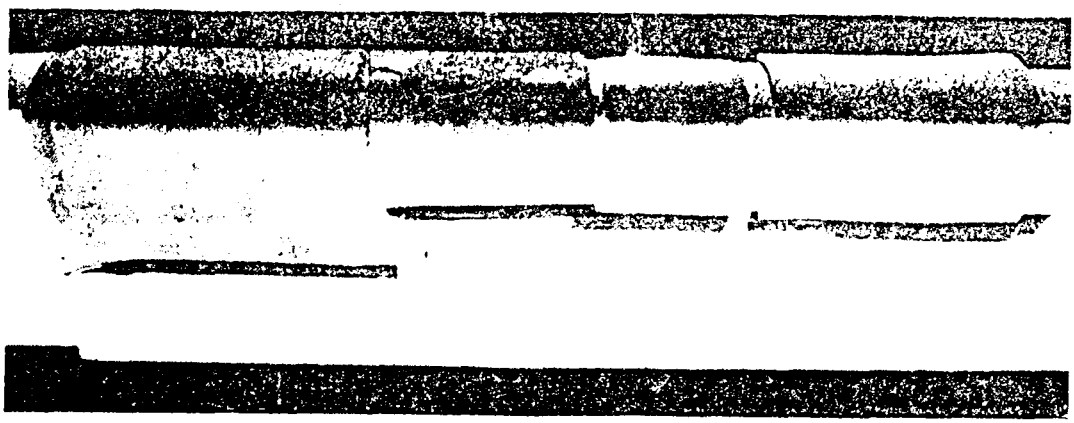

Fig. 6a: Testing of Various Rubber Samples with Fruit Flies. Impact speed about 50 m/s. Right: A 3 mm-thick Silicon Foam Rubber

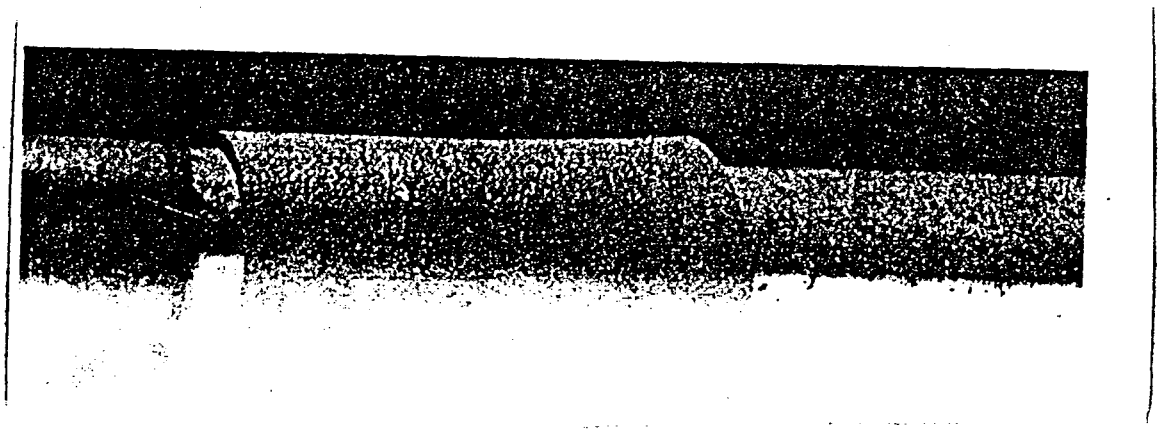

Fig. 6b: Sectional Enlargement of Fig. 6a. The 3 mm-thick Silicon Foam Rubber Allows the Generation of No Insect Roughness. The same Rubber can also be Produced with a Smooth Surface.

Besides these wind tunnel tests which were limited to practically one type of fly--the fruit fly--similar rubber samples were also attached to vehicles and training aircraft and observed daily in suitable weather. In all these tests practically no insect roughness was found on several rubber surfaces.[4] However, tiny traces of liquid remain which change the optical appearance of the surface somewhat, so that one can indeed determine whether or not insects have indeed impacted. Thin rubber membranes about 1 mm-thick are not fully effective above a speed of about 100 km/h. The 3 mm-thick rubber plates were satisfactory in the entire investigated velocity range, i.e. from 40 km/h to about 200 km/h,

[4] In aircraft with a pneumatic rubber deicing system, this effect is practically not observed because the rubber is hardly elastic.

but the rubber samples did exhibit some differences with regard to liquid residues, as can be seen in figure 4. On several rubber samples larger liquid residues and sometimes even insect parts remained,[5] on other samples, especially silicon samples or powdered samples, only tiny traces are visible. A silicon foam rubber with a high air content and a specific weight of about 0.6 proved to be particularly favorable.[6]

In a technical application of highly-elastic rubber plates to create aerodynamically smooth surfaces, additional requirements now also require attention. For example, the elastic surface might not simultaneously provide protection against icing because the mass of subcooled droplets will at least in part be too small to compress the rubber "spring." But it is possible to use the rubber plate like the pneumatic deicing systems without loosing their protective effect against insects.

For more severely pointed wings, elastic surfaces might not be practical because laminar flow can exist there only due to a suction beginning at the wingtip.

In addition, a rubber layer has a higher velocity limit--depending on its density--at which rain-erosion begins. For the light silicon foam rubber used here, this limit is reached at a Mach number of $M = 0.35$; for silicon solid rubber, it is at about $M = 0.6$[7]. A deformation due to the maximum flight stagnation pressure need not be feared in subsonic flight. Since such rubber surfaces are weather-resistant, are easily adhered and a nice fit of rubber surface to normal surface is relatively easily achieved, a simple solution to the insect problem might be developed from this. It would be of primary interest for aircraft

[5]This was observed however, only in wind tunnel tests with high insect densities, probably due to unfavorable interference in the impact process.

[6]This silicon foam rubber was obtained from Rehau-Plastics, Rehau, Bavaria.

[7]According to observations by Dornier-System Co.

operating mainly at low and medium altitudes and on aerodynamically smooth surfaces having a partial or complete laminar friction layer.

Summary

It is proposed to solve the problem of insect roughness by highly elastic rubber surfaces attached to wing and rubber leading edges. Such elastic surfaces are suitable--as high-speed photography shows--to reflect impacting insects or viscous liquid drops elastically. This alone will prevent the generation of insect roughness and the endangered fuselage and leading wing edges remain aerodynamically smooth. Perhaps the simplicity of this method will contribute to the possibility of reducing friction through retaining laminar flow at the boundary layer.

[1] W.S. Coleman: "Roughness due to Insects," Lachmann, "Boundary Layer and Flow Control," Pergamon, London 1961.

[2] G. Hahn: "A Simple, High-Frequency Cinematographic Tool for Interferometric Photography of Instationary Flows at a Frequency up to 3.3 x 10^6 frames/second." Kurzzeitphotographie pp. 257-266, Hellwig, Darmstadt 1960.

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