NASA TM- 76559

NASA TECHNICAL MEMORANDUM NASA TM-76559

EXISTENCE OF A NATURAL INSTABILITY NOT PREDICTED BY THEORY AND CONNECTED TO A WALL DEFORMATION IN A LAMINAR BOUNDARY LAYER

Pierre Gougat and Francoise Martin

Translation of "Existence dans la couche limite laminaire, d'une instabilité naturelle, non prévue par la théorie, et liée à une déformation de paroi". Academie des Sciences (Paris), Comptes Rendus, Serie A - Sciences Mathematiques, Vol. 275, No. 18, October 30, 1972, pp 845-848

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
WASHINGTON D.C. 20546 JUNE 1981

STANDARD TITLE PAGE

1. Report No. NASA TM-76559	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle EXISTENCE OF A NATURAL INSTABILITY NOT PREDICTED BY THEORY AND CONNECTED TO A WALL DEFORMATION IN A LAMINAR BOUNDARY LAYER		5. Report Date JUNE 1981
		6. Performing Organization Code
7. Author(s) Pierre Gougat, Francoise Martin		8. Performing Organization Report No.
		10. Work Unit No.
9. Performing Organization Name and Address SCITRAN Box 5456 Santa Barbara, CA 93108		11. Contract or Grant No. NASw- 3198
		13. Type of Report and Period Covered Translation
12. Sponsoring Agency Name and Address National Aeronautics and Space Administration Washington, D.C. 20546		14. Sponsoring Agency Code

15. Supplementary Notes Translation of "Existence dans la couche limite laminaire d'une instabilite naturelle, non prevue par la theorie, et liee a une deformation de paroi". Academie des Sciences (Paris), Comptes Rendus, Serie A - Sciences Mathematiques, V. 275, No. 18, October 30, 1972, pp 845-848

16. Abstract

The study of natural instabilities which propagate in a laminar boundary layer of a flat plate has shown the agreement which exists between stability theory and experiments. If a wall has a deformation, a second frequency exists, f_2, which is not predicted by the theory, and which is twice the first frequency, f_1. This second unstable frequency only appears if there is a negative velocity gradient. This phenomenon is located very close to the wall, and drops off rapidly when one moves away from it.

17. Key Words (Selected by Author(s))	18. Distribution Statement Unclassified - Unlimited

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	8	

EXISTENCE OF A NATURAL INSTABILITY NOT PREDICTED BY THEORY AND CONNECTED TO A WALL DEFORMATION IN A LAMINAR BOUNDARY LAYER

Pierre Gougat and Francoise Martin**

1. In a previous report [1], we studied the influence /845* of a velocity gradient on the development and the amplification of natural instabilities in the boundary layer.

The spectral analysis of the instantaneous velocity signal gives us an energy spectrum made up of several well-defined zones:

- a low frequency zone from 0 to 300 Hz which has subtantial energy;
- a frequency range between 300 and 700 Hz, whose energy maximum coincides with the presence of an unstable frequency f_1. The value of this frequency is a function of the Reynolds number. It is located around 550 Hz for the experimental conditions considered (U_e = 16 m/s);
- finally, a third zone, which is the extension towards higher frequencies greater than 700 Hz of the range which contains the unstable frequency f_1. Under certain deformation conditions of the wall, it is within this zone that a second unstable frequency f_2, twice the value of the first, occurs, and therefore located at 1100 Hz.

---

*Numbers in margin indicate foreign pagination.
**Meeting of 16 October 1972.

At each point, the variation of these unstable frequencies is characterized by effective values of velocity fluctuations, relative to each frequency.

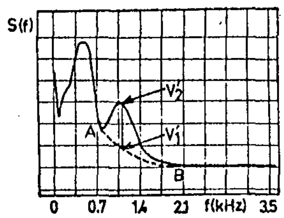
2. The first unstable frequency is always present in the boundary layer, no matter what the amplitude of the wall deformation is. The frequency f_2 only appears in regions where the velocity gradient is negative, i.e., at the deformation peaks when the deformation is negative, and at the end of a deformation when the deformation is positive.

We have restricted our study to the case of a negative wall deformation. Let us note that the phenomenon exists for any velocity of the external flow.

The voltages measured V_2 corresponding to the velocity fluctuations $\sqrt{\overline{u'^2}}$ were obtained from spectra on photographs (Figure 1). When the second unstable frequency f_2 does not exist, there is a general increase in the spectrum for frequencies between 700 and 1200 Hz. Thus a low energy exists for a /846 frequency of 1100 Hz, which one has to subtract from the maximum energy value in this part of the spectrum, in order to obtain the proper perturbation energy at the frequency f_2 = 1100 Hz. It is thus necessary to extend the spectrum after the first maximum located at f_1 = 550 Hz between the points A and B in order to take into account the frequency level f_2.

Since the energy due to the frequency perturbation f_2 is the difference between two energies, it corresponds to a voltage V_2 calculated from the voltages V_1' and V_2' (Figure 1):

$$V_2 = \sqrt{V_2'^2 - V_1'^2}.$$



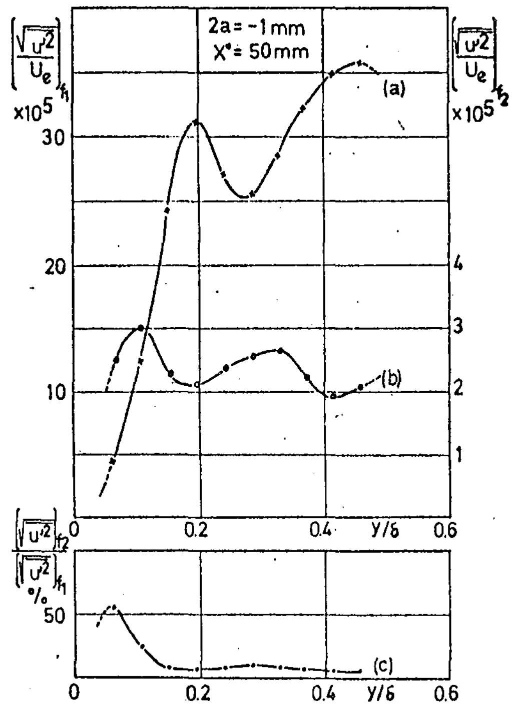


Figure 1

Figure 2

3. We have shown (Figure 2) the variation as a function of y/δ of the effective value of the velocity fluctuations relative to a frequency f, i.e., the quantity $\left(\sqrt{\overline{u'^2}}/U_e\right)_f$ for frequencies f_1 (curve a) and f_2(curve b). These values were obtained for a wall deformation amplitude of 2 a = -1 mm and for an abscissa, x* = 50 mm, measured from the beginning of deformation x_0 (x_0 = 178 mm) [2]. Curve 2(b) shows that the unstable frequency f_2 has an energy maximum for a reduced ordinate y/δ of 0.1, which corresponds to a small distance from the wall (between 0.1 and 0.2 mm). The curve 2(c) shows the variation with y/δ of the ratio $\left(\sqrt{\overline{u'^2}}\right)_{f_2}/\left(\sqrt{\overline{u'^2}}\right)_{f_1}$; /847
It is a maximum near the wall where it reaches a value on the order of 55%, and decreases rapidly when one moves away, and the frequency f_1 is dominating.

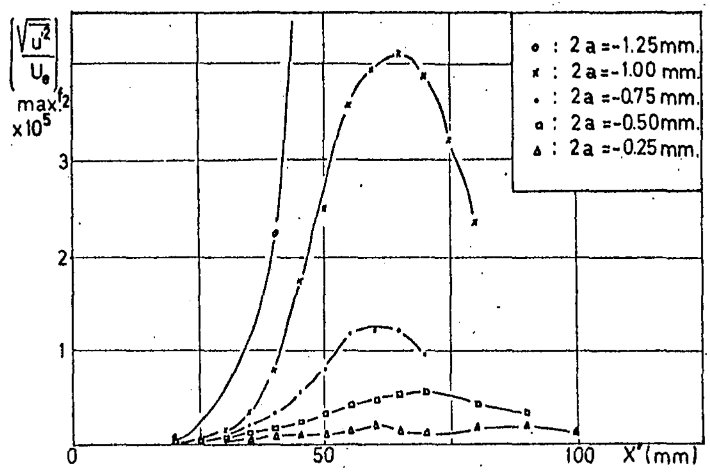


Figure 3

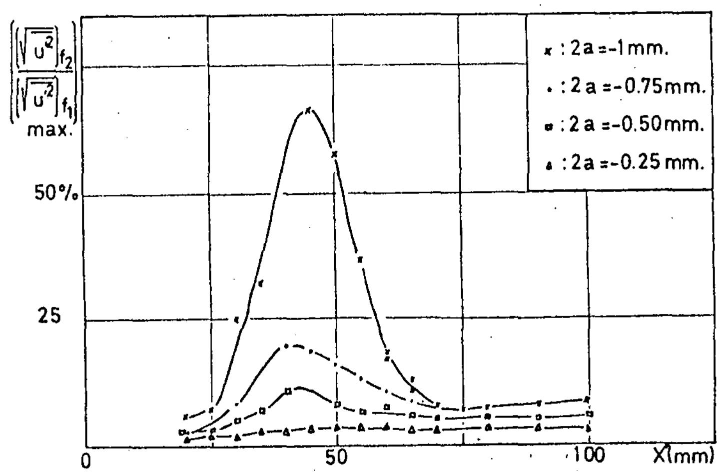


Figure 4

In particular, we are more interested in this maximum energy corresponding to the frequency f_2, and in the maximum value of the energy ratio for the two frequencies.

The network of curves of Figure 3 shows the variation with x* of the maximum energy, i.e., the variation in

$\left(\sqrt{u'^2}/U_c\right)_{f_2 Max}$ for various deformation amplitudes. We should note that the phenomenon becomes more pronounced when

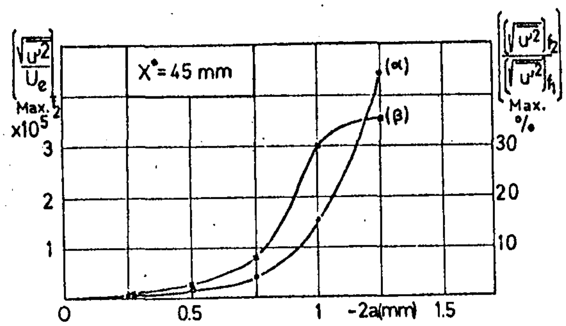


Figure 5

the deformation amplitude increases. We should also note that the curves have a maximum located at an abscissa value x* between 50 and 70 mm, depending on the amplitude of deformation, thus downstream of the cavity center.

On the other hand, the variation curves with respect to x* of the maximum value of the ratio of the two energies /848
(Figure 4) have a maximum for abscissa values between 40 and 60 mm, and thus upstream of the cavity center. These curves rapidly converge towards horizontal asymptotes.

In Figure 5, we show the variation curves as a function of the amplitude 2a, of the energy maximum of frequency f_2 (curve α) and of the maximum value of the energy ratio of the two frequencies (curve β). This latter curve has a curvature change between -0.75 and - 1 mm, which does not occur for the curve α . This shows the differences in behaviour of the frequency f_2 and the energy ratios for the frequencies f_2 and f_1.

REFERENCES

1. S. Burnel, P. Gougat, and F. Martin. Comptes rendus 274, Series A, 1972, p 1417.

2. S. Burnel. Influence d'un gradient de vitesse sur l'amplification des frequences naturelles dans une couche limite (Influence of a velocity gradient on the amplification of natural frequencies in a boundary layer). Doctoral thesis, third cycle, University of Paris VI, 21 March 1972.