BUFFETING

by

16-FOOT HIGH-SPEED WIND TUNNEL

INTRODUCTION

Flight at transonic speeds has introduced new problems and intensified old ones. One of these is the problem of buffeting. Buffeting is the shaking of the airplane due to repeated blows from an unsteady flow of air. Buffeting has been classified as being of two basic types: (1) buffeting of a part (such as the wing) on which unsteady flow originates, and (2) buffeting of, say, the tail by fluctuating airflow originating on the wing. Also, whenever a part, such as the tail, begins to buffet, shaking may be induced in other parts due to force transfer through the structure.

Buffeting previously has been associated with the low-speed stall occurring when the normally smooth airflow on the wing breaks down and separates from the airfoil. Some of this type of buffeting may be considered desirable as a stall warning. More serious buffeting due to compressibility effects now is often encountered in the transonic region when the formation of shock waves over any part of the airplane induces separation of the airflow from the surface.

An intensive investigation of the buffeting problem was recommended recently by the NACA Subcommittee on High-Speed Aerodynamics. A special panel of this subcommittee studied available information and approved a research program for the laboratories. One phase of this program has been the exploration in flight of the buffeting characteristics of fighter airplanes; another, wind-tunnel investigations of the fluctuating air forces on the surface and in the wake of airfoils. We will show you some of the flight results, a method of predicting the onset of buffeting, a demonstration of the wind-tunnel technique used, and some of the wind-tunnel results on fluctuations in the wake, with an indication of some preliminary correlation of the wind-tunnel results with flight research.

FLIGHT

The flight investigations mentioned are designed to explore the buffeting characteristics of fighter airplanes, with the aim of establishing a method whereby buffeting can be predicted. Several airplanes are being used in these tests, including two with swept wings. The type of data obtained and the results for one of the airplanes selected as a test vehicle are presented on this chart.

This figure is a reproduction of a typical research instrument record. These traces show the amount of shaking at the airplane center of gravity, at the tail centerline, and at the wing tip. The other traces show the change in angle of attack of the wing, and of the tail, and the total pressure at the stabilizer. The dashed line indicates time.

The onset of buffeting is readily apparent. The intensity increased until the shaking equaled approximately 3 g at the center of gravity for this flight, which would be equivalent to the pilot being alternately forced against his seat and belt with a force equal to three times his weight. The shaking did not begin simultaneously on all portions of the aircraft, and other records indicate that the shaking of various portions did not always occur in the same order.

The results of an analysis of a large number of similar records are given in this figure. Values of the buffeting intensity are plotted as a function of lift coefficient and Mach number. The lift coefficient is a measure of the effective weight of the airplane, the Mach number a measure of the speed. As you can see, if an airplane is flying at a high lift coefficient, as would be the case if the airplane were climbing or turning, the buffet boundary would be encountered at a relatively low speed. Conversely, if the airplane were flying at a low value of lift, the Mach number at which the buffet boundary would be encountered would be higher. In the case of the airplane shown, the buffet boundary was taken to be the points at which the shaking motions increased in amplitude to 0.03 g as either the angle of attack or speed was increased. These lines represent the contours of constant average amplitude, which as you can see, roughly parallel the buffet boundary. Their close spacing indicates the sharp rise in intensity as the buffet region, indicated by the shaded area, was penetrated.

Several methods of analysis were employed in the development of a criterion for the prediction of buffeting. The criterion which had the most consistent relation to the buffet boundary is shown in this figure. The variation of lift with Mach number for a constant angle of attack of a straight-wing airplane is shown by this line. The data were obtained in the 1- by 3-1/2-foot tunnel. The locus of the inflection points of the lift curves for various angles of attack is shown by this dotted (red) line. The inflection point might be termed the point at which the bending of the lift curve changes from one direction to another. By adding 0.06 Mach number to the curve determined by the locus of inflection points, the predicted buffet boundary, shown by this dotted green line, is established. This 0.06 increment is an average chosen after analyzing the results of a number of flight tests of various aircraft.

This lower figure shows the comparison between the predicted and actual buffet boundaries of two airplanes. One of these aircraft employed a conventional wing section, the other an NACA low-drag wing section. The solid curves show the buffet boundary as determined from flight tests, the broken lines the predicted buffet boundary. As you can see, the agreement between the two curves is quite good, even for two dissimilar airfoil sections. Thus, if the wind tunnel lift data are available, it is possible by using this method to predict the buffet boundary with useful accuracy. It should be pointed out that this criterion would not be applicable if the rough airflow originated from a source other than the wing itself – for example, external stores carried on the wing.

The question naturally arises as to the effects of sweep on buffet boundary. The NACA has to date investigated two swept-wing airplanes for buffet boundaries. The data indicated that the buffet intensity did not increase as rapidly for the swept-wing aircraft as for the straight-wing aircraft. In view of the small amount of data available, however, this should not be assumed to be a generality.

Mr. ______________ will now explain how the wind-tunnel data are obtained.

DEMONSTRATION

Before we demonstrate the technique that was used to conduct an investigation in the 16-foot wind tunnel of the fluctuating pressures in the wake of an airfoil, I will explain the equipment that was used. This photograph shows the model as it was mounted for the investigation and as it is now mounted in the tunnel. The photograph shows the test section of the 16-foot wind tunnel with these two large parallel walls located in the center of the tunnel. The model is mounted between the two walls. This mock-up represents the view an observer would have if he were standing here in the tunnel with this wall removed. This represents the airfoil which is at a 4° angle of attack, and this represents the wake-survey rake. This rake is mounted behind the trailing edge of the airfoil to measure the loss in total pressure behind the wing.

The tubes from the rake in the tunnel are connected to this manometer in consecutive order. The top tube in the rake corresponds to the left tube in the manometer. If there are no losses in total pressure the tubes will remain at about this level. Any losses in total pressure due to the presence of the wing will be indicated by an increase in the height of the liquids. Due to the length of the tubing leading to the manometer and its inherent damping effect, the tubes indicate an average total pressure rather than the instantaneous total pressure. This type of pressure-measuring system, consisting of a survey rake and manometer, even though it does not respond to rapid pressure fluctuations, is commonly used to investigate wake pressures. The limitations of such commonly used pressure measuring devices have led to the development of electronic equipment which permits accurate measurement of pressure fluctuations in the order of 150 cycles per second. The electronic equipment that has been used in this investigation consists of a pressure cell mounted in this electronic survey head which transmits electrical impulses that can be seen on the oscilloscope. This action can be illustrated by lightly touching the cell. Notice the movement of the light spot on the oscilloscope. During the demonstration the survey head will be moved vertically through the upper portion of the wake. This colored indicator will show the position of the survey head with respect to the total-pressure wake indicated by the manometer.

We will now demonstrate how the wind-tunnel data were obtained. As the tunnel speed is increased this meter will indicate the

Mach number at which the tunnel is running. Until a Mach number of 0.7 is reached, the survey head will remain in this location which is near the region of maximum pressure fluctuations.

At a Mach number of about 0.2 we can begin to see the region in which the total pressure is below the value in the undisturbed stream. Notice that the fluctuations on the oscilloscope screen are small, indicating hardly any fluctuations in total pressure.

As the Mach number approaches 0.5, the total-pressure loss in the wake is still not very great and the wake is narrow.

The fluctuations that you see on the oscilloscope screen indicate that the fluctuations of total pressure are still small.

As the Mach number approaches 0.7, the total-pressure loss in the wake becomes large and the wake width has increased considerably. The increased magnitude of the pressure fluctuations is apparent.

As the survey head is moved out of the region of maximum pressure fluctuation, the decreasing magnitude of the fluctuations can be seen on the oscilloscope screen.

Mr. ____________ will now discuss some of the results that have been obtained in the 16-foot wind tunnel using this technique.

The wing section of one of the airplanes discussed in the flight results has been tested in the wind tunnel. Buffeting of this airplane may be caused by rough flow on the wing, at surface junctures, or on tail surfaces. Another possible cause of buffeting is the location of the tail surfaces in or near the wake of the wing, which will be discussed here. To show you some of the wind-tunnel results with a preliminary correlation with flight results, two charts have been prepared.

This chart shows the effect of angle of attack on the wake. The airplane buffet boundary determined in flight is plotted in terms of lift coefficient against Mach number. The circled numbers show the conditions at which wind-tunnel data were taken. The lower circle corresponds to an angle of attack of five degrees indicated by this airplane profile, and the upper circle in the buffeting region corresponds to a ten-degree angle of attack shown by this airplane profile. The wind-tunnel data are plotted on graphs superimposed on the airplane profiles so that location of the airplane wing corresponds to the location of the wind-tunnel model.

The solid line shows the loss of pressure in the wake measured by use of the survey rake and multiple manometer. The amplitude of the fluctuation measured by the pressure cell is plotted on each side of the average pressure. Thus, the pressure is fluctuating back and forth in the red area. The magnitude of the total fluctuations at any point in the wake can be measured by the length of a horizontal line in the red area. For example, this figure shows that the magnitude of the total fluctuation at the peak of the wake was about 80 percent of the free-stream dynamic pressure.

Notice that below the buffet boundary the fluctuations can be ignored, and the horizontal tail is outside the wake. This figure clearly indicates that one possible cause of airplane shaking is buffeting of the tail of the airplane by the wake of the wing.

The next chart shows the effect of Mach number on the wake. The tunnel data were taken at two different Mach numbers with the wing at a 5-degree angle of attack. This figure is the one shown on the previous chart.

On this chart the largest fluctuation occurred in this region. Notice that the horizontal tail of this airplane is in the region where the pressure fluctuations are the greatest. Generally speaking, it has been found that with the airfoil carrying positive lift, the magnitude of the fluctuations from the upper surface of the wing is far greater than the magnitude of the fluctuations from the lower surface. This result would indicate that in order to move the tail out of the fluctuating wake, the distance it has to be moved up from the center of the commonly measured wake is a great deal more than the distance required if it were to be moved down.

A study is being made of the stream-angle fluctuations and frequencies in the wake. It appears that stream-angle fluctuations are always coincident with pressure fluctuations. The data did not show any predominant frequency in stream angle or dynamic pressure fluctuation, but rather a range of frequencies.

SUMMARY

To summarize this discussion: We have attempted to show you the results of just two phases of the buffet research by the NACA.

In the flight-research phase, a method for the prediction of the buffet boundary has been established from wind-tunnel airfoil data.

From the wind-tunnel phase, you have seen the technique of measuring the pressure oscillations in a wake, and finally, you have been shown a preliminary correlation between flight and wind-tunnel research.

This concludes the presentation by the staff of the Ames 16-foot high-speed wind tunnel. Please remain seated while the elevator is brought up to floor level.

Display for Presentation of "Buffeting" by the 16-Foot High-Speed Tunnel

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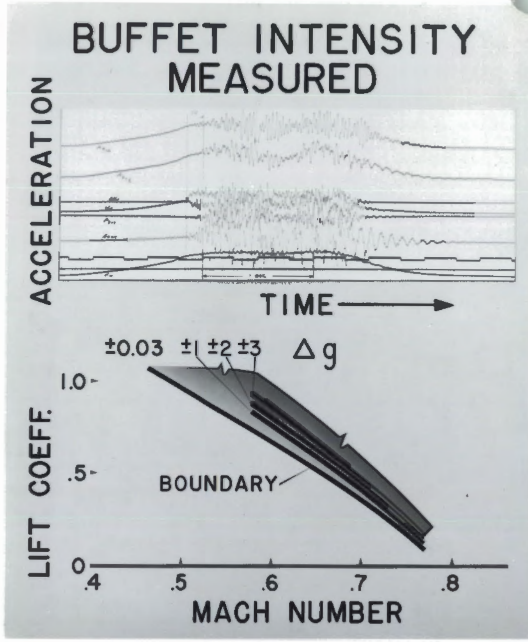

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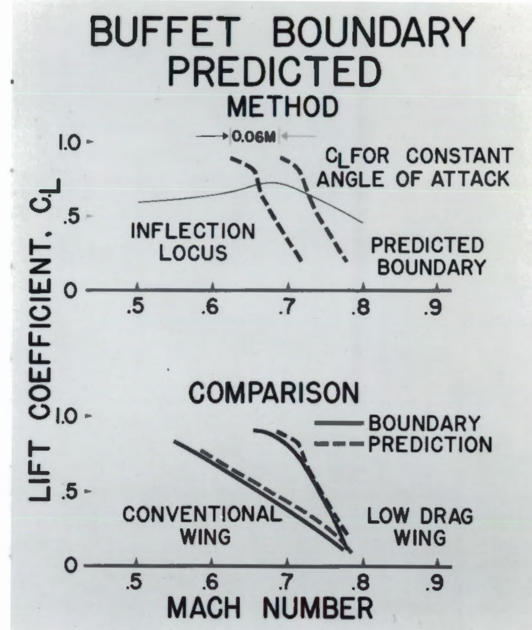

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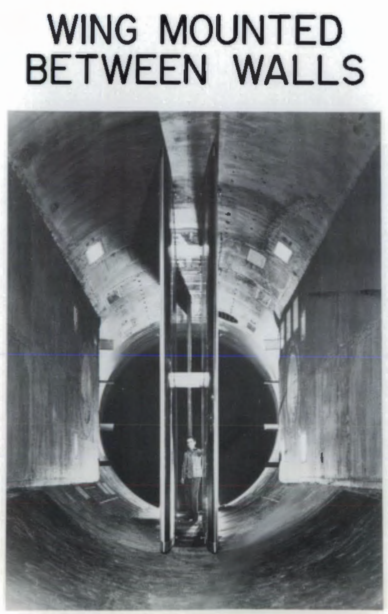

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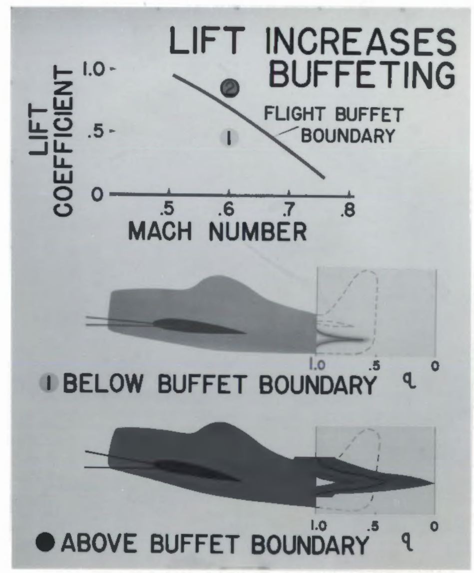

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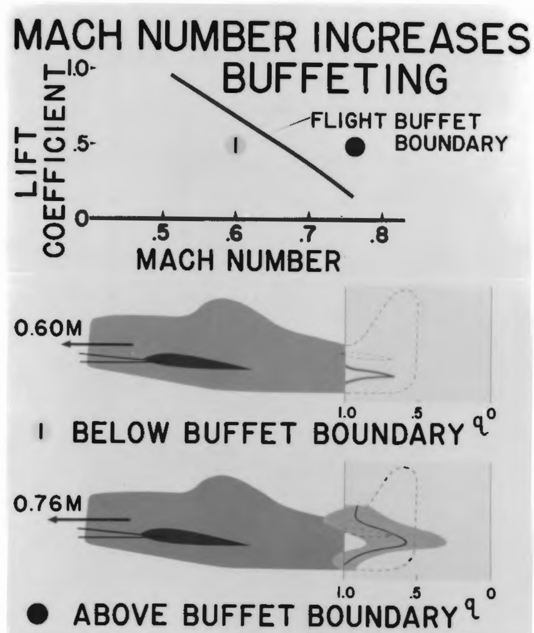

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