FLIGHT FLUTTER TESTING THE B-58 AIRPLANE

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Abstract

The flight flutter tests on the B-58 airplane will be described, and the philosophy of flight flutter testing at Convair, Forth Worth, discussed. A description of the instrumentation used in the airplane and in the telemetering receiving station on the ground will be given. The methods used for exciting the airplane and the flight test procedure will be covered. Also described will be the type of data obtained and its reduction. An evaluation of the procedure and instrumentation will be given with a discussion of desirable improvements for future testing.

INTRODUCTION

To lay the ground work for what we have done in the program, I would first like to describe the problem with which we were faced and our philosophy of approach to it. To begin with, we had to consider a low load factor airplane designed to fly into the high speed flight regime which had hitherto been breached only by research airplanes and a few fighters. To make matters worse from the flutter prediction standpoint, we had four pylon mounted nacelles on a delta wing planform. This was the first time anyone had produced a configuration like this. So we had very little background information on which to draw.

The basic approach to the flutter problem on the B-58 on which we decided was as follows. We would put the basic emphasis on flutter models. Analysis would be used to predict the character of flutter to be expected and the flutter trends arising from the variation of parameters. Finally, flight flutter testing would be employed to demonstrate that the airplane was flutter-free.

To be frank about it, when we started planning this program back in 1952, we weren't sure what portion of the flight envelope of the airplane would be critical for flutter. By the time we were ready to flight test the airplane, we were pretty sure that the critical region was transonic speed at low altitude. However, there were still enough unknowns to cause us to proceed rather cautiously.

INSTRUMENTATION AND TELEMETERING TECHNIQUES

With this as a background, I would like now to proceed with a description of the instrumentation which we used on the B-58. We approached this problem with the thought of pushing the state of the art to a certain extent, but at the same time staying with items which we felt pretty sure would work. We wanted to get both frequency response data and damping records. Basically our thought was to determine the principal response frequencies in flight and to take damping records corresponding to these as a function of speed. We also wished to telemeter this information. By telemetering we could accomplish several things.

First, we wished to be able to proceed with more than one speed increment per flight. This automatically ruled out recording the data in the airplane and reducing it later on the ground.

Second, this procedure would relieve the flight crew of the responsibility of monitoring the records in flight in addition to their other duties.

Third, we would be able to display a number of channels of information on the ground. Also we could employ certain kinds of bulky, special equipment on the ground such as band pass filters and automatic sweep plotters.

Fourth, the flutter information could be monitored by flutter specialists.

To cover the desired frequency range from 1 to 40 cycles per second, we had to provide two types of excitation. For the range of 1 to 7 cps, we introduced a sinusoidal electrical signal into the airplane autopilot servos. This produced a sinusoidal oscillation of the control surfaces about the trim flight position. The amplitude was proportional to the input voltage and could then be adjusted in flight by turning a knob. We had used this system on the B-36 and YB-60 airplanes and knew it would work. However, the characteristics of the autopilot and power control system limited its useful frequency range.

For the range from 5 to 40 cps, we decided to use vibrators of the type developed by our San Diego Division. These are inertia shakers, hydraulically powered, and electrically controlled. The ones we used had overall dimensions of 4.5 x 4.5 x 8.5 inches and weighed 25 lbs. The force output increased linearly with frequency from 40 lbs. at 7.5 cps to 150 lbs. at 40 cps. We installed one vibrator in the tip of the vertical tail, and one in the trailing edge of each wing. The wing vibrators were placed just ahead of the elevons and at about their midspan to excite a high frequency vibration mode which flutter model tests had indicated might produce elevon flutter.

We used the same frequency control unit for both types of excitation. This was operated by the flight test engineer from his post in the third crew station in the airplane. The heart of the unit was a variable frequency electrical oscillator. The flight test engineer was able to set desired frequencies manually, or to activate an automatic frequency sweep mechanism. Selector switches enabled him to use either the high or the low frequency range, and to direct the excitation to the appropriate autopilot servos or vibrators.

We used two types of pickups to detect response. For linear motion we employed strain-gauge type Statham accelerometers. These had ranges varying from ±2g to ±15g, depending on the location. They were fluid damped and had built-in electric heaters to maintain a constant 165°F operating temperature.

For detecting angular motion of the rudder and elevons, we used Eclipse-Pioneer AY503-8 autosyns. With our instrumentation, these were capable of measuring surface deflections down to 1/20 of a degree. Figure 1 shows the location of these pickups. The output from the 9 encircled pickups was telemetered

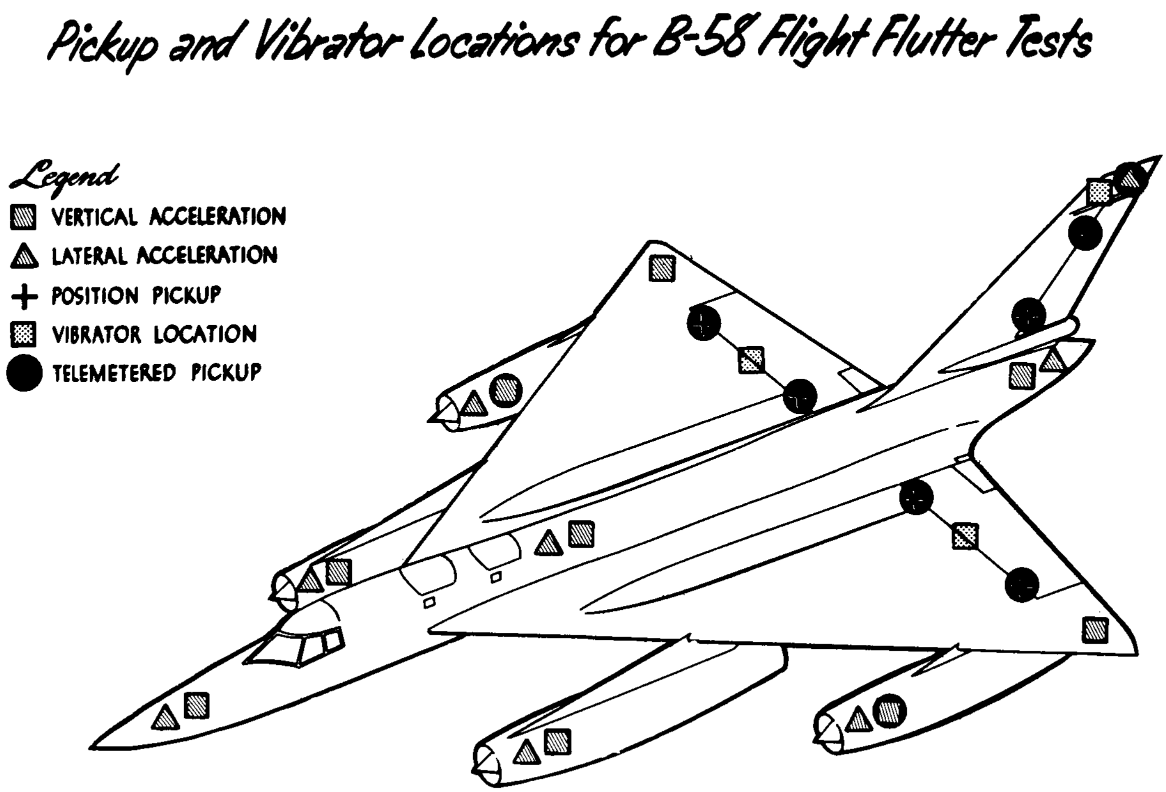

Figure 1. Pickups and Vibrator Locations For B-58 Flight Flutter Tests

along with the excitation signal. The signals from all of the pickups were simultaneously recorded on tape in the airplane.

On the ground the telemetered signals were displayed on two Sanborn direct writing oscillographs as shown in Figure 2. Before going into the recorder, however, each signal was passed through a variable band pass filter. The filters were used as required to remove any unwanted hash from the traces.

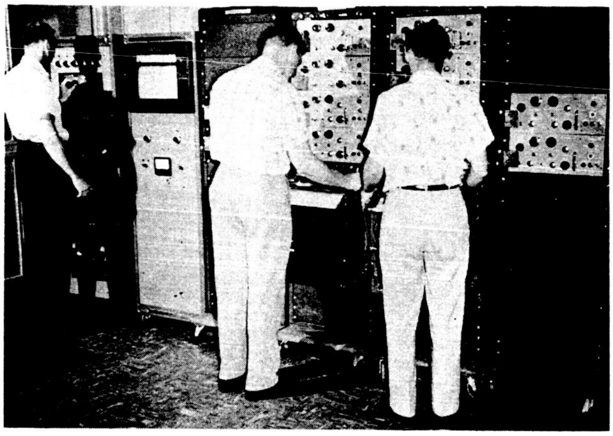

Figure 2. Sanborn Recorders and Filters

We recorded frequency sweeps directly with a special unit made by adapting a two axis Brown re-

Figure 3. Frequency Sweep Recorder

corder. This is shown in Figure 3. The pen was driven across the paper in proportion to the excitation frequency by a circuit similar to that of a frequency meter. The paper was moved up and down in proportion to the amplitude of the signal from the pickup being monitored. Figure 4 shows a typical sweep record from this equipment.

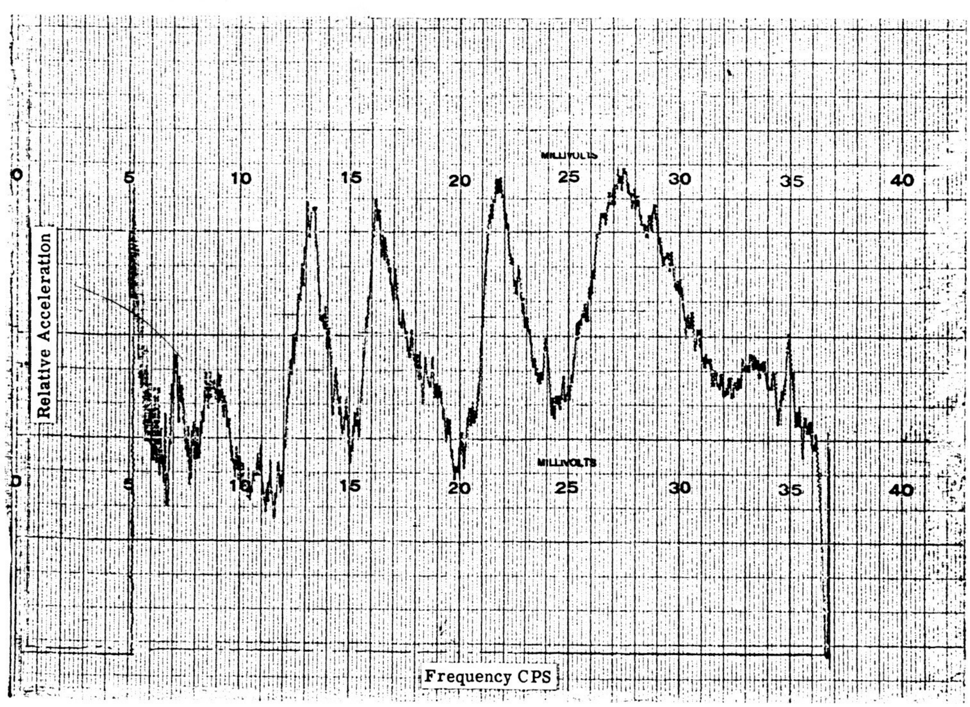

Figure 4. Fin Frequency Sweep Taken in Flight

FLIGHT TEST PROCEDURES

Next I would like to describe out test procedure in flight. I wanted to say "typical" test procedure, but conditions varied so much from flight to flight that there wasn't a set pattern. Basically, however, we went through the following procedure. The flight test engineer informed the ground station when he was ready to start. He then activated the automatic excitation sweep on the tail, the response to which was recorded on the ground. Next, automatic sweeps were taken for symmetric and antisymmetric excitation of the wing. While the wing sweeps were being taken, the tail sweep record was reviewed to determine the major response frequencies. These were then transmitted by radio to the flight test engineer with a request for damping records. He then proceeded to set the requested frequencies manually and to give short bursts of excitation to the tail for damping records. During this period the wing sweeps were reviewed for major response frequencies. These frequency values were then passed on to the flight test engineer as soon as he finished with the tail damping records. The procedure of excitation and recording of damping records was then repeated for the wing.

In the ground station we had a group of about six flutter engineers. These men monitored the information as it was received. They determined damping and response frequency on a preliminary basis within a few seconds and added these new points to the plots of data previously taken. All during this time, the new data points were being monitored and considered by a senior member of the flutter crew. If everything appeared in order at the conclusion of the planned testing at the speed point, the senior flutter engineer would give his O.K. for the airplane crew to increase speed to the next scheduled point. Normally this increment was one tenth of a Mach number.

The procedure described above takes about ten minutes to accomplish three sweeps and six damping runs. In practice, however, we found that we never quite followed this procedure for one reason or another. One thing which effected the plan was the time available. We were limited in telemetering range to about ninety miles radius, and it doesn't take long to fly by at high speed. Also, we often found it necessary to make repeat runs to get good data. As a result of this, other items in the flight test plans, and the inevitable descrepancies which always show up from time to time in experimental airplanes and instrumentation, we usually were in the position of trying to finish one point and start another.

TEST RESULTS

I have some comments and observations that I might pass on as a result of our experience on the B-58.

First, the instrumentation and techniques that we used proved to be practical and worked pretty much the way we expected. This is not to say that they always worked perfectly, but they proved to be servicable.

Secondly, we are pretty well convinced that frequency sweeping yields more information than any other one thing that we can do. Damping records essentially confirm what we expect from the sweep data. In a since damping records give one dimensional information while sweeps give two dimensional data.

For another thing, we have found that the amplitude of excitation is important. We don't know how to specify the minimum acceptable level, but we know from our experience that low excitation amplitudes tend to give erratic damping values. These values also tend to indicate lower damping than actually exists. On the B-58 fin which has an exposed span of about fifteen feet excitation double amplitudes of about one inch gave much better results than amplitudes of one quarter of an inch. On the wing, amplitudes of one inch also gave better results than amplitudes of one quarter of an inch. I am not able to define all the pertinent parameters, but I am sure that the ratio of the excitation amplitude to the random steady state amplitude is important. We try to obtain excitation amplitudes of at least three to four times the normal random amplitude. I suspect that the boundry layer thickness may also have a bearing on this problem. At any rate, the amount of excitation amplitude required to give good flutter data is a subject on which research is needed.

IMPROVEMENTS IN FUTURE FLUTTER TESTING

I might pass along the following comments on what we consider to be needed improvements in the field of flutter testing. One very important practical problem is the amount of time required to obtain data. This definitely needs to be shortened. But directly opposed to this requirement is the need to obtain more complete and better data. I think the best solution of this dilemma lies in automatic data reduction equipment. Our sweep plotter is a step in this direction.

Another thing which would be a definite improvement in our system would be to record information on how much response is being obtained for a given input. Our current B-58 instrumentation does not give this. However, I think that this could be achieved if the necessary development work were done on the instrumentation. I believe it is entirely feasible to obtain an automatic sweep plot in terms of response amplitude per pound of excitation or per degree of control surface rotation.

A very basic need has become clearly apparent during this program. I think this is a need which applied to all of us who are engaged in flight flutter testing. This is to be able to predict in advance what our test results should be. To do a real engineering job on flutter, we need to make our predictions in terms that we can measure directly on an airplane in flight. Then we could spot check enough points to prove that our engineering predictions were correct and greatly reduce the costly task of proving that an airplane is free from flutter.

CONCLUSION

To us at this time, it appears that the best approach to the problem lies through frequency response data. It is technically feasible to obtain information of this type which would be directly comparable to the airplane data by both calculation and model test. This would be costly, but I believe it would save money in the long run if we could do a good job in this respect. Certainly it would enable us to do a better, safer, and shorter job of flight flutter testing.