Initial Flight Testing of the HondaJet

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Abstract

The HondaJet is an advanced, lightweight, business jet featuring an extra large cabin, high fuel efficiency, and high cruise speed compared to existing small business jets. A flight-test program was started in December 2003. Initially, system function tests, such as landing-gear and flap operation as well as pressurization, were performed. After validating the system functions, the handling qualities were evaluated and preliminary performance testing was conducted. The handling-qualities data are in good agreement with analytical results. Flow visualization using tuft was also performed and the results compared to those from wind-tunnel tests. The flight tests were conducted using a telemetry system and the data were analyzed on the ground in real time. A general overview and status of the HondaJet flight-test program is given.

1 Introduction

Small jets are becoming very popular with business people. Market surveys and focus-group interviews, conducted in five major cities in the United States, show that demand for comfort, in particular, a large cabin, and high fuel efficiency are critical to the success of small business-jet development. The HondaJet (Fig. 1) is designed to satisfy these needs. The general arrangement is shown in Figure 2. Design maximum weight is about 9200 pounds. The aircraft is powered by two Honda HF-118 engines, each rated at 1,670-pound thrust at takeoff power. To achieve the performance goals, a natural-laminar-flow wing [1] and a laminar-flow fuselage nose [2] were developed through extensive analyses and wind-tunnel testing. To produce a larger cabin, a novel configuration, called an over-the-wing engine-mount configuration, was developed [3], [4].

Fig.1 HondaJet.

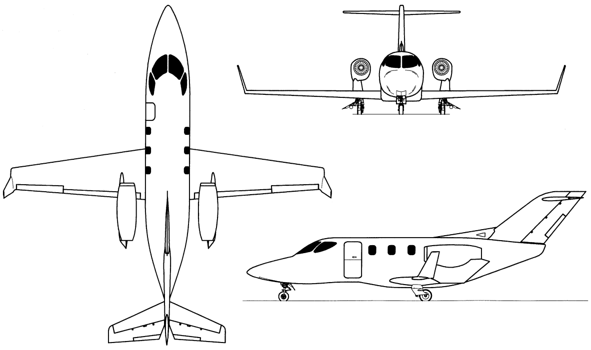


Fig. 2. General arrangement.

By mounting the engines on the wing, the carry-through structure required to mount the engines on the rear fuselage is eliminated, which allows the cabin volume to be maximized. In addition, the wave drag at high speeds can be minimized by positioning the engine nacelle at the optimum position [3]. An advanced, all-composite fuselage structure, consisting of a combination of honeycomb sandwich structure and stiffened panels, was developed to reduce weight and manufacturing costs. By employing these technologies, the specific range of the HondaJet is far greater than that of existing business jets.

After structural, control-system, function, and vibration tests were completed on the ground [5], the first flight was performed on December 3, 2003, at the Piedmont Triad International Airport in North Carolina. Flight testing began in January 2004 and, to date, in-flight system function tests, preliminary handling-qualities evaluations, and performance tests have been conducted. The objective of the flight-test program using the prototype aircraft is to demonstrate the new concept, the new technologies, and to validate the handling qualities and performance of the HondaJet.

2 Instrumentation

To maximize the efficiency of the flight-test program, the HondaJet is fully instrumented with a data-acquisition system and a telemetry system. The onboard system consists of sensors, a data recorder (ATD-800), and a telemetry system [transmitter (ST-810) and antenna (6130)] for PCM data transmission. The ground equipment consists of an automatic tracking antenna having a 2.4-meter-diameter parabolic reflector (Fig. 3), an antenna control unit (ACU-21), a receiver (RCB-2000), a back-up data recorder (ATD-800), and an L-3 Visual Test System (VTS-100), which is a PC-based data-acquisition system. The VTS processes, distributes, and displays the flight-test data in real time (Fig. 4).

The flight data are then analyzed using the Honda Handling Quality Analysis Program. The system diagram is shown in Figure 5.

Fig. 3. Automatic tracking antenna.

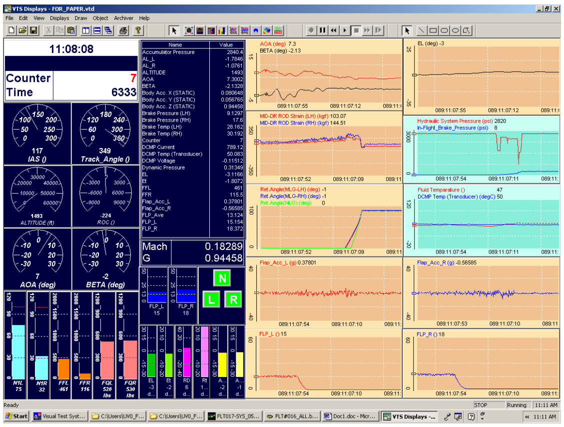


Fig.4. VTS monitor.

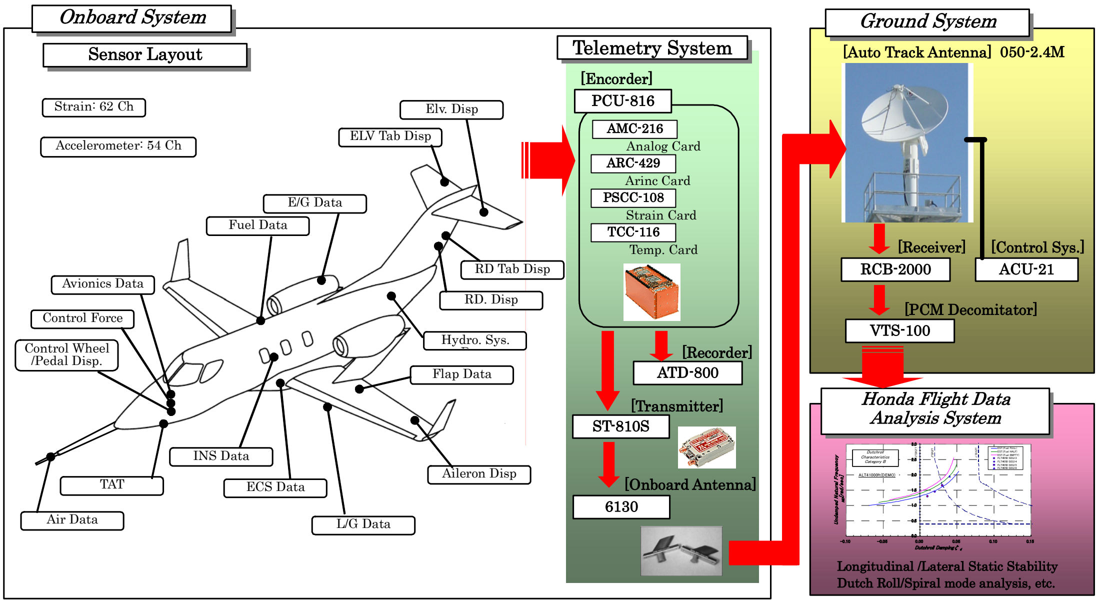


Fig.5. Data-acquisition system diagram.

The data-acquisition system allows the measurement of more than 200 channels of data. The sampling rate is 30 hertz for the handling-qualities testing and can be increased to more than 200 hertz for flutter testing. CCD video cameras were installed on the aircraft to monitor the landing-gear and flap operation. In addition, a CCD camera was installed in the cockpit to record the flight instruments and the pilots' actions.

3 Flight-Test Results

3.1 Calibration Test

To accurately determine the difference between the measured static pressure and the actual free-stream static pressure at each flight condition, a calibration test using the tower flyby method was preformed. The calibrated altitude of the aircraft was determined by using the elevation angle θ of the automatic tracking antenna. The calibrated altitude was calculated by adding the pressure altitude of the antenna h_{ANT} to the altitude $\triangle H$ calculated from horizontal distance and antenna elevation angle. (See Fig. 6) The measured pressure difference is within +/- 1 percent for the low-speed, high angle-of-attack flight condition.

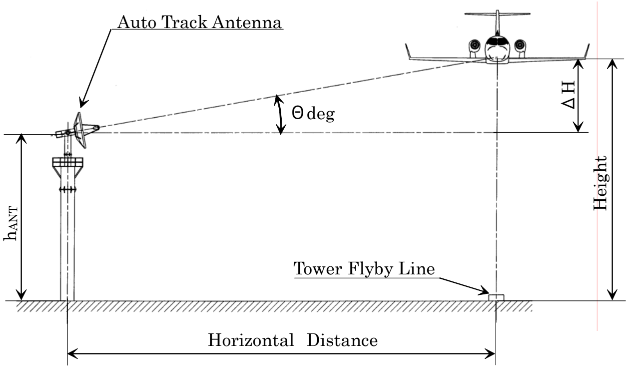


Fig.6. Calibration test.

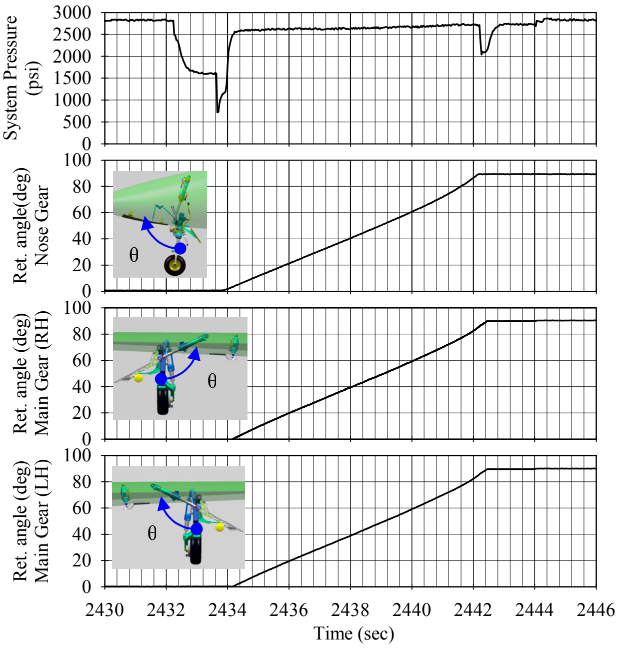
3.2 System Function Tests

3.2.1 Landing-Gear Operation

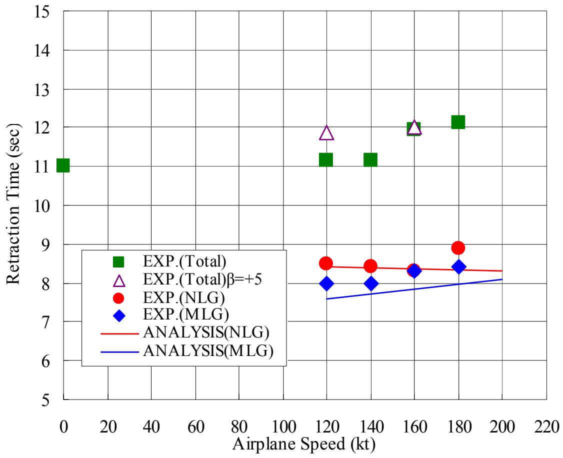
A landing-gear operation test was conducted to validate the retraction and extension functions of the landing-gear system (Fig. 7).

Fig.7. Landing-Gear operation test.

The landing gear is electrically controlled and hydraulically actuated. The test was conducted at various airspeeds below V_{LO} under side-slip conditions. The function was confirmed at each flight condition. An example of the measured retraction angle and system hydraulic pressure versus time at an indicated airspeed of 160 knots and the variation of retraction time with airspeed are shown in Figures 8(a) and 8(b), respectively.



(a)Landing-Gear retraction.



(b)Landing-Gear operation time.

Fig.8. Landing-Gear operation.

An emergency gear operation test was also conducted to validate the extension of the landing gear without electrical and hydraulic power. To simulate the emergency condition, the circuit breaker was pulled and the hydraulic pump was stopped. By opening the dump valve and unlocking the up-lock system manually via a lever in the cockpit (Fig. 9), the landing gear free-fell and down-lock was achieved. The system function was validated.

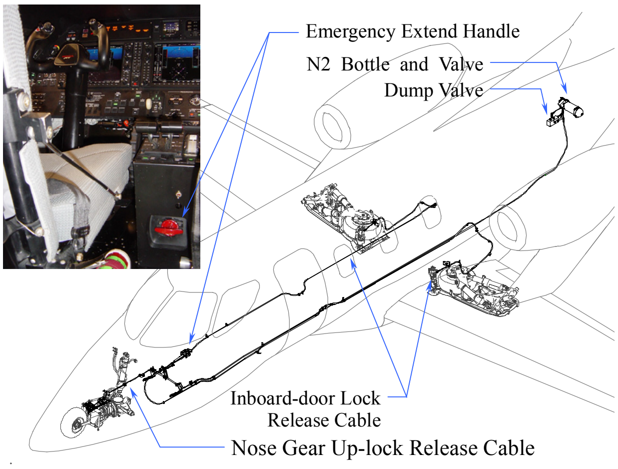


Fig.9. Emergency system diagram.

Video cameras were mounted on the aircraft to monitor the motion of the landing gear and its doors during flight. In-flight brake operation was confirmed to stop wheel rotation after takeoff via video recording (Fig. 10) as well as hydraulic-pressure measurement.

Fig.10. In-flight brake operation.

In addition, the landing-gear door loads and vibration were measured by strain gauges thus validating the structural design. The elevator angle during landing-gear up and down operation is shown in Figure 11. The aircraft pitch change during landing-gear operation is small. The flight characteristics during landing-gear operation are acceptable.

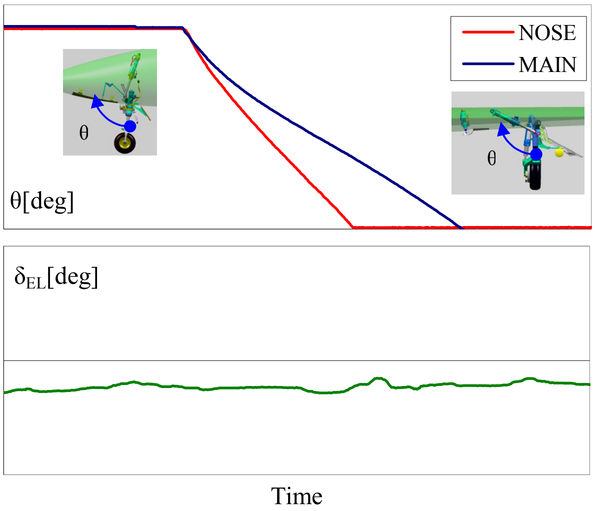


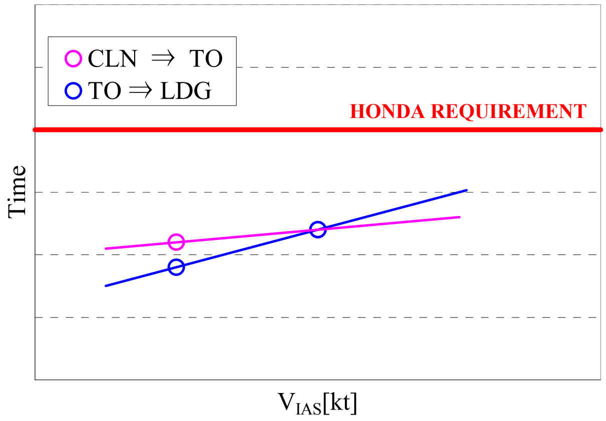
Fig.11. Elevator angle in LG-operation.

3.2.2 Flap Operation

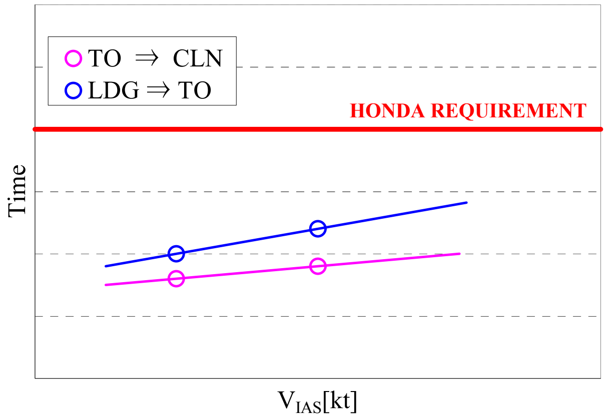
A flap-operation test was conducted to validate the retraction and extension of the flaps (Fig.12). The double-slotted flap is electrically controlled and hydraulically actuated. The flap-function test was conducted at various airspeeds below the flap-operation speed V_{FO}.

Fig.12. Flap operation test.

Operational time, hydraulic pressure, and other aircraft parameters were measured. The function was confirmed at each flight condition. Examples of the variations of the measured flap-extension and flap-retraction times with airspeed are shown in Figure 13(a) and 13(b), respectively.



(a) Extension time.



(b) Retraction time.

Fig.13. Flap operation time.

The operational time satisfied the design requirement. Flap vibration was also measured by accelerometers. It was confirmed that there is no significant vibration for the takeoff and landing positions (Fig. 14). The elevator angles required to trim with the cruise, takeoff, and landing flap positions are shown in Figure 15. The airplane pitch change with flap operation is small. The flight characteristics during flap operation are acceptable.

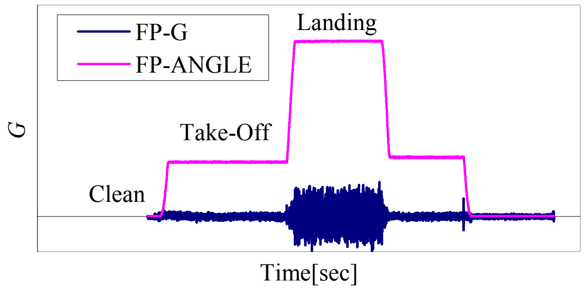


Fig.14. Flap vibration at 140 kt.

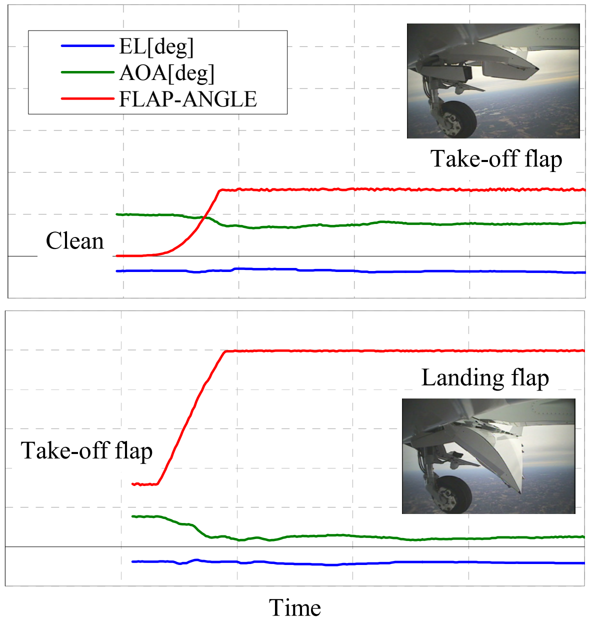


Fig.15. Elevator trim angle for flap setting.

3.2.3 Pressurization

Pre-cooled bleed air from the engines is used to pressurize the cabin and the pressurization level is controlled by two outflow valves located in the front pressure bulkhead. Before the in-flight pressurization test was conducted, a ground proof test was performed to validate the structure as well as the system function (Fig. 16). Then, in-flight pressurization tests were conducted at various altitudes. The temperatures of the structures near the bleed-air tubes were monitored during the tests. The automatic cabin-pressure regulation system function was validated.

Fig.16. Ground pressurization tests.

3.3 Flow Visualization

3.3.1 Tufts

The rear fuselage of the HondaJet is designed to exhibit low drag at cruise while satisfying the required rotation angle during takeoff and landing. The rear fuselage was designed using scale-model wind-tunnel testing and the full-scale characteristics were determined by flight testing. Flow visualization using tufts showed that the characteristics are similar to those observed in the wind tunnel (Fig. 17).

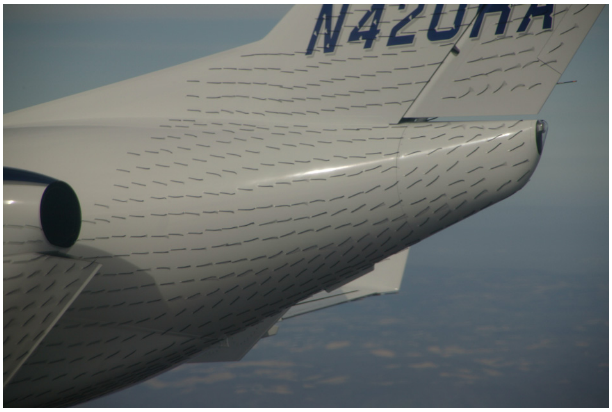


Fig.17. Flow visualization using tufts

There is no separation and, thus, the aerodynamic design was validated.

3.4 Handling-Qualities Test

3.4.1 Static Longitudinal Stability

Static longitudinal stability tests were performed for stick-fixed and stick-free conditions. An example of the elevator angle required for trimmed flight at each airspeed is shown in Figure 18. The agreement between analysis and measurement is generally good. The airplane has positive static stability at the 24-percent and 27-percent C.G. locations. The neutral point of the aircraft is estimated to be about 45% of MAC at 150kt.

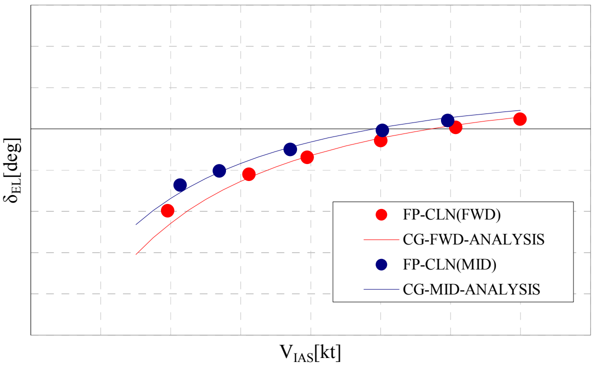


Fig.18. Trim elevator angle.

3.4.2 Short Period Mode

The short period mode was excited using an elevator doublet input. The aircraft exhibits heavy damping in this mode with only one to two overshoots (Fig. 19). The undamped natural frequency and damping ratio were calculated from the time history using the transient peak ratio (TPR) method and compared to those from analysis.

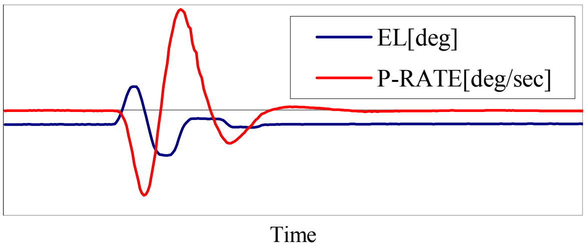
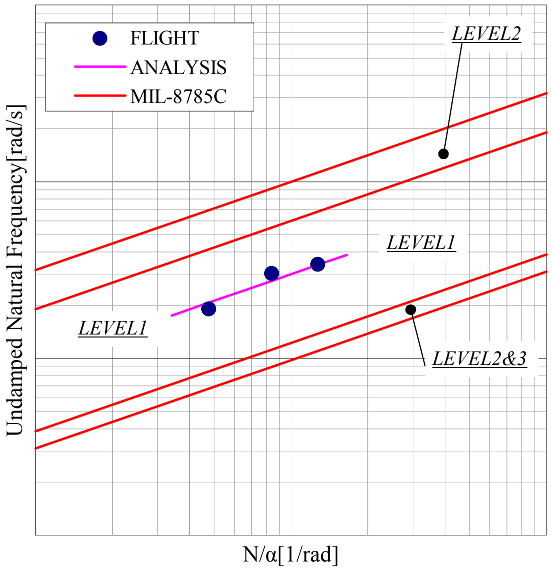
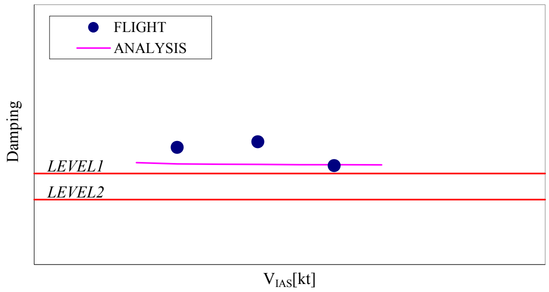


Fig.19. Airplane response by EL doublet.

An example of undamped natural frequency and damping evaluation are shown in Figure 20(a) and (b). Both characteristics are within the range of MIL-8785C level-1 requirements.



(a)Undamped natural frequency.

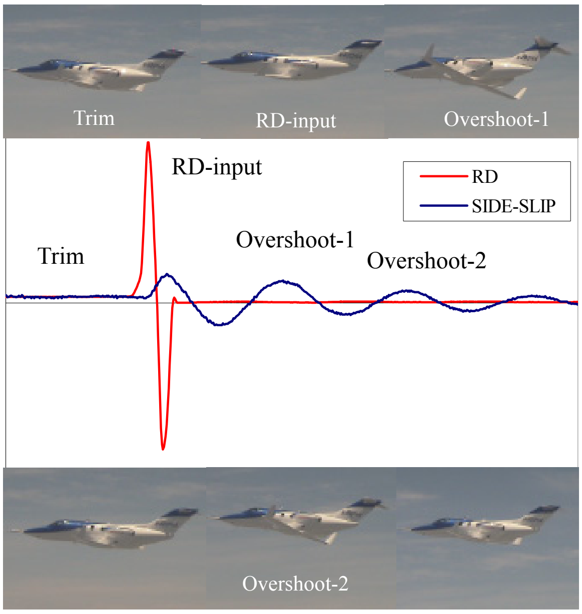


(b) Damping.

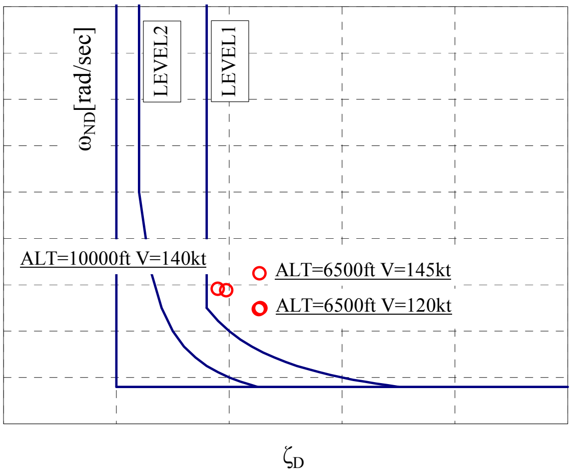
Fig.20. Short-period mode.

3.4.3 Dutch-Roll Mode

The Dutch-Roll mode was excited using a rudder doublet input (Fig 21(a)). The undamped natural frequency and damping ratio were calculated from the time history using the transient peak ratio (TPR) method and compared to those from analysis. The aircraft exhibits adequate damping at mid to high speeds and less damping at low speeds. Examples of the undamped natural frequency and damping ratio obtained from flight test are shown in Figure 21(b) and they are also within the range of MIL-8785C level-1 requirements.



(a) Dutch-Roll motion.



(b) Undamped natural frequency.

Fig.21. Dutch-Roll.

3.4.4 T-Strip on Rudder Trailing Edge

During the initial flight testing, the airplane exhibited a small amplitude rudder oscillation in the mid-speed range. To eliminate this, various sizes of T-strips were added to the trailing edge of the rudder. An example of the effect of the partial span T-strip on the rudder oscillation is shown in Figure 22. A T-strip eliminates the oscillation (Fig. 23).

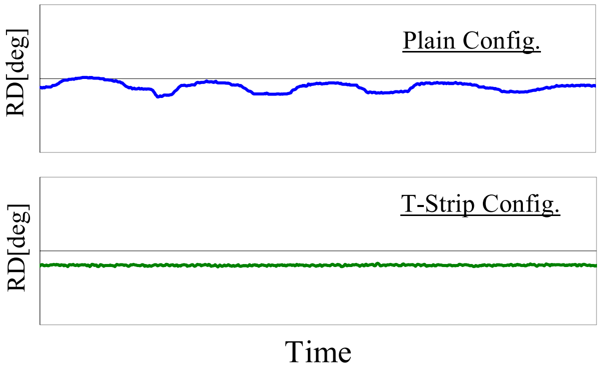


Fig.22. Rudder oscillation.

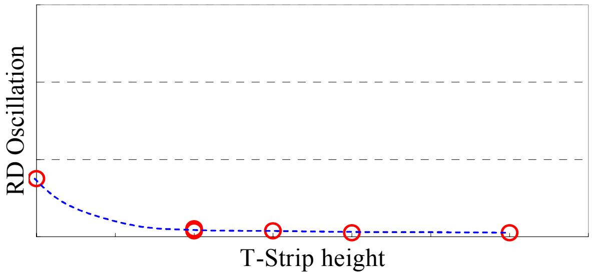


Fig.23. T-Strip study.

3.5 Performance Tests

3.5.1 Cruise

To evaluate the cruise performance, the speed-power method, in which W/δ is held constant, was used. Tests were conducted to determine the drag, fuel flow, and range for various airspeeds and weights. Examples of the cruise performance at altitudes of 10,000 and 25,000 feet are shown in Figure 24. The measured cruise performance is in good agreement with that from analysis.

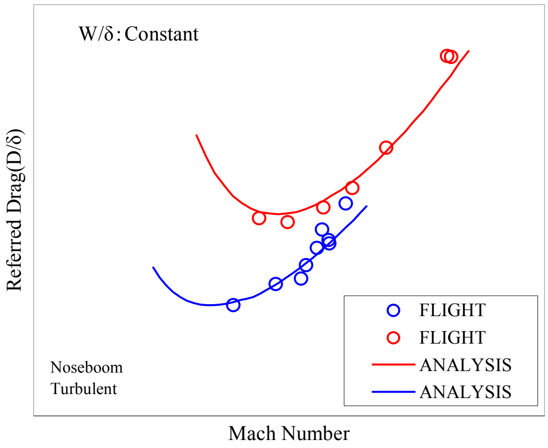


Fig.24. Cruise performance.

3.5.2 Climb

A sawtooth test, in which a series of timed climbs is made over an altitude band bracketing the selected pressure altitude, was used to determine the climb performance. An example of the climb performance at 10,000 feet is shown in Figure 25. The measured climb performance is in good agreement with that from analysis.

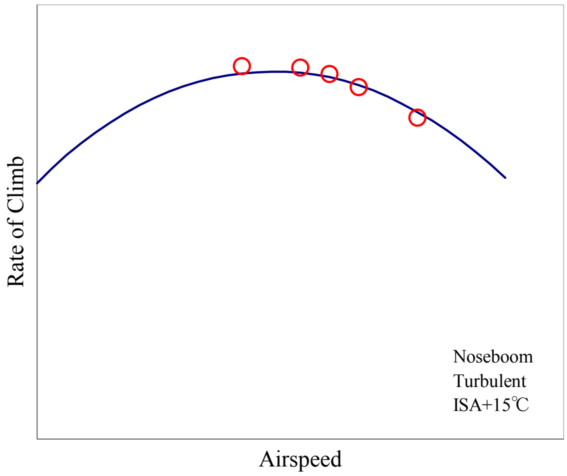


Fig.25. Climb performance

Level acceleration method was also used to obtain the climb performance. The excess power was measured by maintaining a constant altitude and recording the change in true airspeed with time. The results were compared to those from the sawtooth method and a good agreement was obtained.

4 Conclusions

Honda R&D is conducting flight tests on the HondaJet. System function tests have been successfully completed and the system designs validated. Handling-qualities and stability-and-control tests have been performed and the flight characteristics compared to those from analysis. The HondaJet exhibits good flying characteristics. Preliminary performance measurements are favorable. Detailed performance evaluations are planned for the remainder of this year and stall and flutter tests for next year.

5 References

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