Testing Transient Conditions in Wind Tunnels

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We propose to use existing wind tunnel facilities to simulate transient loading conditions and to derive the dynamic response under the influence of suddenly applied **pressure** loads. The objective is to measure directly the actual transient loads, deflections, stress and other effects experienced during transient conditions in operation; and to compare the results with analytical predictions. The proposed work will identify the susceptibility of systems and materials to premature fatigue, early cracking and accelerated corrosion.

In standard wind tunnel tests, models are subjected to the maximum steady-state wind levels that are specified in the operation envelopes. The maximum loads obtained in this way do not represent the true maximum loads experienced during transient conditions; i.e., during the sudden rise or fall of pressure.

During pressure surges, the parts of a system experience greater loads than the equivalent pressures. The true maximum loads can be determined from the steady-state data collected in wind tunnel tests. The standard wind tunnel data represent the input, or the forcing function, to the transient analysis. The transient response in the parts of a system requires separate dynamic analyses.

Measuring the true maximum transient loads in every part of a system is formidable. It requires the instrumentation of every part, which is not practical for systems that are made up of thousands, or tens of thousands, of parts. In the proposed work, critical parts that experience the maximum transient effects will be identified, the actual maximum transient parameters will be measured, and methods of extrapolation of the calculated loads for the other parts will be established, or confirmed.

The start-up transient loads experienced by the parts of a system can reach 100% of the maximum applied pressure itself. Wind tunnels can be used to determine the extent of the transient effects experimentally. To achieve the goal, modifications to the wind tunnel, or additions, will be required.

The transient conditions can be simulated in wind tunnels by making appropriate modifications in the Test Section or in the Wind Tunnel itself to control the rise or fall of pressure. The transient conditions may be simulated mechanically by introducing a test model into the flow at the desired rate; or by regulating the airflow into the Test Section.

The proposed work will obtain the normal measurements of lift, drag, side force, and pitch, roll and yaw moments during the short transient times. Other parameters to be measured during the transient conditions will be identified and measured.

The proposed work will identify critical areas of testing and development. For example, the entry or exit of aircraft into wind shear pockets of definite size and speed. The tests will determine the pointing accuracy of directional systems subjected to sudden wind gusts. Other examples include the start-up, throttle-up, throttle-down, and shut-down of pressure-activated systems, such as, jet or rocket engines, reactors, etc.

Typical tasks to be performed include,

- Prepare and submit a report with the results of a survey of methods used to handle the transient loading conditions in the design of modern systems to date.
- Identify the necessary modifications to wind tunnel facilities to conduct pressure-induced transient loading tests.
- Simulate transient loading conditions in wind tunnel tests.
- Generate pressure-time and response-time curves, photo and video record, etc.
- For every case tested, derive the transient response analytically from the recorded forcing function curves, i.e., the pressure-time curves.
- Compare the analytical results with the experimental results obtained directly from the Transient Wind Tunnel Tests; i.e., the response-time curves.
- Identify the critical and controlling parameters in transient conditions; e.g., transient times, damping, frequency, geometry, etc.
- Simulate low-cycle fatigue conditions for transient conditions; e.g., compare time to failure under maximum steady-state conditions and under repeated start-up conditions.
- Determine the feasibility of modifying existing wind tunnel facilities to test for transient loading conditions in addition to steady-state conditions.
- Determine the feasibility of incorporating transient testing features in new wind tunnels.

Ali F. AbuTaha has conducted extensive study and examination of transient effects in aerospace, power, and other pressure-activated systems.