Correlations of Different Surfaces Tests,

Tire Behavior Math Model for the High Speed Civil Transport (HSCT)

and

Michelin Tire Properties Tests for Boeing 777

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Abstract

In the surfaces correlation study, several different volumetric and drainage measurement techniques for classifying surface texture were evaluated as part of a major study to develop and improve methods for predicting tire friction performance on all types of pavement. The *objective* of the evaluation was to seek relationships between the different techniques, and to relate those results to surface frictional characteristics. We needed to know how each of the tests could be related to each other.

Another of my assigned projects was to make a tire behavior math model for the High Speed Civil Transport (HSCT) using the same methods used for the space shuttle a few years ago. A provided third order equation with two variables was used. This model will also be used for studies with the Boeing 777. Only a few changes will be necessary to adapt it for this other aircraft, which is the newest offered by Boeing.

In my final project I was involved with testing the tires for this new aircraft using the Aircraft Landing Dynamics Facility (ALDF) test carriage within the carriage house (Bldg. 1261) at LaRC. A 50 inch diameter radial tire manufactured by Michelin Aircraft Tire Corporation had to be tested to double overload of 114,000 pounds. The rated load of each tire is 57,000 pounds, but Boeing required tests assuming failure of a companion tire that could have cost Michelin approximately $12 million to build a facility to provide the required test capability. Here at LaRC, only minimum modifications to the facility were required to perform this specific test.

Introduction of Correlations

It has long been recognized that the texture characteristics of a pavement surface can directly influence the frictional forces which pneumatic tires can develop for accelerating, steering, and braking. Many different devices and techniques have been developed to provide quantitative measurement of surface texture, and these efforts have identified two texture classifications, micro- and macrotexture. In general, microtexture consist of the fine, small-scale surface features such as those found on individual stone particles, whereas macrotexture encompasses the coarse, large-scale roughness of a pavement surface-aggregate matrix. Results from studies to evaluate the effects of speed on tire friction have indicated that the slope of the friction-speed gradient curve is primarily a function of the surface macrotexture. On that basis, it would appear that an assessment of both surface micro- and macrotexture characteristics is necessary to relate texture measurements with tire frictional performance.

Explanation of Some Equipment and Test Procedures

Comparative measurements were collected in this study using several different pavement classification techniques which included *volumetric types, drainage devices, a skid resistance tester*, and *another which uses light beam* calibration procedures. Surface preparations were followed during the operation of each technique on sixteen different concrete and asphalt surfaces located at Langley Research Center (NASA), Wallops Flight Center (NASA) and at Cranfield University. For each technique, a stiff, wire-bristle brush was applied vigorously to the surface test area prior to measuring to remove all loose stones, debris, and other contaminants. A minimum of six measurements were taken at different locations on a given surface. Data was collected using all the techniques on the same test area of a given surface. For each technique, an average value was calculated from the individual measurements taken on each test surface. A general description of some of the different equipment and test procedures used for the various techniques follows.

Volumetric Methods:

The volumetric methods involved spreading a known volume of a given material on a pavement surface to fill all voids, measuring the area covered, and computing values of the average texture depth by dividing the material volume by the spread area. The dissimilar material properties required different measurement procedures, as well as different equipment.

The sand patch method was developed at the British Road Research Laboratory, and is one of the first methods used to determinate surface texture. The technique used in this procedure consists of pouring a known volume of fine, dry sand on the pavement, spreading it over a circular area, and using a hard round puck similar to that used in ice hockey, leveling the sand with the tips of the asperities (peaks). A small, open-ended, wood frame provided the test surface area with protection from the wind during each sand patch application. The *average surface texture depth* is obtained by *dividing the volume of sand used by the area covered*.

Another method used in this study is the grease patch method. For this method a metal cylinder with an internal volume of about 16,000 mm^3 (aprox. 1 cubic inch) is used. The actual volume is not critical, provided it is accurately known. Suitable dimensions based on an accurate 1 inch internal diameter pipe would be a diameter of 25.4 mm and a length of 32.3 mm. Other secondary requirements are a putty knife, a tight fitting plunger, a rod to expel the grease from the cylinder, a rubber faced aluminum or wooden squeegee some 30-40 mm in width, and masking tape. In this method the test cylinder is first packed with any general purpose grease using the putty knife in such a way as to avoid entrapping air and the ends are squared off using the putting knife. Two parallel lines of masking tape are placed at right angles to and at one end of the test area and worked in the voids in the surface to the levels of the peaks of the surfacing and in a rectangular shape between the parallel masking tape. Care is to be taken so that no grease is left on the masking tape or squeegee. Measure the volume of the test cylinder and the dimensions of the grease patch. The average surface depths of the voids is given by the equation:

$$Surface\_Texture\_(mm) = \frac{Volume\_of\_Grease\_(mm^3)}{Area\_Covered\_(mm^2)}$$

Two spreaders were available - NASA and Cranfield. The NASA spreader consist of a flat piece of metal approximately 40 mm by

150 mm to which a strip of rubber has been stuck to act as the squeegee. The Cranfield spreader is shaped like a shepherd's crook with a wooden handle and metal head on to which the 40 mm wide rubber squeegee has been stuck. As part of the objectives I tried to determine the differences between both set of values.

Drainage Methods:

The basic static water drainage meter, commonly referred to as an *outflow meter*, consists of a transparent plastic cylinder to contain water and a brass base plate with a rubber ring attached to the bottom face. The cylinder is placed on the pavement and loaded so that the rubber ring will contact the surface aggregate particles in a way similar to that expected of a tire tread element. Water is poured into the cylinder, and a clock measures the time required for a known volume of water to escape through the pores or grooves in the pavement and between the rubber ring and the pavement surface.

Skid Resistance Tester:

The British pendulum skid resistance tester is a dynamic pendulum impact-type tester used to measure the energy lost when a rubber slider edge is propelled over a test surface. The British Pendulum Number (BPN) values measured for flat surfaces represent the frictional properties obtained with the apparatus using recommended procedures. Since pavement surface temperature measurements were taken during all test, the average BPN values on each test surface were temperature-corrected by a nonlinear factor established during a British Road Research Study.

Other:

The Texture Van, developed by Penn State University, is a test where a computer collects data from a frame grabber that looks at a 3 mm by 51 mm rectangular beam of light that is flashed onto the pavement. This produces a shadow effect on both edges which are called Leading and Trailing edges. RMS (Root Mean Square) values are calculated from these edges to be used in results.

Another kind of test was the Texture Beam. It has two types of measuring devices, an infrared laser and a LVDT for measuring texture. The beam has a trolley that is motor powered and carries the measuring devices. A computer collects the data and is displayed in real time.

As part of my work, I did not actually conduct these types of tests. Rather, I had to study and learn how each of these tests work so as to make the best correlation between the different tests.

Results

From all the data collected I made different charts that provided me with a visual meaning of the data and how the different tests are related. With Tom Yager's (Senior Project Engineer) and Robert H. Daugherty's (my mentor) help I could find some of the outlying points and which tests are related or similar. Also, I had to work with the equations for the best curve fit to each correlation. One tries to obtain the nearest value of r to 1 (r=1 ==> the best curve fit), but one must keep in mind the real meaning of the curve obtained. I conducted comparisons between the different tests which were made the last year on similar surfaces. Generating more charts showed the differences found between all the values.

The first of my other two projects involved an HSCT tire model consisting of a worksheet made in MS-Excel to calculate a curve fit to a set of bi-cubic test data. The worksheet could be modified for different coefficients, yaw angles, and rated load factors. As soon as the required data was obtained, MatLab was used to make two different matrices (one for the positive side and one for the negative side) using the sign conventions for the yaw angle and side forces used in LaRC to plot the graphs requested. After this, John Tanner (NASA Engineer) used another plotting software to make a 3D surface using the data sets that the model provided.

My other project with the Michelin tires was slow. We had a few problems with the adhesive used in the sand paper to increase the friction on the surface. A new kind of adhesive used in France for the same purpose was procured to continue the tests. As soon as we obtained the adhesive we started again. Michelin needs three main kinds of tests; *a) Unyawed Relaxation Length - Zero yaw, pull side load up to 47,000 pounds, roll tire forward slowly,* *b) Yawed Relaxation Length - Yaw tire up to ±18 degrees, no side pre-load, roll* *tire forward slowly* and *c) Breakaway Friction - Pull side load up to 80,000 pound with tire stationary* required from Boeing.

As part of this project I was involved in taking data and operating the track data system in the Instrument Room. The procedures consisted of the Test Engineer (Robert H. Daugherty) informing the technician what load to apply to the test article for each test. He had to be on the phone with me to advise me when to commence and cease taking data.

I was learning about how the data system used works. Also I had the opportunity to see how can you make the plots needed and how to extract the data that you need from the system. On one occasion I had the opportunity to see a strange behavior on one of the plots made by the computer. This behavior suggested there was a problem in test wheel axle, and upon physically looking at the axle a small metal spacer had failed.

This testing will continue for another month.