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Dynamic Wheel Endurance Tester

Caster Concepts, Inc.

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Introduction:

This paper details the functionality and specifications of the Dynamic Wheel Endurance Tester (DWET) developed by Caster Concepts, Inc.(CCI) The DWET is a fully computerized and automated wheel testing platform capable of simulating realistic use conditions in order to measure, analyze and verify the performance of Caster Concepts' industrial casters.

Caster Concepts routinely performs quality analysis on their standard product lines, reviews the performance of competitors' product, and runs verification tests for potential customers to ensure that their product is appropriate for the customer's particular application. In the past, the caster industry, in general, has utilized rudimentary drum testers to understand caster wheel performance. These machines are simple, lack sophisticated sensors to measure performance data, and include only a small amount of automation. Testing on these types of machines required constant operator supervision to detect wheel failure. Wheels were subjected to a fixed load and speed for the entire duration of the test which in many cases did not properly mimic the real world experience.

In an effort to build the next generation of caster test equipment, Caster Concepts set out to design, build and integrate a fully automated dynamometer, completely controlled by PC based hardware and software, implemented with a comprehensive set of measurement sensors. This paper describes the resulting testing machine which we call the Dynamic Wheel Endurance Tester or DWET.

General Capabilities:

The DWET is capable of testing wheels as small as 2 inches in diameter and as large as 24 inches in diameter. It is capable of speeds up to 20 miles per hour and loads up to 10,000 pounds. It was designed to be operated fully automatically, needing only an operator to program the machine settings and install the test wheel onto the test bed. The DWET is capable of operating 24 hours a day, 7 days a week, continuously recording performance data and monitoring the condition of the wheel. If wheel failure is detected, the DWET will shut the test down automatically.

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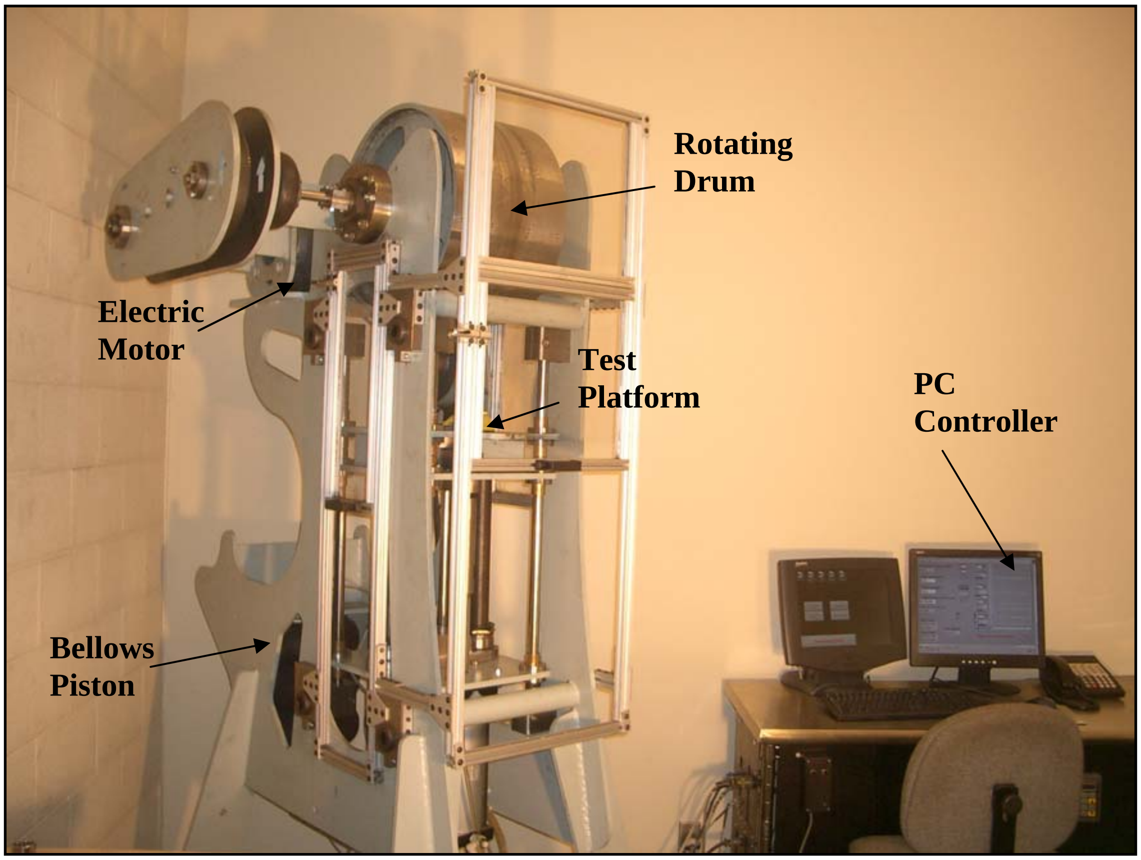
The DWET is able to be programmed to run various dynamic test conditions. For example, during a 24 hour long test, the test wheel can be run at 1200 pounds at 12 MPH for 10 minutes, allowed to idle for another 5 minutes at the same load, and then run at 20 MPH for 10 minutes at a new load of 600 pounds and idled again for another 5 minutes at the second load. This 30 minute cycle will repeat itself 48 times during the duration of the test. This test is designed to simulate the load and speed conditions that the caster would see in the field as it is loaded, used to transport parts to a line, unloaded and brought back to the staging area to be reloaded. The DWET can change load and speed conditions automatically according to the uploaded program.



Actuation System and Structural Design:

The DWET consists of a rotating drum on which caster wheels are loaded and run. The caster wheel to be tested is mounted onto a vertically sliding test platform that presses the wheel against the drum. Force is exerted onto this platform through a pivoting lever arm. One end of the lever arm is attached to the platform. The other end is attached to a pneumatic bellows piston. Also, a set of steel weights rides on a set of linear rails mounted along the lever arm. Adjusting the force applied to the platform and into the test wheel is accomplished by varying the pressure in the bellows piston and moving the set

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of weight along the linear rail. The bellows piston can apply up to 10,000 pounds of static force and the set of weights can be adjusted to simulate up to an additional 5,000 pound of dynamic load.

The DWET was designed to simulate true dynamic loading situations, i.e. include mass and inertia into the testing process. Had the DWET only been implemented with the pneumatic piston, the resulting forces on the wheel would not have truly mimicked the dynamic forces the caster would encounter in the field if it were running over obstructions. The combination of inertial weights and pneumatic force allows the DWET to simulate dynamic running conditions and do so in a very compact test machine. Typical test machines with similar capabilities are 2 to 3 times larger.

The DWET's 19 inch drum is powered by a 5 horsepower AC electric servo motor, controlled by a Baldor Vector Drive. The pneumatic systems are connected to shop air with a maximum pressure of 95 psi. The electrical and pneumatic systems on the DWET are entirely interfaced with a PC based control system. The PC is able to control motor speed and adjust the pressure within the bellows piston and control the location of the set of inertial weights.

Sensors:

The DWET is implemented with a complete network of sensors to fully understand how the test cater is performing throughout the entire duration of the test. All of the sensor data is fed directly into the PC-based data acquisition system. Custom written software, written in LabView, interprets the sensor signals, performs signal conditioning, and records the data into a data file for review after the completion of the test. The software also displays machine status and provides manual overrides to allow the operator to take control of the DWET.

The DWET sensors include an infrared temperature sensor, a load cell, an accelerometer, and torque and speed sensors built directly into the electric motor hardware. The temperature sensor is positioned on the test platform, pointed at the caster wheel. It continuously measures the wheels temperature and relays that information to the data acquisition system. We have found that monitoring the wheel temperature provides a clear understanding of how well the caster wheel and in particular the polyurethane tread is performing. It is a key piece of data that describes wheel performance and longevity. The load cell is mounted below the test platform, between the test platform and the lever arm. The load cell continuously measures the load being applied to the test caster. It provides the feedback loop that allows the computer to control the loading automatically.

An accelerometer is also included in the DWET sensor package. During obstruction testing, testing in which a caster wheel is asked to run over a number of obstructions mounted on the drum to understand its resistance to failure in harsh use conditions, the

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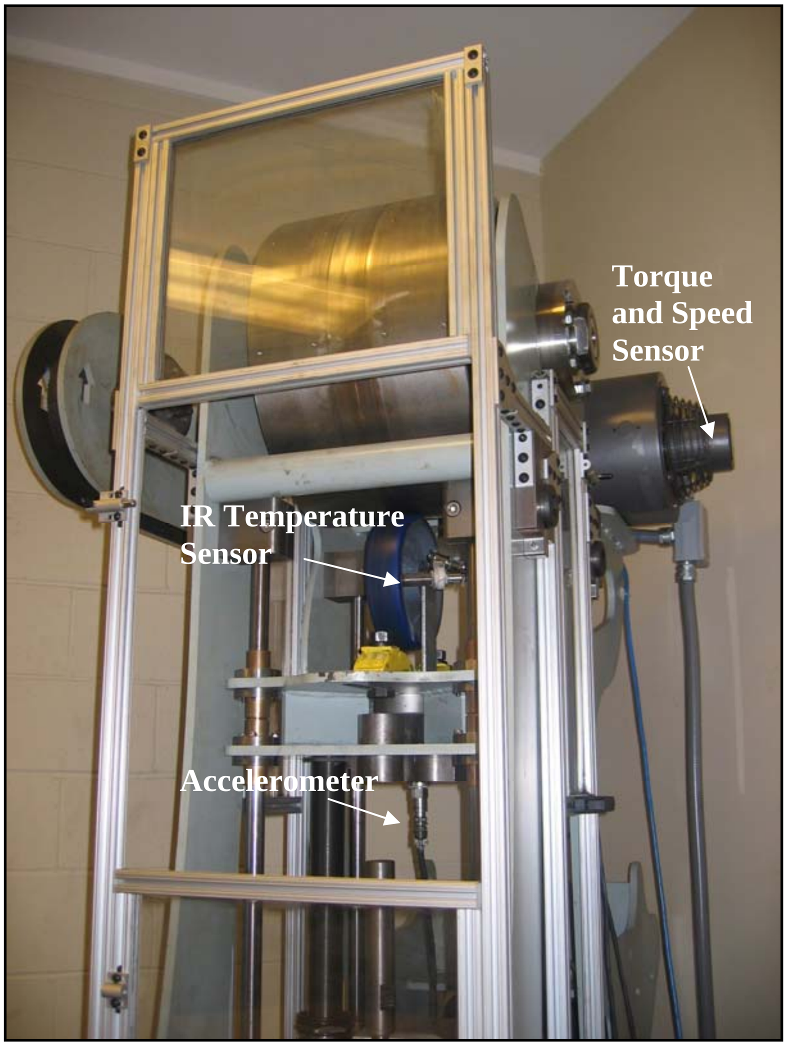
accelerometer is used to measure the amount of shock loading transmitted to the caster wheel. In cases where we are evaluating shock absorption caster performance, the accelerometer allows us to understand how well the caster reduces shock transmisivity. Lastly, the accelerometer allows the DWET to detect if the urethane tread has rip, torn, chunked out or if the bond between the tread and core has failed. The resulting wheel would begin to thump and that shock loading would be picked up by the accelerometer.



Torque and speed sensors are directly built into the drive motor. The speed sensor obviously allows us to monitor and control the speed under which the wheel is tested. The torque sensor gives us an understanding of how easy it is to roll the wheel under the given load. Because the torque sensor also measures the frictional forces within the DWET, the data itself does not provide an absolute understanding of the rolling resistance for each wheel tested. It does however provide us the ability to compare wheels tested under similar conditions. For example, the torque data can show us that one wheel is twice as hard to roll as another wheel. Lastly, the torque sensor provides the DWET another avenue to detect wheel failure. Should the bearings fail, or the urethane tread fail, the resulting wheel will be much harder to roll. A spike in motor torque can be detected by the operating software, signal a failure condition and automatically end the test session.

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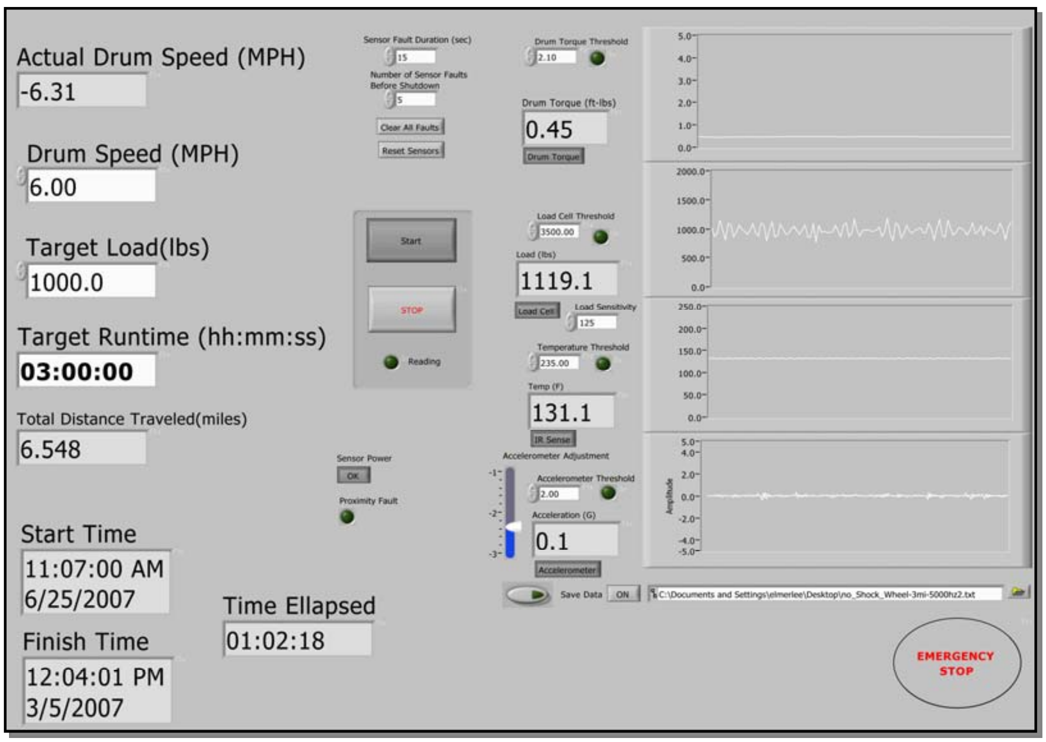
Software

The DWET control software is written from National Instrument's graphical programming language, LabView. The software is designed to operate every aspect of the DWET, including, controlling the motor speed, changing load, and setting the test duration. The software is also designed to record sensor data which is used as a feedback to detect wheel failure and end the test session. The software also takes the data, formats it and saves it into a data file that can be recalled and reviewed after the test is completed. Below is the control panel that displays sensor readings and provides manual machine control.



An additional piece of software has been written to organize the thousands of pieces of data generated by the DWET. This data viewing software searches and sorts the data, and graphically presents the data into an easily interpreted format. It allows the quick and insightful comparison of multiple tests run for the same type of wheel at different operating parameters and of multiple tests run for different types of wheels at the same operating parameters. Below is the data viewing program. It shows the temperature profiles of one type of wheel being run at 6 MPH at loads between 800 pounds to 2000 pounds. We see that as the load increases, the test wheel reaches a higher steady state temperature. Finally at the 2000 pound load, the test wheel fails 60 minutes into the test. The temperature profile of this test shows a spike in temperature.

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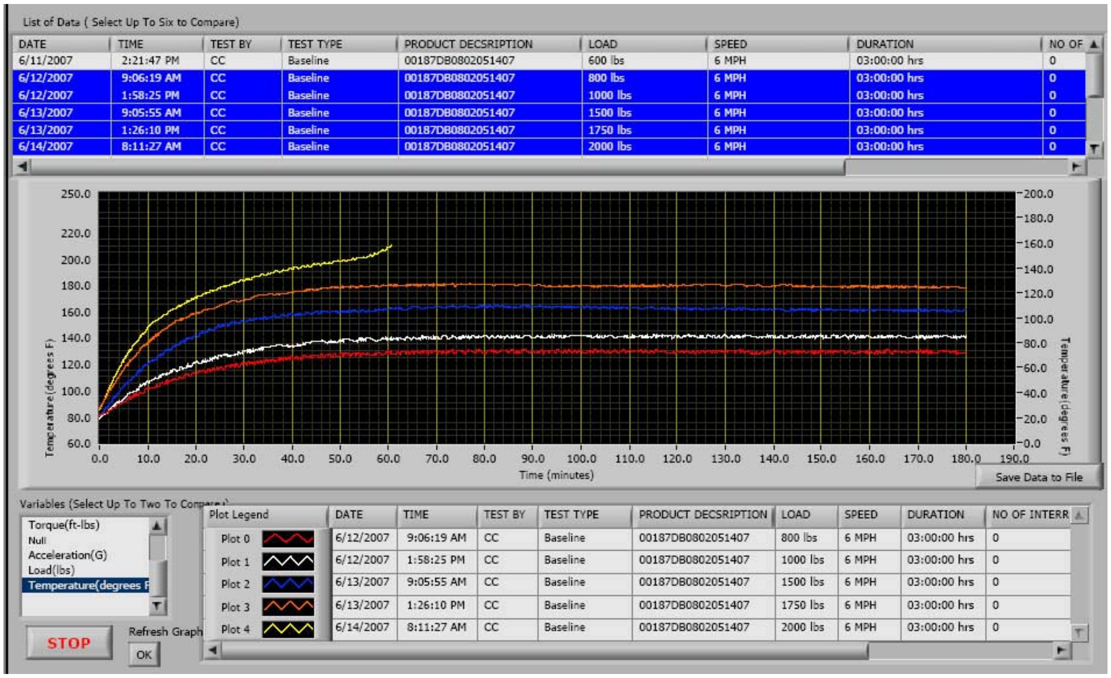

Testing Protocols

The DWET can be used to run a number of different test protocols that Caster Concepts engineers have developed. The three main types of testing performed by the DWET are a baseline, simulation and heat generation test. A baseline test is used to compare one particular wheel's performance to all others of similar size that have been previously run. In a baseline test, the wheel is subjected to multiple 3 hour long tests, in which each consecutive test the load is increased by the amount dictated by the testing protocol. The wheel is subjected to the test until failure is detected. When the wheel fails and how it fails allows us to compare the wheels capabilities against other similar wheels.

A simulation test is typically a single test run under the exact conditions that the test wheel will be subjected to in the field. Careful attention is paid to reproducing the idle times as they will have a direct effect on the performance of the wheel. Simulation test are run until the wheel fails or until it reaches a steady state, stable condition. If the wheel reaches a steady state condition, i.e. the wheel temperature and torque data remain constant, then it can be concluded that the wheel will function well for that application and that it will predominantly be subjected to normal wear and tear.

A heat generation test was developed in an effort to create a predictive failure model for polyurethane caster wheels. From experience, it is understood that polyurethane wheels typically pre-maturely fail either in the polyurethane tread or in the bond between the tread and the core. Heat generated by the deformation of the tread builds up and eventually causes the tread or the bond to exceed its operating temperature. Caster

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Concepts engineers developed a mathematical heat transfer model to predict wheel failure and used the DWET to measure certain material properties such as the heat generation co-efficient, K_{hg}. With the model, Caster Concepts can easily and accurately predict the speed and load combinations that will lead to wheel failure. A more detailed discussion about this model can be found in the Caster Concepts whitepaper, "Caster Concepts' Predictive Product Failure Model."

Detecting Wheel Failure

The DWET can automatically detect wheel failure for a number of different failure situations. If the tread chunks out, flat spots, melts or rips, the accelerometer will easily pick up the vibrations caused by a poor rolling wheel. In addition, both the torque sensor and IR temperature sensor is relied upon to detect more subtle wheel failure. In cases where the wheel has partially debonded, or the tread is beginning to break down in composition, we see the temperature of the wheel jump suddenly. At the same time, we see the torque required to roll the wheel spike as well. Both sensors indicate that heat has built up in the wheel and begun to melt the tread or break down the bond.

Conclusion

The Dynamic Wheel Endurance Tester is a powerful, state of the art caster testing machine that provides a new world of understanding of how our products perform. Coupled with our continuous improvement programs to evaluate new polyurethane tread materials, we are able to provide customers with the best products that the industry has to offer. For example, our new High Performance Polyurethane Tread material was developed by our material supplier and then proven using our testing and prototyping capabilities.

Questions and comments are always welcomed. Please contact Dr. Elmer Lee elmerlee@casterconcepts.com about our testing facilities. Also, Mr. Ben Miles, our chief engineer, would be happy to help with caster applications and products. He can be reached at bmiles@casterconcepts.com.

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