


A close-up photograph of several interlocking green gears. The gears are illuminated from the side, creating strong highlights and deep shadows that emphasize their curved, toothed surfaces. The background is a soft, out-of-focus green.

# The Next Frontier in Gear Testing

A close-up photograph of several interlocking polymer gears. The gears are a vibrant, translucent green color and are set against a dark, almost black background. The lighting is dramatic, highlighting the smooth, curved surfaces of the gear teeth and creating a strong contrast with the shadows. The focus is sharp on the central gear, while the others in the foreground and background are slightly blurred, giving a sense of depth.

Kleiss Gears has been at the forefront of R&D efforts improving the attributes of polymer gearing, including testing methods to insure tight tolerances and maximum repeatability.

By Douglas Felsenthal

Having pioneered the science of polymer gearing, Kleiss Gears continues to focus on improving the state of the art. In past articles we have explored the science of measurement. Here we will discuss the next frontier: extraordinarily accurate polymer gear testing. Where design defines the theoretical, and measurement defines tolerance of shape, testing puts a measure to the intangible quantity of engineering intent. Validating the operational performance of a transmission requires accurate testing. It goes beyond specification and allows a measured approach to such things as optimization and material selection with traceable data. Despite the purity of engineering intent in a transmission design, the final stage performance is the only metric that truly counts. This is a research area that we are proud to have spent a great deal of time investigating and developing.

In many projects it is not enough to simply meet print specifications. The transmission does not respond to specifications, it responds to real-world physical forces. The specifications may be met perfectly and you can still have a transmission that performs significantly below expectations or outside the realm of the designer's intent. The only way to determine these forces and how they interact



Fig. 1: One of Kleiss Gears' test platforms.

with the theoretical design is to dynamically test and measure efficiencies, strengths, and noise attributes while varying materials and geometric parameters. These are the performance tuning aspects that we see in a highly optimized world.

In highly optimized systems there is more than gear shape, there are also efficiency and

power transmission parametrics. A successful outcome is based on several factors. The gear components must relate to the chassis component with rigidity and center distance movement while maintaining harmonic balance, which is the component that varies with tooth engagement and determines how energy is distributed throughout the gear train. In the end, the drive efficiency depends upon everything working in harmony throughout a variation in speed and load. If we met this min to max condition of operation and still transmit the required power, we have built a successful transmission. As an industry, the focus must be on the overall performance of the system with high performance individual components complementing each other, working in concert to achieve a synergistic end result. The goal should be to exceed expectations rather than to meet them.

On a component basis we can measure and verify each and every part of the system. But that is only the static view of the transmission. In a moving, dynamic system we need to view the transmission in motion. Not only in static motion but also in a real-time environment, capturing data as the system creates it. The question is how to measure and/or observe our system in this

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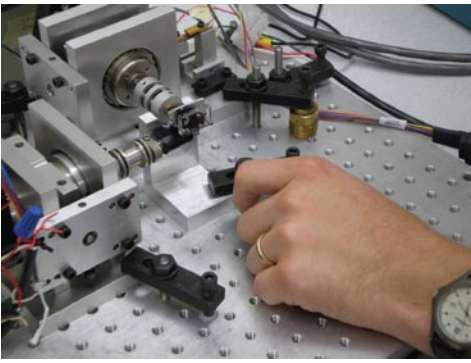


Fig. 2: Dynamic tester platform.

condition. This is the basis of gear testing.

With accurate testing we determine precisely where the transmission will fail and the resonant point of failure. We can find the cause and mode of the failure, which in turn allows us to compare materials and how they affect the efficiencies of power transmission. Better yet, we can reproduce these results at will.

With the constant evolution of testing and measuring ever-shrinking tolerances and systems we have created gear testing equipment that is flexible in design and extraordinarily sensitive, yet rigid in repeatability. Our testing platform can be configured to meet the requirements of various systems with the minimum of customization, and it is computer controlled for accurate data collection down to very small measures of torque and speed.

## Case in Point

In a recent project the customer required a precise level of strength while maintaining efficiencies that would allow a 4mm micro motor to power the system on an intermittent basis. We were asked to determine if a double worm gear configuration would meet the project's design intent and provide enough output power to operate the drive device. We were also asked to investigate the optimal materials to use to ensure the success of the project. The question was how to make these determinations and move from an earlier static method of measurement to a dynamic methodology.

With the micro motor size, efficiency would determine whether or not we had achieved a successful design. The chosen solution was to operate the transmission in various stages and then all together within its own chassis. Then we instrumented the meshes with micro sensitive components and recorded the dynamic parameters of the system. After completion, we compared the results of each stage and then determined the overall efficiency of the system with varying materials to

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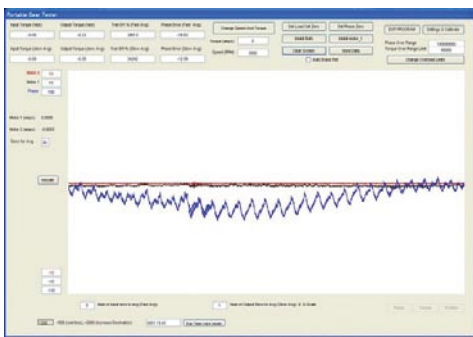
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**Fig. 3: Real-time results from dynamic tester.**

optimize the entire transmission. Our flexible testing platform allowed us to exceed the client's expectations while saving time, money, and duplicated effort.

This method of testing allowed us a confident glimpse into real time torque and efficiency dynamics. The double worm configuration used a worm final stage, which needed substantial strength while maintaining a high surface finish to maintain efficiency. During the development stage it was determined that multiple materials were the key to success. We found the middle stages were less prone to this effect and would operate correctly with unfilled acetyl/nylon meshes.

Finally, the input stage was deemed to need nylon, and the tester allowed us to test this choice quickly and accurately. Without real-time testing we would have been chasing a ghost for the correct permutations and combinations with only luck on our side in determining when we were at the correct decisions for success.

### Dynamic Testing

A basic requirement for a testing platform is flexibility. The platform needs to be standardized yet flexible for use in customized testing. We have developed several flexible test platforms to accommodate various types of projects. The goal is a standard set of components that interfaces to a standard computer process control environment and has the option of being reconfigured on the fly for different application requirements. Standard test motors are of the highest quality brushless motors from Switzerland to eliminate as much motor rotational influence as possible. These are coupled to the computer system through micro miniature torque strain gauge sensors that have been programmatically calibrated.

Depending on the dynamics of the system we are currently testing, we choose the



**Fig. 4: Testing PSI, final gear and cavity shaping.**

appropriate motor size with the specifications required. One motor cradle combination drives the system, while the other acts like a dynamic load using phase shifting mathematics to provide smooth torque to the output. Both are infinitely variable by the computer

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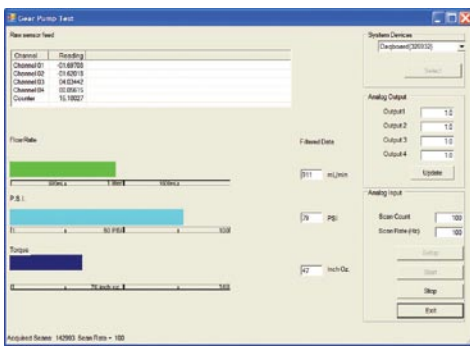


Fig. 5: Time test results.

system and can be programmed for multiple testing protocols during any given test.

The results are delivered to the computer system, verified, tabulated and then converted for output in various forms to fit the intended purpose of the measurements. Since the system is real-time, it displays resultant information in a continuous manner throughout the testing procedure. This is all done through a custom software control and display system. The accompanying diagrams give illustration to the components and physical attributes to this system.

### Specialized Methods

It is crucial to remain flexible in testing fixtures. The test platform for one project may not be appropriate for another. A critical point for one of our customers was the ability to map the performance and characteristics of a gear pump. The pump would maintain a head 75psi with a 1L/min flow rate, which is no simple feat for an assembly without secondary operations. The illustration here shows how the same methods of testing, in a slightly different configuration, can be used to accomplish a design goal. The physical configuration of the test platform changed, but the methodologies and manner in which the testing was conducted were very similar. If you visited our booth at Gear Expo 2007, perhaps you saw this system in operation.

The testing approach allowed us to quickly determine the final gear and cavity shaping to achieve the design intent. It wasn't hard to get water pumping and to maintain the pressure of 25psi. To lower noise, improve performance, and stay within our torque limits, however, highly accurate and repeatable "real-world environment" testing was crucial. Without it this program would never have been completed.

Polymer gear production has moved from simply preparing tools and the molding of gears. It has evolved to include research and development for each application and system to target particular performance intent. With

advances in testing technology and methods, polymer gears continue to increase in performance and suitability, while decreasing in cost and weight. At Kleiss Gears we take pride in our ability to produce polymer gears of the highest quality and accuracy, maintaining a standard of .02mm repeatability, in fact. Advanced polymer gear testing leads to better gears, quieter and more-efficient systems, quality products... and happy customers!

**ABOUT THE AUTHOR:**

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