



R & D Note

Repeatability Testing & Evaluation on Micro-Poise Tire Uniformity Machines

Dr. Shaun M. Immel

Chief Technology Officer
Micro-Poise Measurement Systems
AMETEK Materials Analysis Division

March 23, 2012



Goal

The goal of this paper is to educate the reader on the fundamentals of assessing the measurement repeatability of a Micro-Poise tire uniformity machine. This will include some background and extended discussion of the most important repeatability testing requirements and some guiding suggestions for addressing this issue in a standard production environment.

Background

Our customers periodically request more information and explanation as to why there are specific requirements for testing or evaluating the repeatability of Micro-Poise tire uniformity testing machines. The list of specific critical testing requirements¹ includes but is not limited to:

- Selection of special “master” tires with low or no nylon content and inherent tire stability
- Tire stiffness and tire speed rating limitations
- Requirement for room temperature tires with “warm up” runs prior to measurement qualification testing
- Tire lubrication method and material
- Clarification of standard tire loading, inflation, and rim profiles

Even though Micro-Poise tire uniformity machines are used for testing and measurement of production tires, it is critical that these guidelines, as stated in various ways in the Micro-Poise technical machine specification, be followed when evaluating the repeatability performance of a machine. The evaluation of repeatability under normal production measurement conditions is a very important topic to investigate and will be discussed briefly in this paper; however, the special process of “machine only” evaluation should be completed prior to any assessment of production measurement process repeatability.

Discussion

The overall tire measurement process repeatability is a function of

- the machine-induced measurement variation
 - e.g. spindle and instrumentation signal noise
- the measurement variation induced by the tires being used to test a machine
 - e.g. stiffness and inherent stability of the tire
- the measurement variation caused by the interaction between the machine and the tires
 - e.g. tire fitment on the rim

Each of these three factors contributes to measurement variation and adds up to produce the overall measurement process repeatability for the machine. In many different types of measurement equipment, a traceable standard exists that can be placed into the measurement equipment and used to ascertain both the accuracy and the repeatability of the measurement device.

¹ Micro-Poise ASTEC PLUS™ Machine Technical Specification, February, 2010, Section 8.3.



For example, in tire dynamic balance machines, high precision weights with known values can be installed into precision holes on the machine tooling and measured. Since these “known” weights are traceable, they can be measured several times and compared to “truth” values resulting in an assessment of the machine’s repeatability and accuracy. In the case of tire geometry (runout) measurement, a high-precision machined metal test piece, which contains very well-known and controlled runout and geometric features, can be used to evaluate the repeatability and accuracy of the geometry measurement device.

In the case of tire uniformity measurement, no such traceable standard exists to evaluate the repeatability and accuracy of the tire uniformity machine and tires must be used to perform this measurement quality evaluation. Tires are typically not a known standard because their uniformity properties change over time as well as with the number of times they have been measured. This makes it very difficult to use tires to evaluate the accuracy and repeatability of a tire uniformity machine.

As a Micro-Poise customer with a tire uniformity machine, when qualifying the repeatability of that machine, it is very important to isolate the machine as much as possible since the first and foremost goal of the process is to quantify the repeatability of the machine itself and not the whole system measurement process. Obviously, the repeatability of the whole measurement process is important (especially to the end automotive customer), but only after removing as many outside variables as possible can one truly assess the “machine performance”. These outside influences are minimized by following specific testing protocol recommendations, which will be discussed in the next section. It is this machine performance, which Micro-Poise has quantified, to which the machine was designed to comply. Micro-Poise technical machine specifications are very clear to state the measurement performance of the machine including the very specific method and requirements under which the machine must be tested. Each of these requirements is discussed in the following sections.

A. Selection of special “master” tires with low or no nylon content and inherent tire stability

If tires are pulled at random and measured for force variation several times on a tire uniformity machine, the measurements are sure to change each time. In general, the measurements will change considerably at first and then settle down and change less after numerous subsequent measurements. After numerous testing cycles, some tires will stabilize more than other tires. This universally known and accepted fact is due to several constructional characteristics of the tire resulting from the manufacturing process as well as the interaction of those differences with the physical and chemical design of the tire itself. So, in order to reduce the amount of measurement variation caused by the tires being used for the test, much attention must be given to choosing a set of specific tires that are inherently stable to aid in the evaluation of measurement repeatability for the force variation machine.

The selection and creation of a set of “master tires,” which may be used for testing measurement repeatability, are complicated and difficult and deserving its own detailed technical document. However, included in this paper are some basic guidelines to help the reader begin to learn about developing an acceptable master tire set. Typical guidelines include selection of a set of tires well above in number of the final quantity desired for the master set. This way several tires can be exercised and evaluated and only the most inherently stable set of tires should be selected for the final master set. The tires should be non-speed rated and of non-nylon ply or breaker construction and not considered to be low aspect ratio. This is not as important as maintaining a low enough tire stiffness rate. This item will be discussed in greater depth in the next section.



The candidate tires should not be ground for force or concentricity and should have a reasonable spread in actual measurement values. It is best to load and test these tires on a tire test machine on standard rims for at least four hours at 50 mph under 80% of rated load and at 100% of rated inflation pressure. Once the set has been developed, the tires should be stored at ambient temperatures that do not fall below 15 °C (60 °F) and the tires should be stored flat and not stacked making sure they cannot be deformed when stored. The repeatability measurements (typically standard deviation measurements) should be recorded and tracked for each tire. If the repeatability of any given tire begins to fluctuate or change on a machine consistently, then it should be replaced.

These guidelines are not comprehensive by any means, but do represent a good set of directions to begin developing an appropriate master set of tires that can be used for repeatability evaluation.

B. Tire stiffness and tire speed rating limitations

Any slight geometric runout in the tooling and spindle assembly inside the tire uniformity machine will be amplified by the stiffness of the tire being measured. Micro-Poise takes great care in their machines to keep this geometric runout below 0.0008 in (0.02 mm) in both the radial and lateral directions, but even so there can still be an effect from this on measurement repeatability especially when using high stiffness ratio tires. A great way to think about this is using the simple spring equation:

$$\Delta F = k * \Delta x,$$

where k is the spring constant of the tire, ΔF would be the force measurement variation created by the runout, which is expressed as Δx . It may then be concluded from this equation that the stiffer the tire, the more measurement variation the tire will induce. Hence, the spring rate constant of the tire being measured is an important factor indicating how much of this effect contributes to the overall measurement repeatability. Micro-Poise technical specification repeatability performance numbers are stated for tires with spring rates less than 1,000 lbs./in. When tires with spring rates greater than this limit must be used to test a machine's repeatability, the best rule-of-thumb is to take the Micro-Poise stated measurement performance specification number and multiply it by the ratio of the stiffness of the tire being tested and 1,000 lbs./in. For example, if a tire with stiffness of 1,500 lbs./in. is being used, take the repeatability specification and multiply by $1,500/1,000 = 1.5$ to provide the "modified" repeatability specification.

Stiffness ratios for non-speed rated tires with aspect ratios greater than 70 are typically in the acceptable range (< 1,000 lbs./in.). Tires containing nylon cap material (typically used to create higher speed ratings for tires) and tire aspect ratios much less than 70 typically have higher stiffness ratios and may be unsuitable for use in repeatability testing. The most important part here is to evaluate the actual stiffness ratio of any candidate master tire set and evaluate accordingly.

C. Requirement for room temperature tires with "warm up" runs prior to measurement qualification testing

When testing any tires, even stable "master" tires as described in Section A. above, the tires will generally repeat better (become more stable) after some "warm-up" measurements. The term "warm up" relates less to actually raising the temperature of the tire and more simply to exercising the tire through some number of measurement cycles before recording data as part of a measurement repeatability testing process. Micro-Poise recommends at least 3 warm-up passes of the tire before recording repeatability results. This specific



requirement helps to further reduce the measurement variation caused by the inherent stability of the tire under test and should be done each time a repeatability test is executed.

D. Tire lubrication method and material prior to measurement qualification testing (e.g. castor oil)

Both the lubrication application methodology and the material used to lubricate a tire before testing have a direct effect on the measurement repeatability. Micro-Poise takes great strides to deliver a high quality precise automatic lubrication system for tires, which can be used to lubricate tires before testing during normal production conditions. The design of the applicator roll, lubrication pumping system, lubrication set-up duration, and even the chemical composition of the lubrication itself is incredibly important. Micro-Poise's AkroLUBE II™ is specifically formulated to achieve maximum repeatability performance in a production environment. Proper maintenance of luber equipment, the luber's number of years of service, and luber setup are other very strong factors that can add variation to the repeatability testing process. It is because of these "hard-to-control" factors that Micro-Poise requires the following consistent method for lubricating tires specifically for repeatability testing.

Hand lubing tires with a water-glycol mixture (e.g. castor oil) reduces the measurement variability caused by the tire mounting and seating on the tooling so that the machine can be truly evaluated for measurement repeatability. Proper manual lubing will uniformly cover the bead contact surface completely and will prevent the accumulation of excess lube. The manual action of wiping the bead area also removes contamination from the bead area. This can certainly be problematic when rolling tires across a plant floor to the in-feed of a machine when performing a repeatability test. The goal here is to make the lubrication method and material as consistent as possible in order to minimize these variables affecting the machine measurement repeatability.



E. Clarification of standard loading, inflation, and rim profiles for measurement quality testing

Testing setpoints like tire loading, inflation and the actual rim profiles of the tooling being used for testing have a direct impact on both the repeatability of measurement and the actual values being measured (accuracy). It is, of course, important to have these defined and consistent for the measurement repeatability testing processes. It is the requirement of Micro-Poise that repeatability tests be performed at 85% of rated load and at a nominal inflation pressure, usually 30 psi or 2 bar. Tires should also be tested while not at any temperature extreme and measured only on rim profiles per the T&RA standard.

Summary

Establishing measurement repeatability for the entire measurement process is very important but can be difficult to truly assess. Each production measurement situation presents its own unique challenges. The automatic lubrication system can be incorporated, the lubrication material of choice can be used, and even production tires used for evaluation. However, each of these conditions adds a given amount of measurement variability into the evaluation process making it difficult to know the true "bottom line" process measurement repeatability.

It is critical to monitor and control several key factors when assessing the measurement repeatability of a Micro-Poise tire uniformity machine. Only after these factors are controlled and kept consistent, as described in Sections A. through E., can the Micro-Poise tire uniformity machine be evaluated for machine measurement quality through repeatability studies.

Specific attention is devoted to the design and manufacturing of Micro-Poise tire uniformity equipment leading to the best-in-class repeatability. The repeatability specification for the Micro-Poise ASTEC tire uniformity machine, expressed as the average standard deviation of measurements², is

Measurement Parameter	σ_{avg} ← Metric Units	σ_{avg} ← English Units
Radial Force Variation	0.169 daN	0.38 lbs
Lateral Force Variation	0.133 daN	0.30 lbs
Conicity	0.133 daN	0.30 lbs

In order to evaluate whether or not a specific Micro-Poise ASTEC machine is performing to these specifications, the guidelines detailed in this technical paper must be followed. It is also worth noting that the guiding principles described in this technical paper also apply to all Micro-Poise tire uniformity testing equipment.

² Micro-Poise ASTEC PLUS™ Machine Technical Specification, February, 2010, Section 4.