Why measure TSO?
Measuring TSI/TSO properties of samples helps predict the performance of paper and when manufacturing corrugated board. L&W Autoline TSO is also an ideal tool for process optimization, as it allows mills to take early action in the headbox, press and dryer sections as well as to reduce raw material usage. For example, you can use measurements to troubleshoot problems related to the headbox, such as pressure pulsations or a deviating pressure profile.

TSO/TSI measurements have many applications. They can be used for predictions of the runnability of a paper in sheeting, copying, and printing operations. In a multi-color printing process, the orientation of hygroexpansion (related to the TSO-angle) needs to be under control. In corrugated board manufacturing, matching liner single facer and double backer with the same TSI/TSO-value is important to avoid twisting or warping.

Measurement results
The module uses the same measuring technology as the well-proven L&W TSO Tester stand-alone testing equipment that has been the industry standard since 1992. The measurement results are presented as a polar diagram or high resolution profile, which provides the complete picture of the paper sheet’s elastic properties. Fast, accurate TSO measurements from the L&W Autoline TSO are the solution to many mill challenges. Mills can lower costs through optimization of fiber usage and decreasing refining energy consumption.

Features
• Based on the proven L&W TSO Tester
• Non-destructive, ultrasonic method
• TSO profiles
• TSI\text{MD/CD} profiles
• TSI\text{MD} profiles
• TSI\text{CD} profiles
• TSI\text{HC} profiles

Benefits
• Enables strong correlation with important strength properties
• Improves runnability
• Helps predict performance of product
• Reduces testing time
**Definition**

The speed of an ultrasonic pulse in the plane of a paper depends on the elastic properties of the paper – its tensile stiffness index (TSI). TSI can be compared with Young’s modulus (or the “E” modulus) for other materials. The relationship can be expressed as:

\[ \text{TSI} = v^2 \times c \]

where:

- \( \text{TSI} \) = tensile stiffness index (kNm/g or MNm/kg) of the paper measured using the ultrasonic method
- \( v \) = propagation velocity (km/s) of the ultrasonic pulse
- \( c \) = a dimensionless constant close to 1 depending on Poisson’s ratio for the paper

Velocity is measured in eight directions. The result is converted by the processor using a Fourier transformation to an ellipse. The ellipse shows the elasticity in all directions of the plane of the paper. This allows the identification of the direction of the greatest stiffness. This property is known as TSI_{max}.

The difference between the machine direction in the sheet and the direction for TSI_{max} is referred to as the TSO_{angle}.

Other reported properties are:

- TSI_{MD} = tensile stiffness index in the machine direction
- TSI_{CD} = tensile stiffness index in the cross direction
- TSI_{MD/CD} = tensile stiffness index ratio (i.e. the anisotropy in the sheet)
- TSI_{max} = tensile stiffness index, maximum value
- TSI_{min} = tensile stiffness index, minimum value
- TSI_{area} = the tensile stiffness index, ellipse surface area

**Measurement principle**

An ultrasonic longitudinal pulse is sent from the transmitter along the paper to the receiver 100 mm apart, from the transmitter. The average pulse velocity in the paper is used in the calculation of Tensile Stiffness Index (TSI).