

Enhanced Inline Diameter and Fault Control by 3-axis Laser Scanning

Abstract

A new inline measuring system for extruded products is based on 3-axis laser scanning and measures diameter, ovality and extrusion faults at high accuracy. It is largely independent of shape, ovality and orientation of the product.

Background

Many extruded or coated products, such as cables, fibres, tubes and hoses, require high tolerances for outside diameter, roundness and fault-free surface.

The parameter "diameter" has to be defined more clearly because these products are never ideally round (circular). Many cable and tube products are fitted later with fittings or connectors, i.e. the average diameter or, indirectly, the circumference is important for proper fitting, tightness, etc.

Often, there is also a need for an accurate inside diameter of the extruded layer, e.g. for medical tubing where the flow rate is vital. Also, for cables with non-round conductors or conductor bundles, an accurate average inside diameter is important. In the case of tubes, this parameter can be defined in combination with an ultrasonic wall thickness measurement.

For multilayer extrusion, e.g. for compound tubes, the innermost tube is the basis for further extrusion steps and is therefore especially critical regarding diameter and roundness.

Reasons for out-of-roundness

Almost every extruded product undergoes a deviation from the ideal circular shape. This shape deviation, or "ovality", depends on the product geometry (diameter and wall thickness), materials, gravity, cooling process and other factors.

Measurement in 1, 2 or 3 axes

In the early days of inline measurement, optical sensors had just 1 axis. Considerable fluctuations of the measured diameter occurred for reasons of ovality and changing orientation, even when product dimensions were constant. Therefore, such sensors had often only limited value.

Later, 2-axis (XY under 90°) sensors became the standard. The goal was to improve the measurement and consider the ovality in the measurements.

With this system, the average diameter can be measured with more reliability; however, the following facts are often overseen:

- Under certain circumstances, the ovality is not recognised at all
- The average diameter still varies considerably depending on the orientation
- The min. and max. values are not measured reliably

With the goal to eliminate the above shortcomings and in order to improve control for increasingly tighter tolerances, a 3-axis laser scanner ODAC[®] TRIO with a 60° geometry was developed **Fig. 1**.



Figure 1

Advantages of a 3-axis measurement

Theoretical considerations and practical tests show clear advantages over today's "classic" 2-axis measurement. **Fig. 2** shows the error for the arithmetic average of 2 measuring axes for a 20 mm product with a true average value out of 36 readings, when the oval is rotated by 180°. The arithmetic average varies by 0.25 mm, i.e. more than 1% of the nominal. This is often not tolerable.

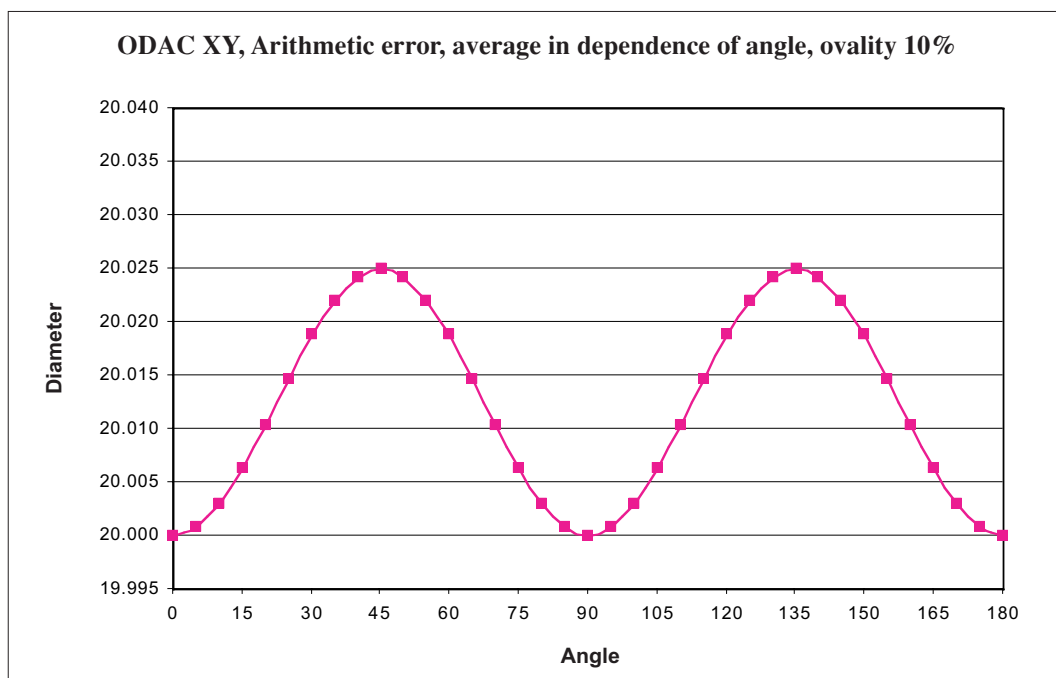


Figure 2

Fig. 3 shows the same parameter for a 3-axis system. In this case, the arithmetic average remains practically independent of the orientation, the error is now less than 1μ (metric micron).

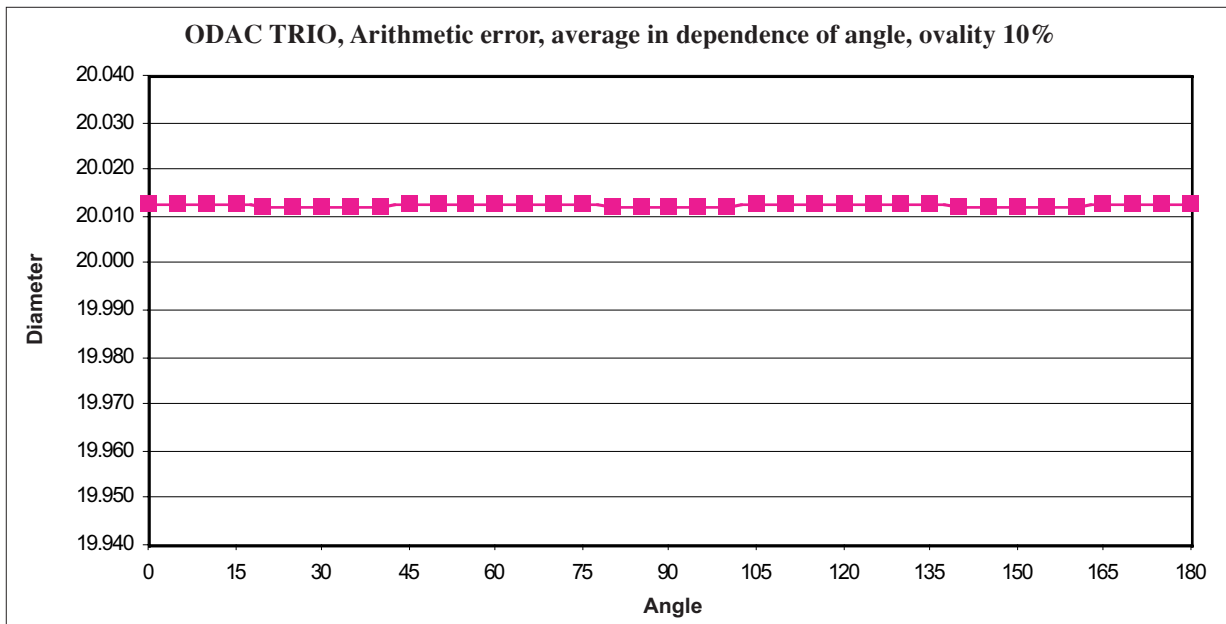


Figure 3

Fig. 4 illustrates the problem clearly: With the 2-axis measurement the ovality $(D-d)/2$ remains in the worst case undetectable and the average varies considerably.

With the 3-axis measurement, the ovality varies only marginally, whereas the average remains practically constant. With an accurate average the circumference of the product is also defined.

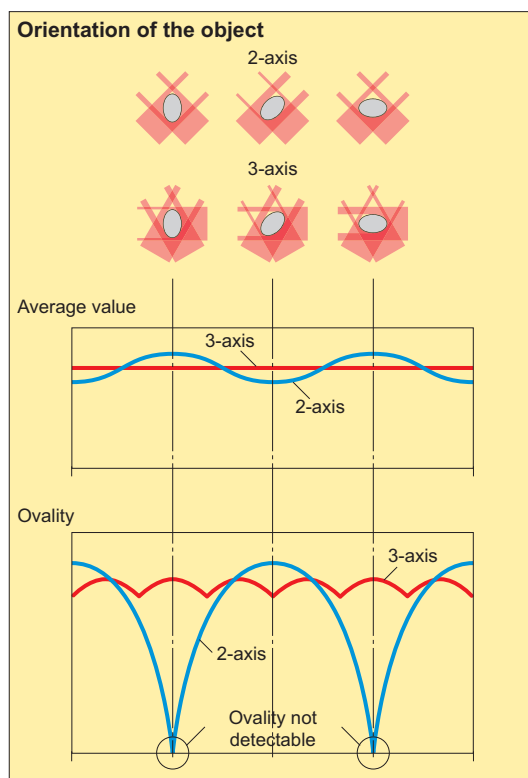


Figure 4

Detection of localised faults

For many extruded products, a reliable detection of localised faults, such as lumps and bulges, is a must. In this case, the 3-axis concept again offers a considerable improvement. **Fig. 5** shows the reason: The blind zones in the 3-axis system are much smaller, the detection probability for small faults increases by approx. factor 3 versus the 2-axis system.

By adequate signal processing and filtering of the readings, the diameter sensor becomes this way also a reliable fault detector (within limits regarding speed and fault dimension). Note that for very small faults and high speeds a specialised fault detector is available, which is also based on the 3-axis concept.

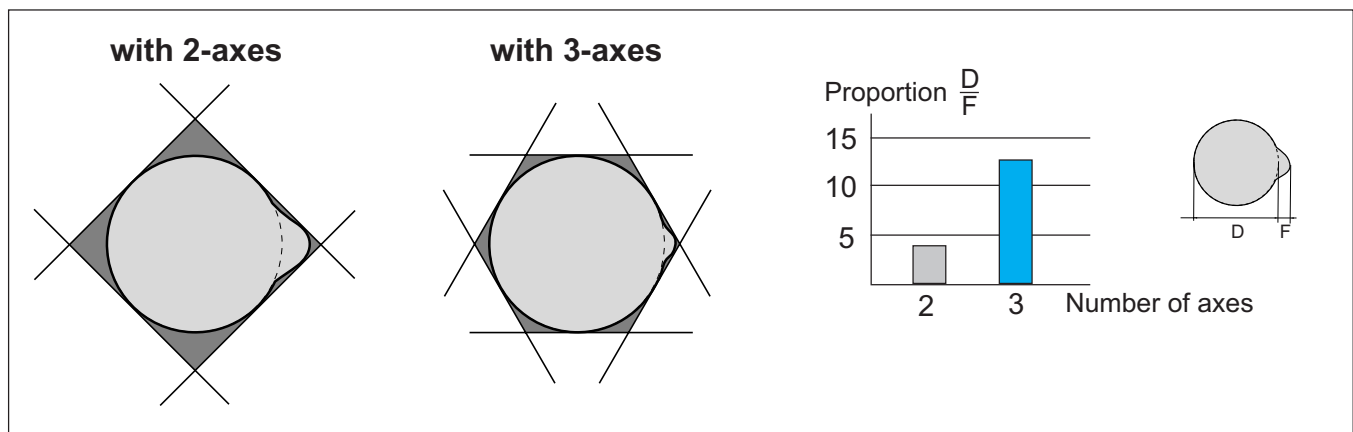


Figure 5

Design goals

For the 3-axis sensor the following main criteria were defined:

- Simultaneous measurement in 3-axes in the same plane
- Compact and fully sealed (IP 65)
- Open design (no threading of the product)
- High life-time (diode laser)
- High dirt immunity (special optical geometry)
- Top accuracy (resolution / linearity / repeatability)
- Costs = max. 1/3 over typical 2-axis system

All above design criteria have been fulfilled.

Technical data and dimensions

The chart *Fig. 6* and the outline *Fig. 7* show the main data.

Measuring field	34 x 34 x 34 mm (1.34 x 1.34 x 1.34 in.)	
Min. diameter of object	0.15 mm (.006 in.)	
Repeatability	± 0.0002 mm (.000008 in.) (Averaging time 0.2 s) ± 0.0001 mm (.000004 in.) (Averaging time 1 s)	
Linearity	± 0.001 mm ± 0.08 ‰	
Resolution	0.0001 mm (.000004 in.)	
Scanning frequency	3 x 600 scans/s	
Scanning speed	98.3 m/s (306.1 ft/s.)	
Light source	VLD (Visible Laser Diode) class II	
Power supply	90 ... 265 V~ / 48 ... 62 Hz	Supplied by the USYS processor unit (24 V)
Type of protection	IP 65	
Available interfaces	Serial, PROFIBUS DP, ETHERNET TCP/FP or USYS	

Figure 6

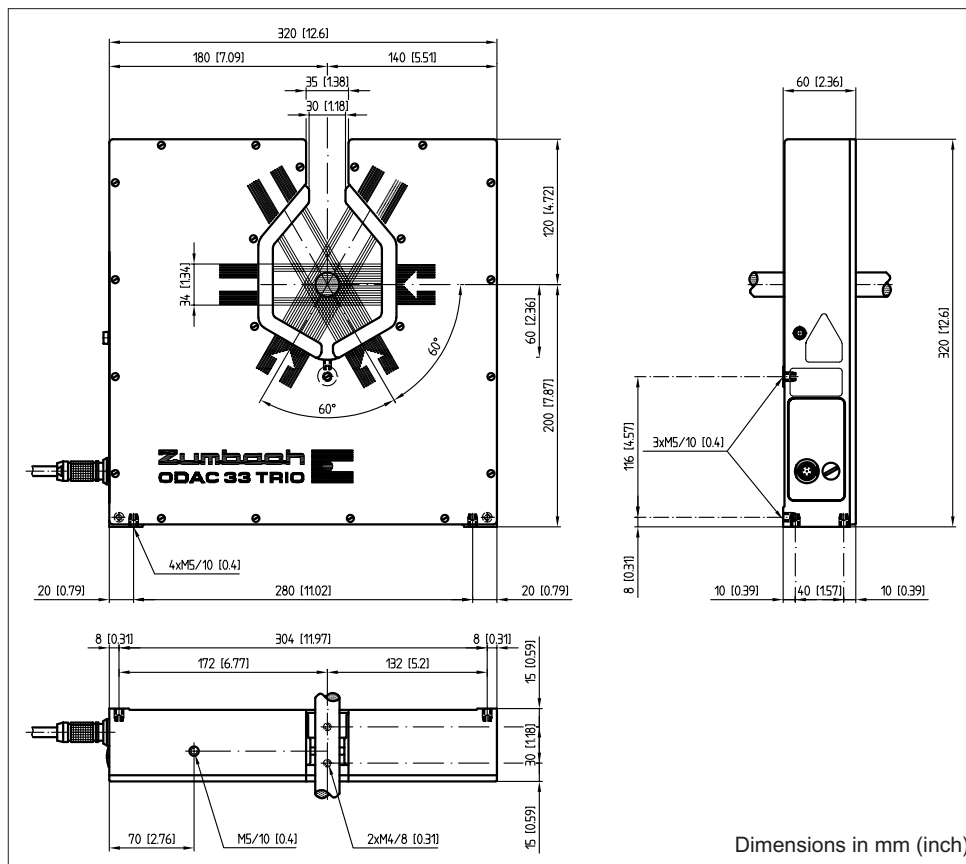
Dimensions

Figure 7

Comparison: 3-axis versus 2-axis measurement Fig. 8

Criteria	2-axis (XY)	3-axis
Angle between axes	90°	60°
Accurate average value	Only approx.	Yes
Accurate circumference	Only approx.	Yes
Reliable recognition of ovality	No	Yes
Angle dependency of average value	Low	Negligible
Angle dependency of ovality	High	Low / negligible
Investment ratio	100%	130%
Reliable fault detection (lumps, bulges)	No	Yes, within limits

Figure 8

User benefits

The benefits of the measuring data for display, process control, quality statistics etc. are multiple. The data can be transmitted directly from the sensor via ETHERNET, PROFIBUS or other interfaces to the customer's network or can be further processed with USYS® processors locally at the extrusion line for operator display, SPC statistics or closed-loop control.

Of particular interest are the possible combinations with ultrasonic wall thickness and eccentricity measurement. **Fig. 9** shows a combination which is often used for tube extrusion

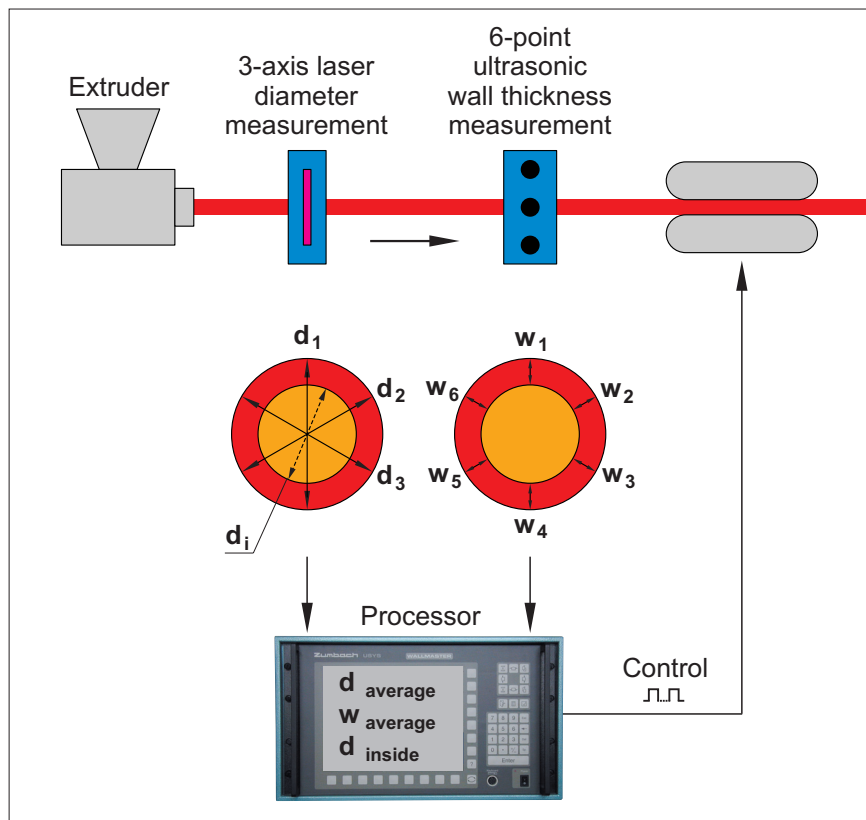


Figure 9

A UMAC® ultrasonic scanner with 4 or 6 transducers measures wall thickness and computes eccentricity. Together with the ODAC® TRIO readings, the inside diameter can be computed or controlled in real-time.

A similar combination is possible for cable extrusion when wall thickness and eccentricity of the insulation or sheathing must be controlled because the conductor diameter/ovality can vary.