Monitoring Extrusion of Large Tubes Precisely

Millimeter Waves Provide Parameters such as Diameter, Wall Thicknesses, Ovality and Sagging on a Non-Contact Basis

A millimeter wave measuring system determines the dimensions of large tubes very precisely and independent of ambient or material influences. It can be applied for hot measurement as well as at the cold end of the line for final quality control and thus represents a key technology for future-oriented quality assurance.

During the extrusion of plastic tubes with large diameters and wall thicknesses product quality as well as the reduction of material costs that can amount up to 90 % of the total manufacturing costs have the highest priority. Depending on throughput of the line, used material type and underlying norm there is between the minimum and maximum permissible tube dimensions an annual savings potential in the single-digit millions euros range [1]. In addition, the compliance with norms and standards for minimum and maximum permitted diameters and wall thicknesses forms the basis for a flawless processing of the tubes, for example that they can be welded easily.

As a result of the specifications and increasing requirements during tube extrusion manufacturers use measuring and control devices for quality assurance in their production lines. The use of a precise measuring system leads to significant time and material savings as well as to a high quality end product.

Dimension Measurement of Plastic Tubes during Extrusion

Sikora AG, Bremen, Germany, in cooperation with the Fraunhofer Institute for High Frequency Physics and Radar Techniques (FHR) and the Süddeutsches Kunststoff-Zentrum (SKZ), has developed a new technology based on millimeter wave technique. This technology measures online, on a non-contact basis and precisely the inner and outer diameter of large plastic tubes with a diameter from 120 mm and determines ovality, wall thicknesses and the sagging (sagging of the melt during solidification at a too high viscosity). The measuring system (**Fig. 1**) adapts itself to the characteristics of the extruded plastics and does not require any calibration by the operator. This increases product quality and ensures significant material and cost savings during extrusion.

Today, for quality assurance during the production of plastic tubes optical methods are used e. g. lasers for determination of the diameter or X-ray for the additional measurement of the concentricity and wall thicknesses. Conventional technologies such as ultrasonic also measure tube dimensions, however they often reach their functional limits. An additional technology for quality control is presently undergoing practical trials. It works with terahertz impulses generated by – an expensive femto-second fiber laser, whereby the terahertz beam is directed into the measured object. The wall thicknesses are determined from the reflected echoes striking the inner and outer boundary layers.

In this article there will be explained the significantly more cost-effective, frequency modulated radar technology FMCW [3]. Those systems work in the sub terahertz range and have already been used for some time in the automotive technology for distance measurement. They are based on semiconductor technology that is economically priced and their lifetime is practically unlimited. However, it was necessary to increase the bandwidth of the frequency modulation by a multiple to increase the resolution. In the selected range from 80 to 300 GHz all

Fig. 1. Millimeter wave measuring technology: the system has a clear span of 600 mm and determines diameter, ovality, wall thicknesses and sagging of large tubes. By means of two transceivers (one transceiver is positioned top left in the measuring system) all measuring values can simultaneously be measured at four points of the circumference (© Sikora)

plastics with low absorption are penetrated and can be measured regarding their wall thicknesses.

Millimeter Wave Technology for Measurement

In recent years, researching metrology applications of millimeter waves have already achieved enormous successes: Measuring accuracies could be increased due to the increase of the modulation bandwidth down to the micrometer range. Without any knowledge of the properties of the extruded materials and its temperatures, the system measures the outer contour as well as the wall thicknesses simultaneously at several points of the circumference. Also individual layer thicknesses of multi-layer tubes can be measured precisely. A calibration is not necessary.

Several static or a continuously rotating transceiver, arranged around the circumference of a tube, continuously send and receive frequency modulated millimeter waves (**Fig. 2**). A static system measures selectively the wall thickness and the outer/inner diameter of the tube. If there is a complete recording of the wall thickness around the entire circumference of the tube required, a rotating gauge head is used. This design concept also allows to precisely measure and represent the sagging. The measurement is based on the runtime difference of the reflected signals that are reflected by the boundary layers, as for example each front and back side of a plastic. The signals that are detected and demodulated by the receiver of each transceiver contain information regarding the distance between boundary layers of different materials. Measurements are made from a wall thickness of 4 mm with an accuracy of a few micrometers and with a measuring rate of 250 single measuring values per second.

After an algorithmic processing of the received signals of each sensor, the requested measuring results are ready for visualization and control of the diverse tube dimensions in real time. A connected processor system provides in addition to a numeric display and graphic presentation of the measuring values a comprehensive trending and statistical information (**Fig. 3**). If we assume that a line, where tubes are produced with an outer diameter of 400 mm and a wall thickness of 22.7 mm, runs at a line speed of 0.66 m/min, the machine operator receives accurate measuring results already after ca. 15 min, if there is at first a cooling trough to pass of ca. 10 m length for stabilization of the extruded tube. New developments are going into a direction to measure wall thicknesses and diameters right after the cross head of the extruder.

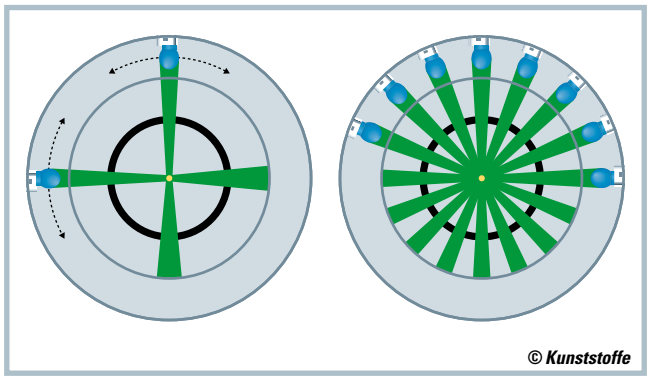

Fig. 2. Alternatives: measuring system with sensors that rotate (left) or that are statically arranged (right) (source: Sikora)

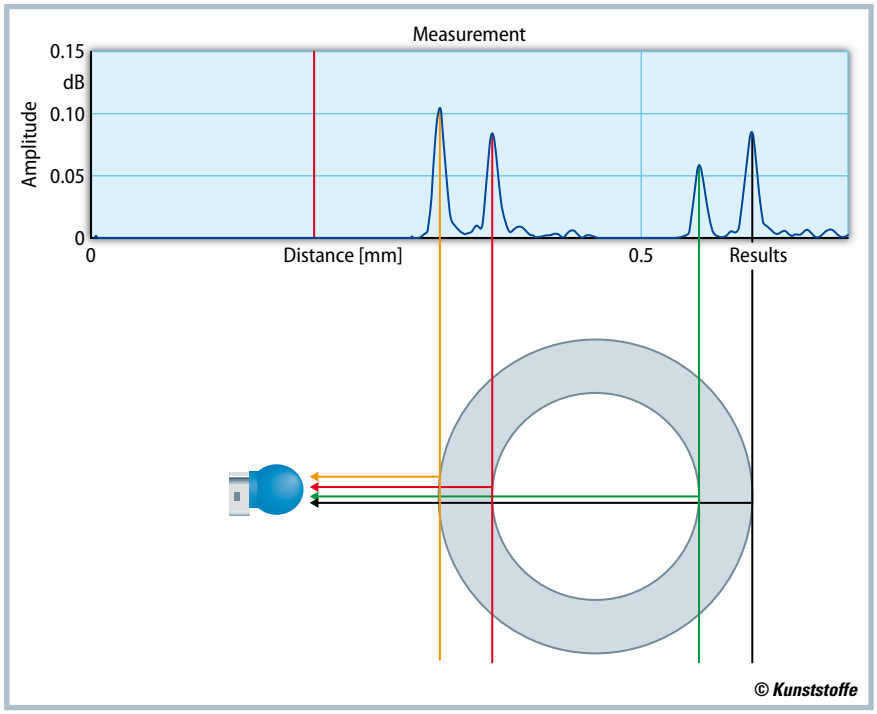

Fig. 3. Runtime method: from the runtime of the (at the boundary layers) reflected millimeter waves, which are continuously frequency modulated, tube dimensions are defined (source: Sikora)

Optimize Tube Quality, Save Time and Costs

As temperatures have no influence on the measuring result when using millimeter wave technology, the system is installed for hot measurement as well as at the cold end of the line for final quality control. Immediately after the first cooling, the system provides precise information. In addition, the technology covers the entire range of plastics such as PE, HDPE, PP, PA6 and PVC (see also **Fig. 4**).

In the last decades ultrasonic technology has become a standard with the help of which wall thicknesses of tubes could be measured. However, this represents a challenge because the absorption of sound waves is enormous, in particular at high temperatures. Thus, the measurement of larger wall thicknesses in the hot area is limited. Moreover, the accuracy of the measuring result – in the hot as well as cold area – is largely limited as a result of the temperature-dependent runtime of the sound. But, the goal is to achieve as early as possible in the production process, reliable and precise information about tube dimensions in order to »

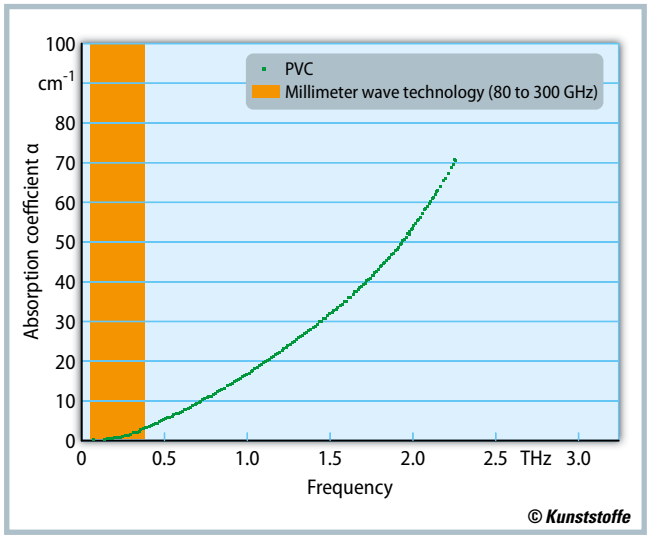

Fig. 4. Absorption of radio waves in PVC: the measuring method operates within a spectrum from 80 to 300 GHz, in which the absorption coefficient is small, so that even large PVC wall thicknesses can be measured precisely (source: SKZ Würzburg)

take actions if necessary and to avoid failure deliveries. Moreover, it is necessary to approach early in the production process the minimum permissible tube dimensions to produce a minimum meter weight. Cost savings resulting from the low meter weights are often decisive in competition.

Application of the System

The millimeter wave technology is suitable for the measurement of any kinds of plastic tubes with a diameter from 120 mm to 2,500 mm and larger that are for example used for conducting water, gas, chemicals and oil. Particularly interesting is the use of the system for the extrusion of PVC, which is one of the most widely used material for tubes in the construction and transport area. Also for PVC tubes with thick walls the system provides precise measuring values.

Another area of application is the measurement of multi-layer tubes and curved surfaces. During production, there is the risk that the melt that leaves the tube tool flows down as a result of gravity and thus negatively influences the tube wall thickness distribution [2]. This "sagging" is identified by the measuring method. Via a display and control device the machine operator immediately receives information on the production process to take action if necessary.

Conclusion and Outlook

Quality demands when manufacturing large plastic tubes are continuously increasing. Norms precisely define the dimensions of the products to be produced. The precise and reliable quality assurance of plastic tubes during extrusion is increasingly gaining importance. By the use of a system on the basis of millimeter wave technology for hot measurement and at the cold measuring end for final quality control important product parameters are continuously monitored online.

The method is applicable to different material types, in particular PVC. Curved product surfaces as well as wall thicknesses of multi-layer tubes are determined and precisely measured. Consequently, the millimeter wave technology in combination with processor systems contributes to process optimization, increase of tube quality, minimization of material consumption as well as time and cost saving. ■

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Service

References & Digital Version

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