

3-D - Microwave - Measurement of Capsules and Tablets

A fast and precise measurement of the mass of relative small objects is especially requested by the pharmaceutical industry for the measurement of capsules and tablets. Since the masses of these objects are proportional to their contents of medical active substance, the control of the mass is important.

A precise measurement of the mass of capsules and tablets can be realised by use of a balance. Due to the relative long measuring time, that is needed for a balance - measurement, a 100% - control of the masses of a pharmaceutical production is impossible, especially for tablets.

By microwave resonator measurement, a fast and precise mass measurement can be realised. The speed of the measurement is limited by the requirements of separation and transportation of the objects through the resonator. Up to now, a attainable measuring rate seems to be 40 objects/second. The microwave measuring unit itself could measure up to 100 objects/second. The moistures of the objects can be measured by microwave resonator measurement at the same time. This is also an important product parameter, especially for capsules.

A fast mass and moisture measurement by the microwave resonator measurement by use of one single resonance mode is documented in EP 1 467 191 B1 (TEWS Elektronik) „Method and device for determining the mass of portioned ingredients units". When measuring the mass with only one resonance mode, a precise mass and moisture can only be realised if the measuring objects are passing through the resonator in the very same stable way, without tumbling. However, a stable transportation of small objects of arbitrary shape through the resonator is hard to realise at a high speed.

The reason for the request for a stable transportation is the dependence of the microwave signals of a measuring object, that is not spherical, on the ratio of the surface of the object parallel to the electric flux lines to the ratio perpendicular to the electric flux lines.

If the electric flux lines are parallel to the surface of the object, the field penetrates into the object continuously. The shift of the resonance frequency is a result of the shortening of the wavelength inside the object. The resonance frequency is lowered, but the distribution of the field stays almost the same as in case of an empty resonator.

The approximation of the solution of Maxwell's equations in this case leads to equation (1):

$$\frac{f_0 - f_m}{f_0} = F \cdot (\varepsilon - 1) \quad (1)$$

with f_0 : resonance frequency of the empty resonator in Hz

f_m : resonance frequency of the filled resonator in Hz due to parallel field

F: ratio of the energy of the electrical field inside the object to the field energy in the whole resonator

ε : permittivity ($1, 1 \leq \varepsilon \leq 3$ for most materials)

If the electric flux lines are perpendicular to the surface of the object, the field is lowered when penetrating into the object by the factor ε (permittivity) to E/ε . The approximation of the solution of Maxwell's equations in this case leads to equation (2):

$$\frac{f_0 - f_m}{f_0} = F \cdot (\varepsilon - 1) / \varepsilon \quad (2)$$

with f_0 : resonance frequency of the empty resonator in Hz

f_m : resonance frequency of the filled resonator in Hz due to perpendicular field

F: ratio of the energy of the electrical field inside the object to the field energy in the whole resonator

ε : permittivity ($1, 1 \leq \varepsilon \leq 3$ for most materials)

Fig. 1 shows the behaviour of the electrical field penetrating into a fibrous material to be measured.

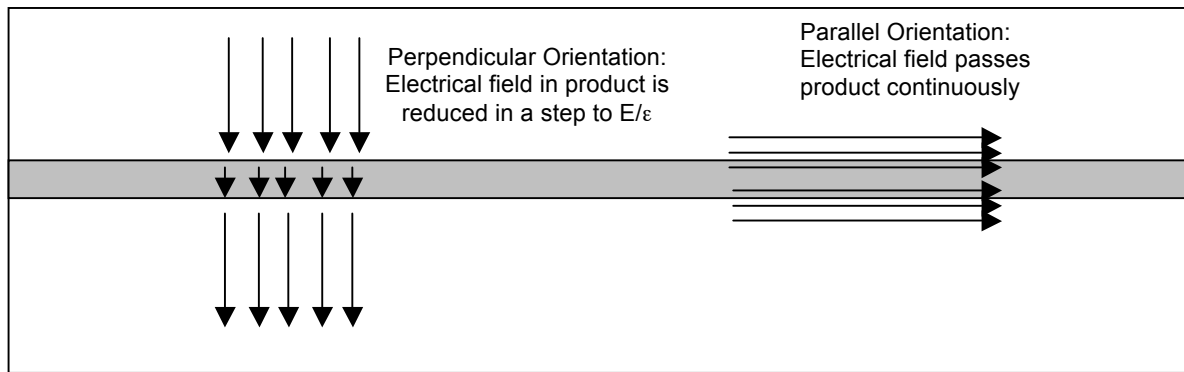


Fig. 1: Fibrous material to be measured in the electrical field

By comparison of equation (1) and equation (2) it can be seen easily, that an object of arbitrary shape, that is placed inside a microwave resonator, will cause different microwave signals in dependence of its orientation in the resonator. This is of special importance when measuring at fast moving objects, that pass through the resonator unguided. The precision of the mass and moisture measurement is limited by tumbling and side motion of the moving objects.

To improve the precision of the mass and moisture measurement, a resonator with three resonance modes, that are perpendicular to each other and can be generated simultaneously, is used, a so-called 3-D - resonator. The measurement with a 3-D - resonator is documented in EP 2 009 427 A2 (TEWS Elektronik). By use of such a resonator, it is possible to measure the different parts of the object in all three directions in space with the same orientation of the electrical field.

At the measurements with the 3-D - resonator, the changes of the parameters of the resonance curves of the three resonance modes caused by the measuring object are detected, when the object passes through the resonator. The parameters of the resonance curves are the shifts of the resonance frequencies A_i ($i = 1...3$) and the broadening of the resonance curves B_i ($i = 1...3$). Thus, for each measuring object 6 measuring values are detected. By use of these 6 values, the mass and the moisture of the objects can be calculated independently of the orientation of the object in the resonator. At different orientations of the objects in the measuring fields, the signals of the three different resonance modes change, but the calculated values of mass and moisture stay the same.

Equations (3) and (4) are used to calculate mass and moisture by use of the 6 measuring values A_i and B_i :

$$\text{mass} = k_1 \cdot A_1 + k_2 \cdot A_2 + k_3 \cdot A_3 + k_4 \cdot B_1 + k_5 \cdot B_2 + k_6 \cdot B_3 + k_7 \quad (3)$$

$$\text{moisture} = c_1 \cdot B_1/A_1 + c_2 \cdot B_2/A_2 + c_3 \cdot B_3/A_3 + c_4 \quad (4)$$

with A_i : shifts of the resonance frequencies in Hz

B_i : broadening of the resonance curves in Hz

k_i, c_i : calibration - coefficients

The mass measurement is independent of the moistures of the objects, and the moisture measurement is independent of their masses.

Measurements at tablets with a speed of 30 tablets/second were realised by separating the tablets by use of a disc sorter and a transportation by air pressure. Fig. 2 shows the disc sorter at work, Fig. 3 the sensor unit (enclosure removed), and Fig. 4 the whole prototype arrangement.

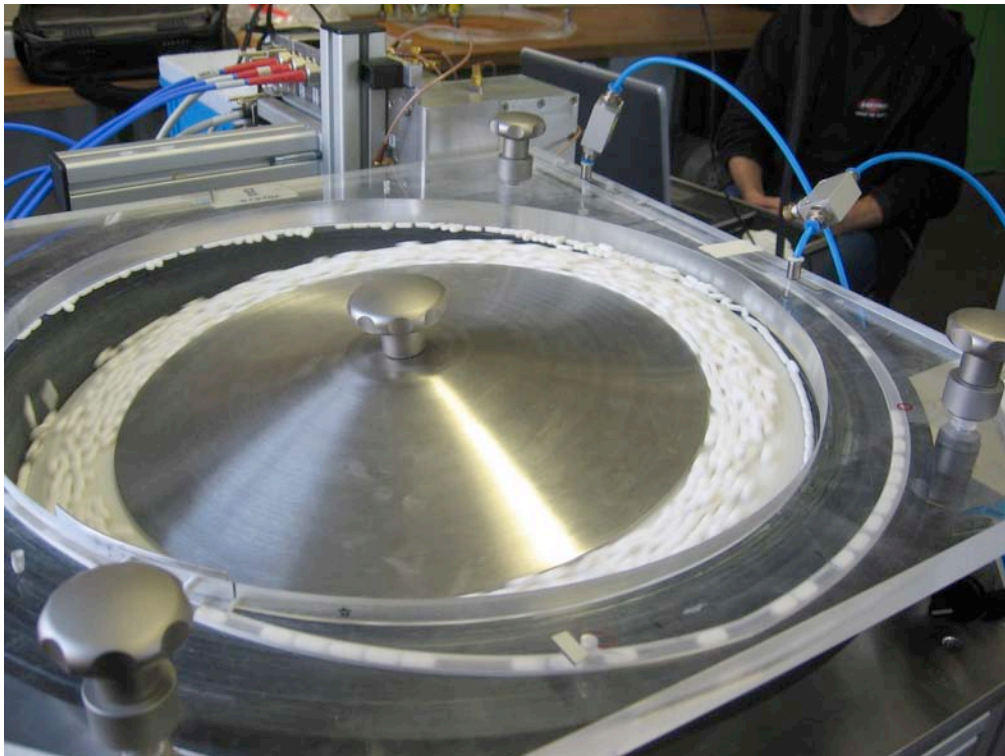


Fig. 2: Disc sorter for separating the tablets

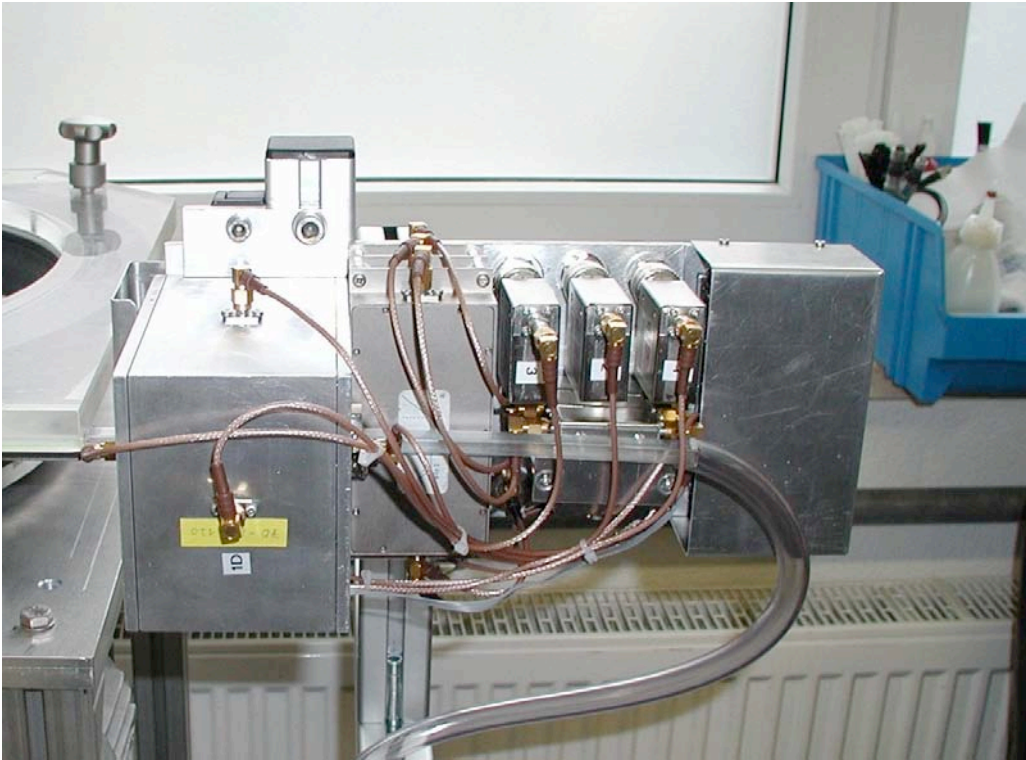


Fig. 3: Sensor unit (enclosure removed)



Fig. 4: Whole measuring device (prototype)



Fig. 5: Tablets, that were used for the test measurements

Fig. 5 shows the tablets, that were used for the test measurements. Fig. 6 and 7 show the results of the measurements. The result of the measurements at small, white, elongate tablets (see Fig.5) shows Fig. 6. The tablets had an average mass of about 195 mg. The standard deviation SD between mass detected by microwave 3-D measurement and reference measurement (balance) is $SD = 0,36$ mg.

The result of the measurements at green, round tablets (see Fig.5) shows Fig. 7. The tablets had an average mass of about 333 mg. In this case, the standard deviation SD between mass detected by microwave 3-D measurement and reference measurement (balance) is $SD = 0,40$ mg.

The moisture content of the tablets can be measured at the same time.

Fig. 8 shows microwave 3-D measurements at green, round tablets in comparison with measurements with a check weigher consisting of twelve parallel lines equipped with balances. 1700 tablets were measured, and the results are quite similar.

standard deviation SD = 0,36 mg

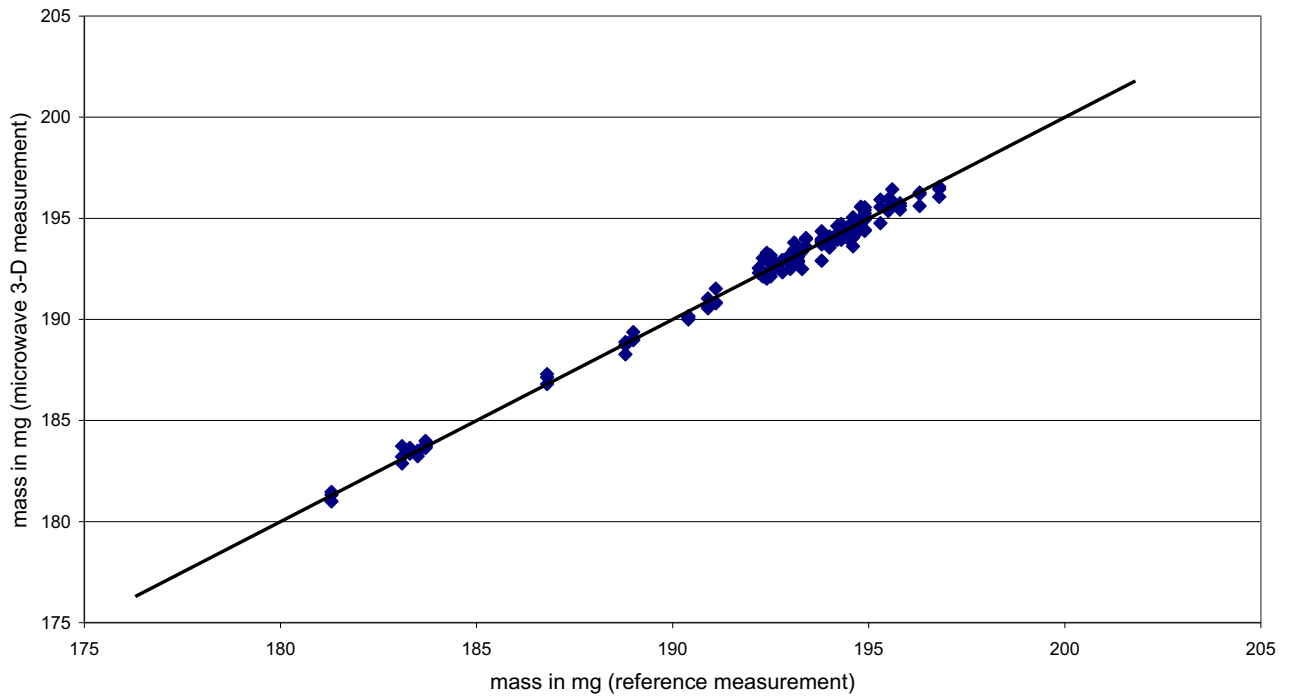


Fig. 6: Measurement at small, white, elongate tablets (see Fig.5)

standard deviation SD = 0,40 mg

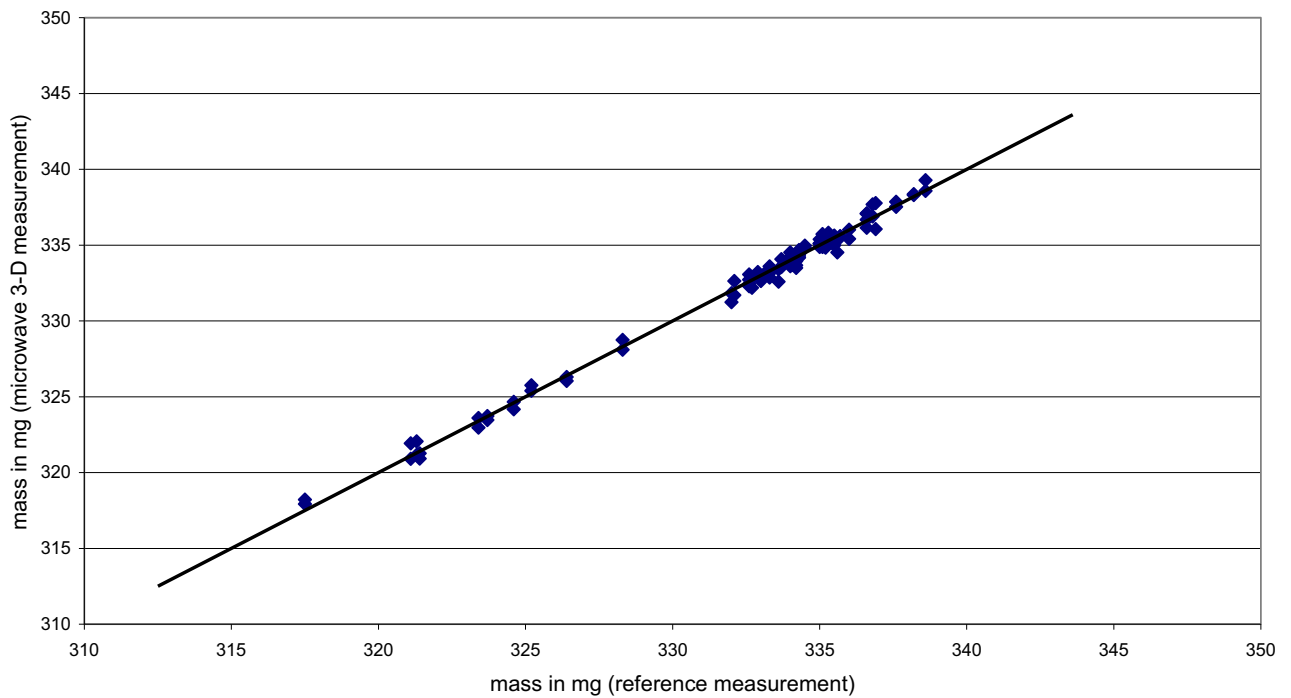


Fig. 7: Measurement at green, round tablets (see Fig.5)

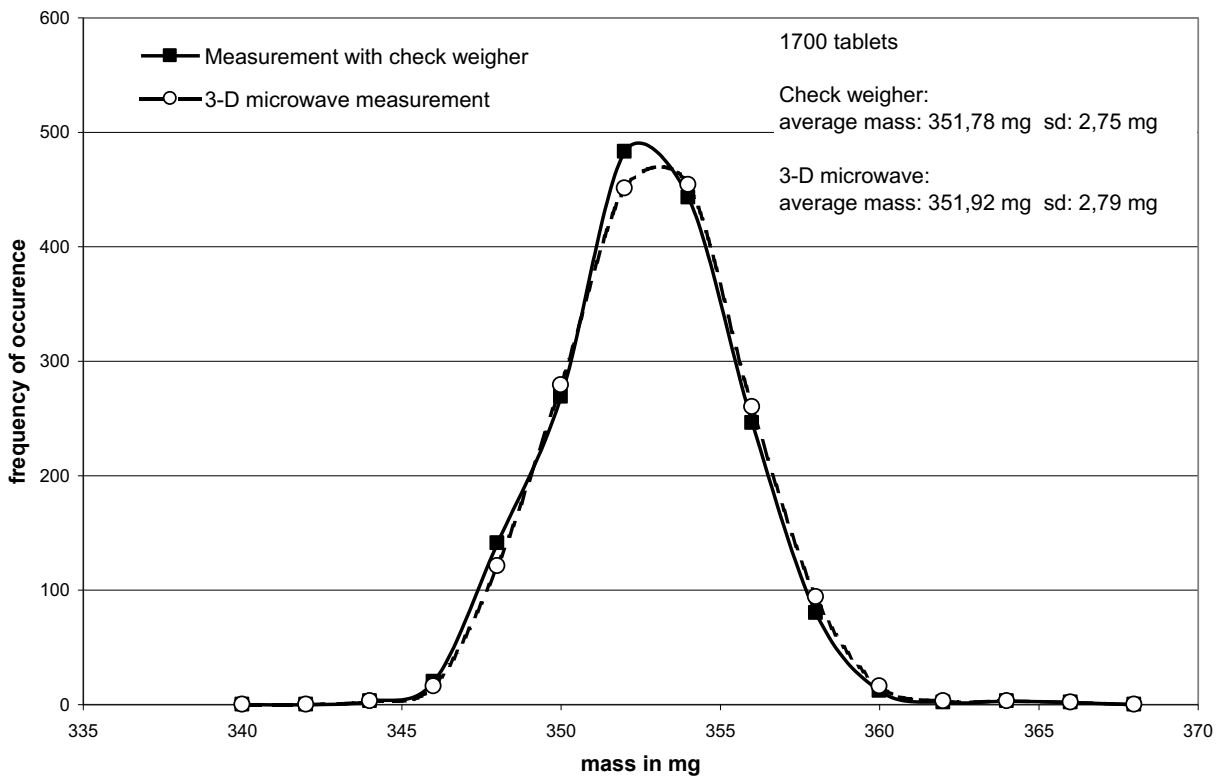


Fig. 8: Microwave 3-D measurements in comparison with measurements with a check weigher

Summary

The mass and moisture measurement of single small objects can be realised by applying a hollow cavity resonator and use one resonance mode for the measurement. In case of measuring objects of arbitrary shape, like tablets, that perform arbitrary movements when passing the resonator, the precision of the measurement can be increased by use of the so-called '3-D - microwave measurement', as developed by TEWS Elektronik.

It could be shown, that at a speed of 30 tablets/second a very precise mass measurement of tablets is possible. The moisture content of the tablets can be measured at the same time.

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