Zwick Roell

Zwick
Materials Testing

Testing systems for foodstuffs and packaging

FP 485 2.0204

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Zwick Roell AG - Over a century of experience in materials testing

Mechanical technological testing is the oldest discipline in materials testing. Leonardo da Vinci and Galileo Galilei pondered over flexural loading and the elastic behaviour of materials. Further knowledge has been gained over the years. The first test machines appeared in France in the middle of the 18th century.

The firm Amsler (previously in Schaffhausen, Switzerland) began dealing with materials testing, as did Roell & Korthaus from 1920 onwards. In 1937 Zwick began with the construction of devices, machines and systems for mechanical technological materials testing. Long before this, as far back as 1876, Professor Seger founded a chemical laboratory as a scientific technological advisory company for the earth and stone industry. Today's Toni Technik developed from these beginnings during the 20th century as one of the leading specialists for building material test systems. Excellent performances have been furnished by MFL (Mohr & Federhaff), grounded as early as 1870, by the way, Carl Benz was one of its employees.

These firms constitute the company group Zwick Roell since 1992. Whereby the firms Dartec, Rosand, Kelsey and Indentec in Great Britain joined them in the two years following.

The Zwick Roell company group was reorganized to form Zwick Roell AG, a public limited company (joint-stock company), in July 2001. It encompasses the firms Zwick, Toni Technik, Indentec Ltd. and Zwick Roell Controllers Ltd. These companies supply a comprehensive program for materials, building materials and function tests; from manually operated hardness testers up to complex test systems that can be used for production accompanying applications. Inclusion of the French company Acmel Labo in 2002 supplements the Zwick Roell AG product program with laboratory products for the cement, plaster and lime industry.

Zwick has many years of experience resulting from the supply of a multitude of equipment. This is complemented by continuous communication with

Fig. 1: Zwick headquarters

the users of such equipment. The company supplies an extensive program of efficient products based on this solid basis. These products range from economic standard machines to special complex models designed for special test tasks. State of the art mechanics, efficient electronics and the applications oriented software constitute the prerequisites for the versatility and high "intelligence" of these modern test machines and systems.

The Zwick Roell AG, however, offers a lot more than just the supply of products. The company was certified to DIN EN ISO 9001 as far back as 1994 and thus vouches for constant high product and service quality. Accredited DKD[1] or UKAS[2] calibration laboratories authorise the Zwick Roell AG companies to check and calibrate test devices, and to document it with internationally recognised certificates.

[1] DKD: Deutscher Kalibrier-Dienst (German calibration authorities)
[2] UKAS: United Kingdom Accreditation Service

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Contents

1. Foodstuff testing

1.1 Foodstuff testing in general and definitions of terms

Foodstuffs are the raw or processed basic elements of our nourishment. There are animal and vegetable foods.

Animal foods are meat, animal fats, milk, eggs and the foods which are prepared from these e.g. cheese, butter, sausage, canned foods.

Vegetable foods are the grain foods (e.g. the flours and baked goods processed from them), fruit, nuts, vegetables, starchy vegetables (potatoes, soy beans, etc.) and the foods processed from them.

Picture 2: Optical and sensorical pizza testing

Picture 3: Gelatine

In addition to the foodstuffs, there are also foods eaten only for enjoyment (luxury foods). As opposed to the foodstuffs, these have little or no nourishment value. They do not serve to nourish the human body, but they have a stimulating affect via the central nervous system, sometimes increasing the physical and mental performance. Some luxury foods are tobacco, coffee, tea, cola and alcoholic drinks.

Foodstuffs have various “material characteristics” according to type, consistency, make-up and physical condition. These greatly determine the rheological characteristics of a foodstuff.

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Rheology

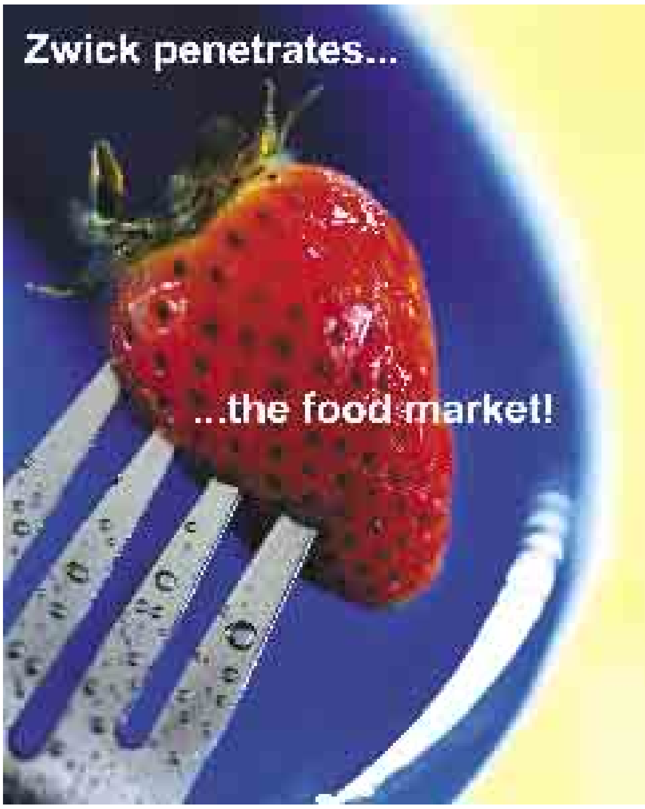
The rheological characteristics of a foodstuff can be described as follows: Rheology is the science of mechanical behaviour of fluid, pasty and viscous materials during their deformation.

A more technical definition of rheology is the relationship between stress and strain, or, the material´s behaviour which is indicated by stress, strain and time effects.

Tscheuschner wrote about the basic rheological characteristics: Foodstuffs serve as nourishment for people. They must have rheological characteristics which satisfy the requirements of biting off, chewing and swallowing, while generating impressions which are sensed as textures of the food and give them a quality.

Rheological tests can be manifold and often have the most varying reasons. Some of today´s tests on food stuffs are performed for the following reasons:

- Evaluation of the quality and processing characteristics of raw foodstuffs.
- Characterisation of the structure and structural changes during technical processing.



Picture 4: „Zwick penetrates the food market!“

Picture 5: Viscosity test on mustard

- Rheological process control for rheological relevant changes in conditions.
- Process planning and system calculations for rheological processes.
- Creation of foodstuffs with a desired texture.
- Quality control of finished products in relation to their rheological characteristics and texture.

Texture

Textures are the characteristics of a foodstuff which can be determined from a combination of physical characteristics and the percepted feelings such as touching (including the feeling in the mouth), look and acoustic behaviour. Thereby, size, form, number of cells and their structure, influences the texture characteristics of the foodstuff.

Examples of texture characteristics are the crispness of frankfurters, the firmness of cheese or the crispness of waffles.

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Texture and viscosity testing of food stuffs

The texture of foodstuffs describes the physical nature of each foodstuff. It results from the structural composition and is determined through mechanical deformation.

Texture characteristics are dependent upon the forces applied, the failure of the molecular structure and the flow characteristic under loading influence. It is represented as a function of time, mass and deformation.

Viscosity can be described as the inner friction of a liquid, or the tendency of a liquid to resist flowing.

Rheology involves itself with both parts of foodstuff technology; viscosity and texture testing. The difference between texture and viscosity is found in the basic material. Texture is measured in a solid foodstuff, viscosity is measured in a liquid, or pasty, food stuff, e.g. biting an apple, cutting cheese or bread with a knive.

Picture 7: You can test foodstuffs of all types with Zwick testing tools

Picture 6: Testing of foodstuffs are taken from everyday practice

Texture characteristics of foodstuffs	Sensoric designations of foodstuffs characteristics
Hardness	soft solid hard
Composition, cohesion	crumbly crisp brittle
Elasticity	plastic elastic
Adhesiveness	adheres sticky very sticky
Viscosity	highly fluid semifluid

Table 1: Texture characteristics of foodstuffs with sensoric descriptions

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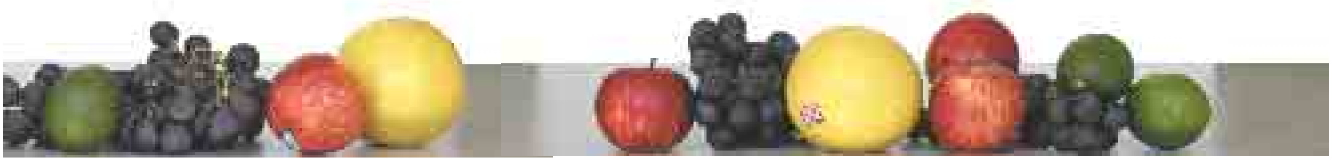
1.2 Overview: Foodstuffs and typical test methods

Foodstuff	Type of test	Tool/Test device	Sensoric characteristics
Bread and baked goods			
Bread	Compression, penetration test	Compression test device, Compression die (AACC 74-09: cylindrical die dia. 36 mm)	Firmness
Cake, pastry, cookies, waffles	Penetration, flexure, shear test	Compression die (ball), 3-point flexure test kit, Warner-Bratzler test device	Firmness, hardness, breaking strength
Croutons	Compression test	Compression test device, OTMS test device with rod blades	Hardness, crispyness
Dough	Tensile, compression test	Dough tensile test device, Compression test device	Elasticity, adhesiveness
Salted snacks e.g. pretzel sticks	Compression, flexure test	Compression test device, OTMS test device with rod blades, 3-point flexure test kit	Flexure, breaking strength, crispyness
Peanut flips	Compression, extrusion test	Compression test device, Kramer shear test device	Crispyness, hardness
Chips, rice cracker	Compression, extrusion test	Compression test device, OTMS test device with rod blades	Crispyness, hardness
Noodle and rice products			
Cooked spaghetti	Shear, compression (adhesiveness test)	Shear and compression units (AACC 66-50)	Hardness, strength adhesiveness
Raw noodle products	Bending tests	3-point flexure test kit	Flexure, breaking strength
Cooked Gnocchi	Compression test	Compression test device	Hardness, strength, adhesiveness
Cooked noodle products	Compression test	Warner-Bratzler test device, Compression test device	Hardness, strength, adhesiveness
Cooked rice	Compression test	Compression test device	Hardness, strength, adhesiveness
Rice pudding	Penetration test	Compression die (cylinder)	Strength
Sweets			
Breakfast cereals	Compressibility test	OTMS test device with sealing plate	Crispyness, hardness
Chewable hard candy, sugar-coated drops	Compression test	Cutting knive	Hardness, (cutting strength)
Chewing gum	Tensile test	Dough tensile test device	Elasticity
Ice creme	Indentation test	Compression die (ball)	Strength
Chocolate bar	Compression test, extrusion test	Compression test device, Kramer shear test device	Hardness, strength, crispyness
Chocolate creme	Indentation test	Compression die (ball, pyramid)	Strength, hardness, spreadability
Chocolate (raw mass)	Viscosity test	Back extrusion test device	Viscosity, consistency

Table 2: Overview of test methods

[1] American Association of Cereal Chemists

Foodstuff	Type of test	Tool/Test device	Sensoric characteristics
Milk products			
Butter, margarine	Cutting, spreading, penetration test	Butter-cutting unit, Compression die (ball, pyramid)	Firmness, spreadability, hardness
Cheese spread, soft cheese	Spreading, penetration test	Compression die (ball, pyramid)	Spreadability, firmness, hardness
Hard cheese	Penetration test	Compression die (ball, cylinder)	Hardness
Yoghurt, mousse,	Penetration test	Compression die (cylinder)	Firmness (surface)
Peanut butter	Viscosity test	Back extrusion test device	Viscosity
Sauces, pastes, gels, oil, ...			
Mayo, mustard, ketchup, veg. oil, marmelade, honey	Viscosity test	Back extrusion test device	Viscosity, consistency
Mayo, mustard, ketchup, veg. oil, marmelade, honey	Penetration tests	Penetration die (cylinder)	Firmness, consistency
Gelatin	Compression test to Bloom	Bloom penetration die (dia. 1/2")	Bloom hardness
Fruit, vegetables			
Apples, pears	Penetration test	Compression die (ball, cylinder) penetration test device	Firmness, hardness
Grapes, berry fruits	Penetration test	Penetration test device, compression die (cylinder)	Surface hardness, elasticity
Potatoes	Shear test	Warner-Bratzler test device	Firmness, shear work
Potatoe salad, mashed potatoes	Extrusion test	OTMS test device with perforated insert	Extrusion work, firmness
Peas	Compression, shear, penetration test	Compression, penetration Kramer shear test device	Firmness (surface), hardness
Corn	Compression, shear test	Compression test device, Kramer shear test device	Firmness, hardness
Beans	Extrusion test	OTMS test device with rod blades	Extrusion work, firmness
Pickles, canned goods	Shear test	Kramer shear test device	Firmness, shear strength
Sausage, meat and fish products			
Chicken	Shear test	Warner Bratzler test device, Kramer shear test device	Shear strength, toughness
Crab	Shear test	Kramer shear test device	Shear strength
Meat, fish	Shear test, penetration test	Warner Bratzler test device, Compression die (cylinder)	Shear strength, toughness
Frankfurters	Penetration test, shear test	Penetration test device (needle), Warner Bratzler test device	Crispness, shear strength
Sausage	Penetration test, shear test	Compression die (cylinder, ball), Warner Bratzler test device	Firmness, shear strength
Animal food			
Canned food	Extrusion test	OTMS test device with rod blades	Extrusion work
Dry food	Compression test, penetration test	Compression test device, compression die (cylinder)	Hardness, firmness

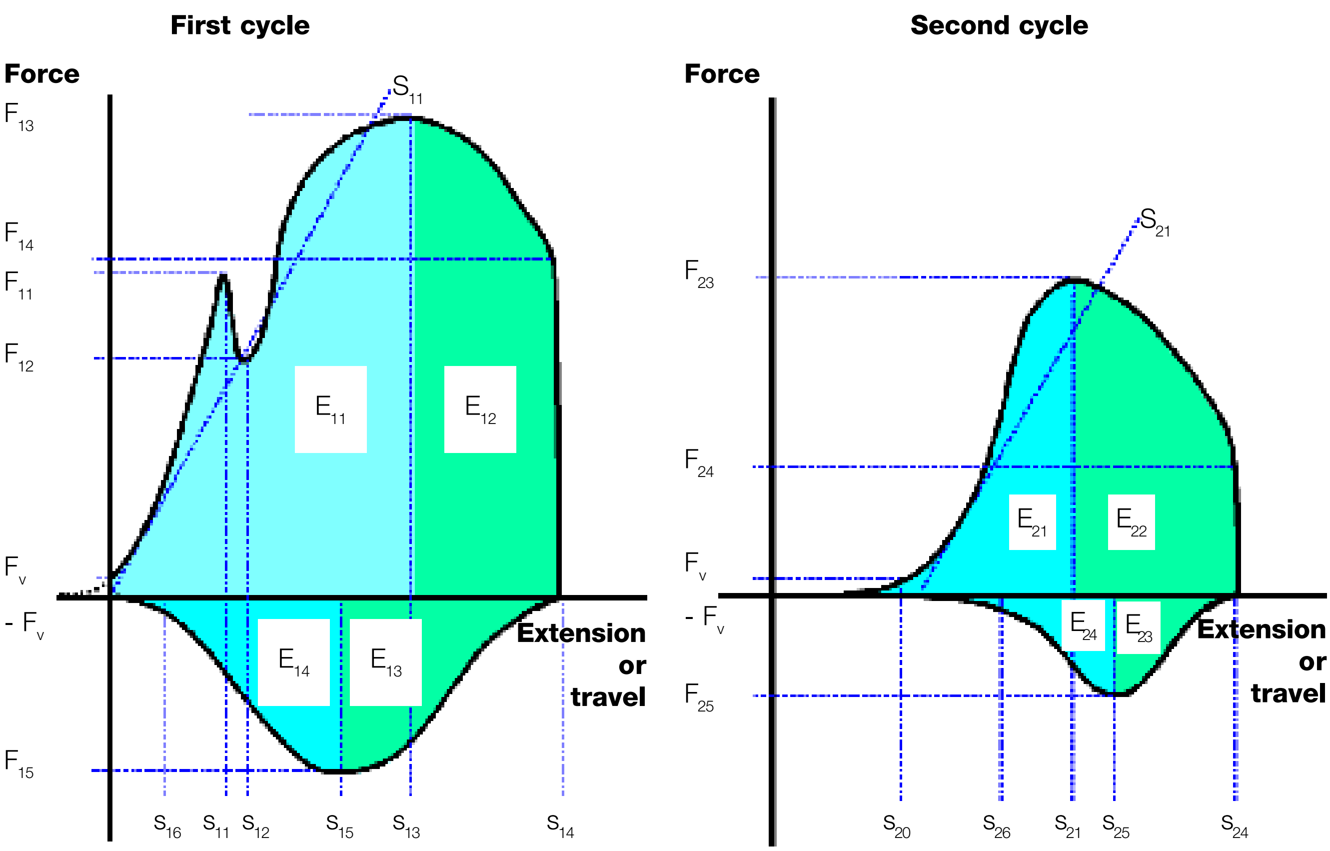


1.3 A typical measurement curve from foodstuff testing with description of results

In the following table and the example test curve (force-path-diagram), of a typical texture test, the important results necessary for the determination of foodstuffs characteristics are shown.

English	German	Test result
Modulus	Steigung	s_{11}, s_{21}
Specimen height	Probenhöhe	H_0
Fracturability	Bruchneigung	F_{11}
Brittleness	Sprödigkeit	$F_{11} - F_{12}$
Hardness	Härte	F_{13}
Indentation	Stauchweg	S_{13}
Cohesion strength	Bindekraft	F_{15}
Adhesiveness	Klebneigung	$E_{13} + E_{14}$
Springiness	Rückfederung	$(S_{23}-S_{20}) / (S_{13})$
Gumminess	Zäh-elastisch, klebrig	$F_{13} * (E_{21} + E_{22}) / (E_{11} + E_{12})$
Chewiness	Kauverhalten	$F_{13} * (E_{21} + E_{22}) / (E_{11} + E_{12}) * (S_{23}-S_{20}) / (S_{13})$

Table 3: Measurement results of the Zwick test program for texture analysis



Picture 8: Typical graphical evaluation of a texture test with 2 cycles, with individual evaluation by the *testXpert*®-texture analysis-program

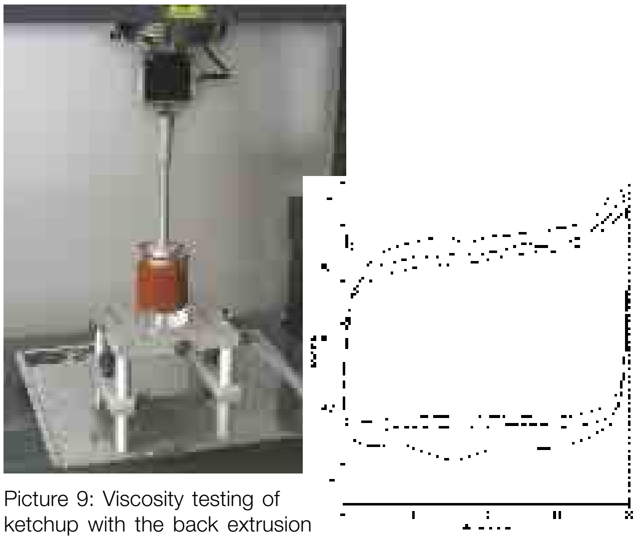
1.4 Zwick Roell test devices with applications examples

Back extrusion test device
Back extrusion test

With the back extrusion test, a die is moved up and down in a fluid test material. The measured forces at defined speeds, determine the viscosity .

Setup and performing a test

The back extrusion cell consists of a cylindrical container and a cylindrical compression die. The container is fixed to the machine to prevent lifting during the reverse stroke. A certain volume (min. 75 % of the container´s volume) of the test material is filled into the cell. The die pushes into the specimen with a defined speed and continues until a pre-set position has been reached. When this position has been reached, the die drives back to the beginning position. During this movement, the specimen material flows through a ring slot between the container and the piston into the other container area. The force required for this action allows the viscosity to be determined.



Picture 9: Viscosity testing of ketchup with the back extrusion test device

Applications

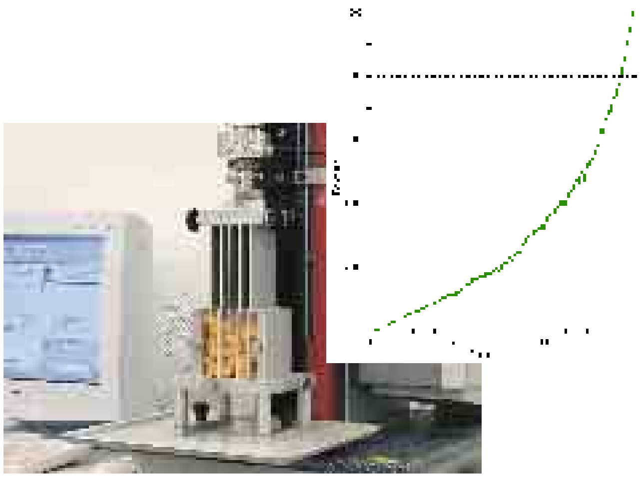
- Testing of viscosity, consistency or cohesion of fluid and pasty masses, e.g. joghurt, pudding, mustard, tomato paste, oils

Kramer shear test device
Kramer shear test

The Kramer shear cell was developed in 1959 by Kramer & Twigg and it is the most widely used test method in the area of foodstuffs testing. It simulates as nearly as possible, the single bite of prefragmented foodstuffs.

Setup and performing a test

The Kramer shear cell consists of a box, which has a floor with slotted openings. The specimen material is filled into this box. The rectangular shaped cutters are affixed via guides (the Kramer shear cell is available in two options, with 5 or with 10 cutters). The cell is mounted on a basic platform so that a free space remains underneath. Here the specimen material which is pushed out can be collected. The advantage of a Kramer shear cell is that not only one position is measured, but 5 or 10 positions at the same time. Local texture deviations are compensated for with this method. The cutters drive at a constant speed through the specimen material, compressing and shearing the specimen until it is pushed through the floor of the cell. The force-path or force-time curve is the result and conclusions as to the chewing characteristic, the crispiness or the freshness can be made.



Picture 10: Shear testing of cereals with the 5-blades Kramer shear test device for determination of crispiness

Applications

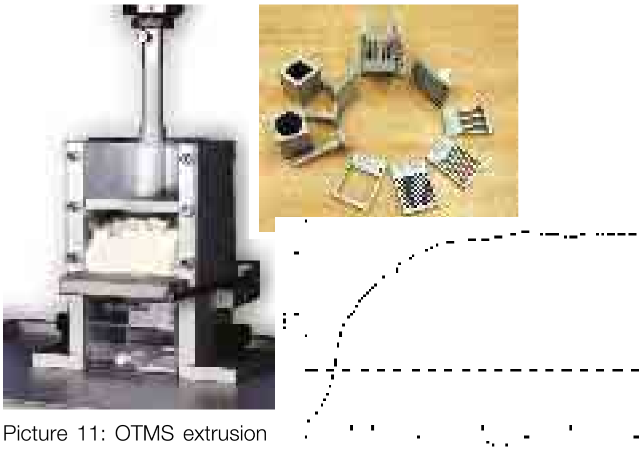
- Simulates as nearly as possible, the single bite of pre-fragmented foodstuffs.
- Texture characteristics of small sized fruit and vegetable products, cereals, etc.

OTMS test device
Ottawa Texture Measuring System (OTMS) Test

The Ottawa Texture Measurement was developed by the Engineering Research Service of Agriculture, Canada under P. Voisey, 1971. The test simulates the chewing characteristic through compression and displacement of the specimen.

Setup and performing a test

The OTMS cell consists of a rectangular container with open floor in which various inserts can be mounted. There are different inserts (see picture 11), e.g. with rod blades, with perforations, with wire blades or a closed insert (sealing plate). A rectangular or round die compresses the specimen material through the various inserts. The OTMS cell is available with various volumes (depending on the reduction insert or die used).
The die moves down with a constant speed (e.g. 200 mm/min), compressing the specimen and pushes it through the insert. The force-path or force-time curve is the result. From the type of curve, parameters can be taken which indicate the crispiness, hardness, ripeness or the extrusion work.



Picture 11: OTMS extrusion testing on fresh cheese

Applications

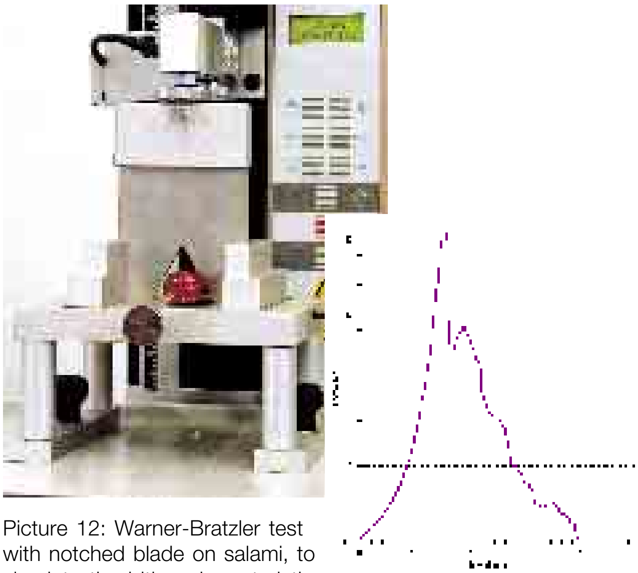
- Determination of the hardness/softness of vegetables
- Determination of the hardness/crispiness of granola, Cornflakes etc.
- Comparable simulation of the chewing characteristic through compression and displacement of the specimen

Warner-Bratzler test device
Warner-Bratzler test

The Warner-Bratzler Test was developed in 1932 by L.J. Bratzler in his Masters Thesis, Kansas State University, Manhattan, and has been in use since the 1950s. The test gives information about the softness/toughness of meat and fish products as well as baked goods.
The cutter simulates the edges of teeth during biting. Because of the good reproducibility of the results, this test is used very often and is considered as a type of "Standard".

Setup and performing a test

The Warner-Bratzler test device consists of a slit plate, on which round or rectangular specimen are placed, and additional blades. The blades (straight blade for rectangular specimen or notched blade for round specimen) have a thickness of 3 mm. The specimen are placed on the base plate and the cutter drives down with a constant speed and cuts the specimen. The force-path or force-time curve is the result. The shear characteristic can be seen from this test curve.



Picture 12: Warner-Bratzler test with notched blade on salami, to simulate the biting characteristic

Applications

- Comparable simulation of biting characteristic ("cuspid teeth") on fish, meat and baked goods
- Determination of the softness/toughness of meat and fish products
- Determination of the shear behaviour of baked goods

Compression test unit
Compression test

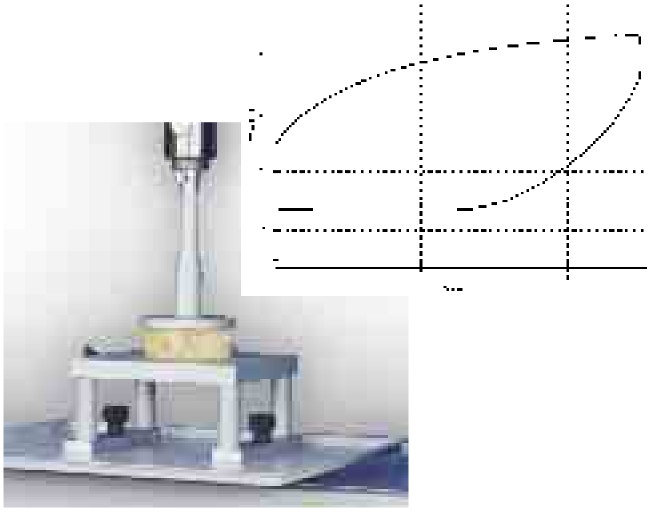
With the compression test we simulate the stacking behaviour of fruit. The test is also suitable for testing the freshness (aging behaviour) of bread or fruit, cheese, fish and other comparable foodstuffs.

Setup and performing a test

The test unit consists of a basic plate and a compression die. Attention must be paid that the specimen is smaller than the compression die. The specimen is compressed to a certain degree and (in a cyclic test) decompressed. In a force-path or force-time curve the compression and decompression characteristics are shown. Conclusions as to composition, freshness or degree of ripeness of the product can be made.

Applications

- Testing of bread, fruit, cheese fish
- Testing of the compression sensitivity of products which must be stacked when stored



Picture 13: Compression test on hard cheese to determine the degree of ripeness

Penetration test device
Penetration test

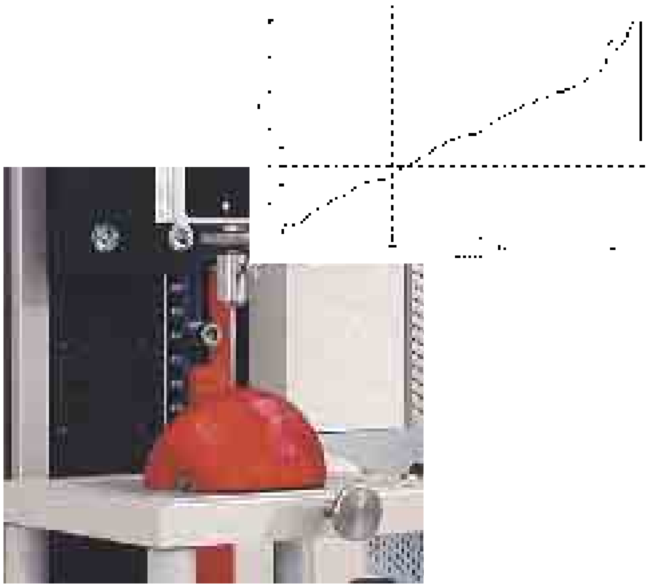
The penetration test, also called „puncture test“ or „force penetration“, was used the first time in 1925 to judge gelatin masses. In the meantime, it is used more and more to test the degree of ripeness in fruits and vegetables.

Setup and performing a test

The penetrator (needle) is pushed into the specimen to a certain depth.
The force-path and force-time curves are drawn. Initially, the force increases greatly. As soon as the needle penetrates the specimen, the force reduces since the skin (biggest strength) has been penetrated. The degree of freshness can be read from the drawn curve.

Applications

- Determination of the degree of freshness on fruit and vegetables
- Determination of the freshness of baked goods

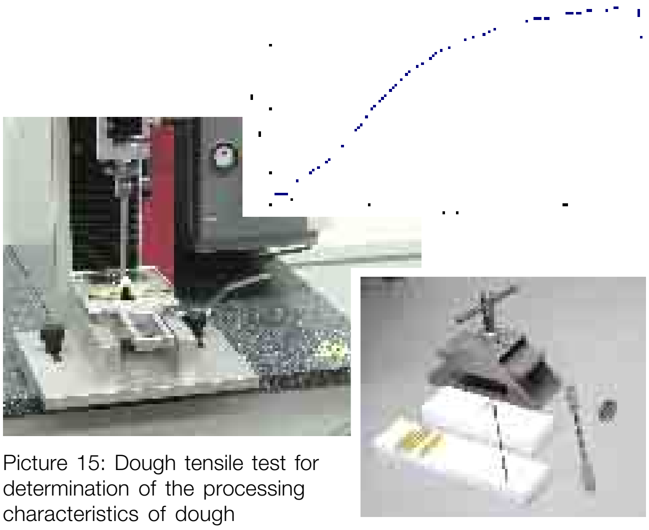


Picture 14: Penetration test on fruit, to determine the degree of freshness

Dough tensile test device

Dough tensile test

The dough tensile test is performed on dough and gluten (protein binders). The special dough tensile test device makes it possible for dough and baked goods producers to determine the material characteristics of dough. The elasticity and strength of various doughs and glutens can be determined. Mechanical testing of dough can show the characteristics through technically measured proof. Various recipes, processing types- and times, as well as admixed material, can be improved in order to have the optimal end product.
The increasing use of automated dough processing requires the most constant product characteristics possible to which the machine parameters are set. Through constant monitoring of these characteristics with the dough tensile test device, product quality as well as processing steps can be optimised.



Picture 15: Dough tensile test for determination of the processing characteristics of dough

Setup and performing a test

The dough tensile test device consists of a specimen table which holds the dough specimen, and a tensile hook for deformation of the specimen. A device for specimen preparation is used to produce identical specimen (dough strands).
Specimen preparation: Approx. 200 to 300 g dough is placed into the special device for specimen preparation which is also supplied with the dough tensile test device. By compression several identical specimen strips get formed which are placed via a piece of paper in the test device.

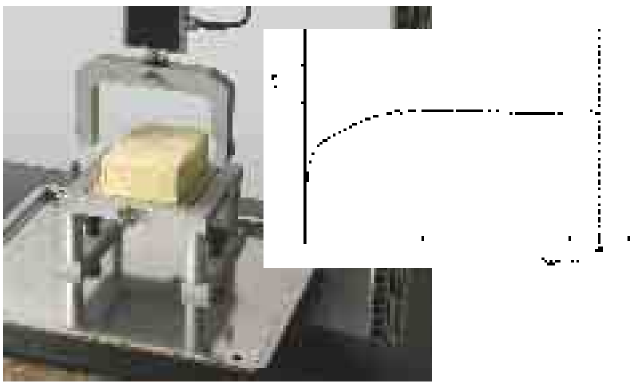
Test: After the specimen has been placed on the testing table and the table mounted in the test device, the dough is deformed with the hook. Thereby force and travel are acquired and evaluated by the testing machine.

Applications:
- Determination of dough characteristics for bread and baked goods
- Determination of the elastic characteristics of chewing gum

Butter cutting test device

Butter cutting test

This test is used to determine the spreading quality and firmness of butter or cheese specimen to DIN 10331 / ISO 16305. A stainless steel wire with dia. 0.3 mm cuts through a block of butter. The force required is acquired by the testing machine. This test is very dependent on temperature and should only be performed under defined temperatures (see temperature chamber, page 14, picture 21).



Picture 16: Butter cutting test to ISO 16305

Setup and performing a test

A complete block of butter (500g) is placed on the universal work platform. The cutting fixture, which cuts through the complete block of butter, is affixed to the moving crosshead of the testing machine. The force required to cut through the butter is acquired by the testing machine. Information as to the butter´s characteristics such as hardness and spreadability can be determined from the force-path curve.

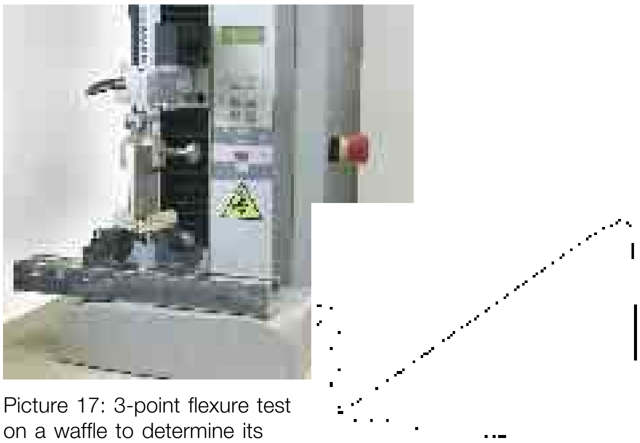
Applications:
- Determination of hardness and cutting tenacity of butter
- Determination of hardness and cutting tenacity of cheese, eggs, vegetables, fruit

3-point flexure test kit
Setup and performing a test

The 3-point flexure test kit consists of a flexure table on which 2 supports can be fixed at variable distances to each other. The specimen is placed on these supports and centrally loaded with a flexure fin.

Applications:

- Determination of the flexure strength (breaking characteristic) of baked goods (cookies, waffles, pastries,...), dough products (noodles, lasagne,...), chocolate bars and fruits



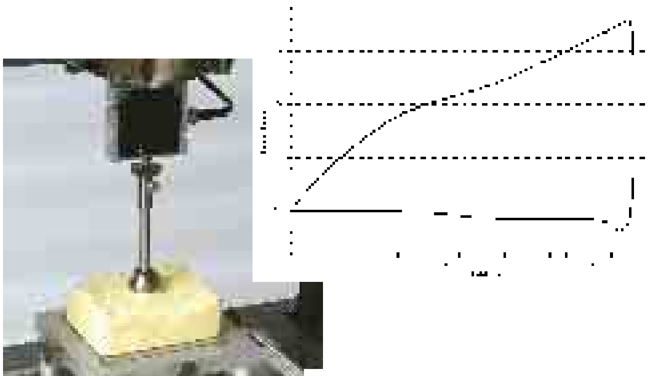
Picture 17: 3-point flexure test on a waffle to determine its crispness

Compression dies for hardness penetration test
Penetration test

The determination of the hardness of foodstuffs using a penetration test is of great importance for the quality testing of the most various foodstuffs. This test is widely used and finds its application with many foodstuffs since the hardness of a foodstuff has a great influence on the sensoric characteristics of a product.
In order to test a multitude of foodstuffs, Zwick offers penetration dies with various diameters and materials (stainless steel, plexiglass, aluminium,...), cylindrical, ball, beveled or conical.

Setup and performing a test

With the penetration test care should be taken that the specimen has as flat a test surface as possible, and a flat under surface as well.



Picture 18: Penetration test on butter to determine the firmness

Applications:

- Determination of hardness of fruits, vegetables, milk products, sausages, dough products, gelatins

Bloom – test unit (hardness testing on gelatin)

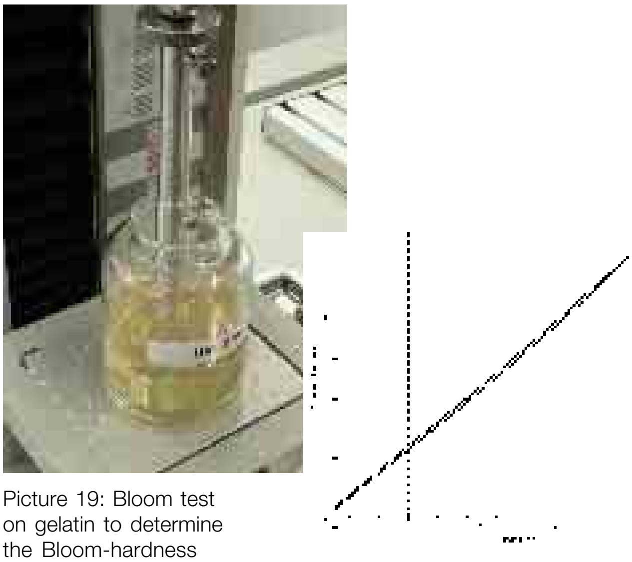
The hardness test on gelatin according to Bloom is well defined in the British Standard BS 757. The test is recognized and accepted outside the borders of Great Britain and is used by many gelatin producers.

Setup and performing a test

A cylindrical compression die is pushed into the gelatin with a constant speed. The maximum force required to penetrate 4 mm into the gelatin, gives information as to the firmness (“Bloom value”) of the gelatin.

Applications:

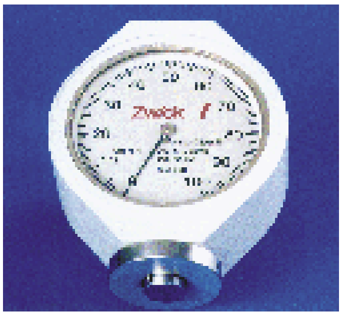
- Determination of the “Bloom-Firmness” on gelatin



Picture 19: Bloom test on gelatin to determine the Bloom-hardness

Hardness test on sausage products

The sausage hardness tester is a modified analogue Shore A hardness tester. A compression cylinder with a surface area of 1 cm² is used as the penetrator. This unit is used especially in the quality control of sausages and luncheon meat. A comparable quality control can be performed using comparable measurements of the hardness of a sausage.



Picture 20: Sausage hardness testing with a Shore A hardness tester

Foodstuffs testing under defined temperature

Foodstuffs are products which are usually very sensitive to temperatures. In order to receive reproducible and comparable test results from foodstuffs, a test under defined, constant temperature is very important, since the products characteristics are often influenced greatly.
Zwick offers a temperature chamber which fits on the texture testing machine (zwicki) especially for these requirements.
The chamber has a temperature range of -30°C to +130°C. Almost all foodstuffs can be tested in this range. The cooling is performed with liquid nitrogen and warming is performed with a bar heater.
Typical testing under defined temperature is, for example, the testing of ice cream at a storage temperature of –20°C, or the testing of pizza cheese at approx. +80°C.

Picture 21: Food stuff testing in a temperature chamber

2. Packaging test

2.1 General to packaging testing

The development of packaging is very strongly influenced by the requirements of the foodstuffs industry. The foodstuffs industry always demands improved storage and transport characteristics from packaging.

Packaging should be, as much as possible, the following:

- Stable
- Practical
- Inexpensive
- Simple to produce and process
- Temperature insensitive
- Non-poisonous
- Secure
- User friendly
- Light
- Storable / stackable
- Leakproof
- Easy to compress
- Easy to open

Not only the foodstuffs industry, but almost all producing industries require packaging which have the optimum characteristics for their special requirements. Not only the original characteristics of the packaging are important here, but also the protection of a product.

Other factors, e.g. product marketing and environmental considerations receive more and more importance. Since packaging nowadays is made of the most various materials, it must fulfill the most varying requirements. A small overview of the most important packaging materials follows.

Packaging of paper / cardboard

- Carton
- Paper packaging (paper sacks, paper bags)
- Corrugated cardboard

The most important applications: Foodstuffs, luxury foodstuffs, industry packaging, transport packaging.

Picture 22: Various packagings

Picture 23: Packaging of foodstuffs

Packaging made of plastic

- Foils
- Bottles, canisters
- Cases, containers, pails
- Beaker

The most important applications: Foodstuffs, chemicals, industry packaging, transport packaging.

Packaging made of metal

- Cans
- Barrels
- Containers

The most important applications: Drinks, chemicals, industry packaging.

Packaging made of glass

- Bottles

The most important applications: Drinks, foodstuffs, chemicals, cosmetics.

Other packaging

- Packaging made of textile, composites (bags, sacks, Big Bag)
- Packaging made of wood (crates, palettes)

Constant materials testing is required so that the listed packagings can be optimally used. The most important testing on finished packaging is described on the following pages. Mainly, mechanical testing of finished packaging is described in this prospectus. Information for specific material testing of other materials can be seen in other prospects (plastic, metal, paper, textile).

2.2 Zwick Roell testing devices with applications examples

Testing of plastic packagings

Compression test on plastic beakers, canisters, pails and barrels
The compression test is one of the most common tests in the packaging industry. Since a lot of packaging is made of plastic, it is very understandable that a multitude of compression tests are performed on these packagings. Since the form of the packaging varies greatly, there is very often no Standard available. For this reason, most testers orient themselves to the general material Standards and try to recreate the finished product´s function or a production problem using a testing machine.

Stacking test (ISO 12048, DIN 35526-1)
During a stacking test, the packaging is loaded with a force which corresponds to a defined number of packaging units which would be stacked on top of it. In this test, it can also be seen if the foreseen stacking height can be reached. A packaging unit is loaded until it fails. The force required to destroy the packaging unit can be used to calculate the maximum stacking height. This test is usually not performed on individual packagings. Plastic beakers are almost always transported in trays (cardboard holders for beakers, e.g. joghurt). In order to receive test results which are close to practice, completely filled trays are loaded in a compression test.

Picture 24: Stacking test on plastic pails

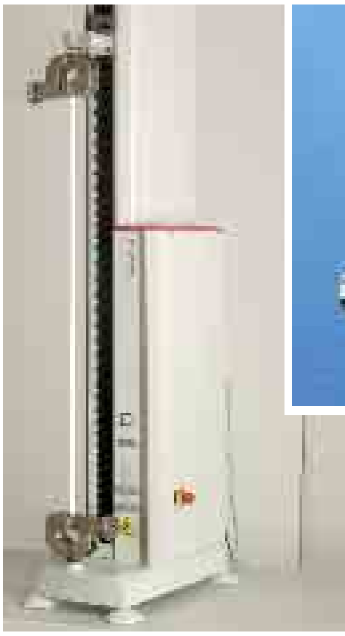
Picture 25: Compression test on plastic packagings (plastic barrel, joghurt beaker)

Determination of inherent rigidity
The packaging unit is loaded until failure. This test gives information mainly used in the processing of packaging, since this unit has a certain load applied when it is closed (when the lid is put on), and the packaging unit must withstand this closing process without problem.

Testing of packaging foils

Tensile test on plastic foils

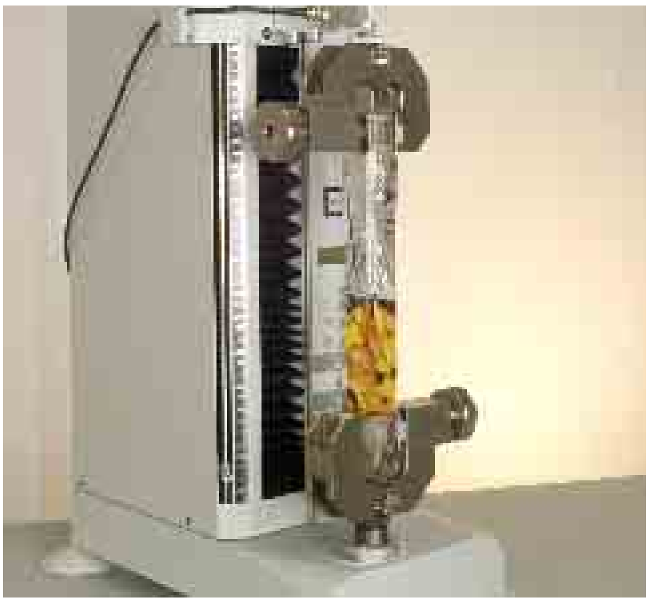
The tensile test on plastic foils is clearly described in Standard, DIN EN ISO 527-3. It serves to exactly determine the single axis stress-strain-characteristic. It is important that the test speed is exactly maintained since plastics also have visco-elastic characteristics. This sometimes changes the stress-strain-characteristic greatly.
Plastic foils can display a strong anisotropy (the stress-strain-characteristic is dependent upon the direction the specimen is taken from the basic material).
The stress-strain-diagram contains additional information when the test temperature is varied. Tests under temperature are necessary in cases where the foil is exposed to temperature swings during use, and the chance of the foil failing is greater.




Picture 26: Tensile test on plastic foils with different elasticity

Tear test

Standards DIN 53515 and DIN 53363 exist for tear tests on plastic foils. The test simulates the behaviour of packaging foils when the package is opened.
When opening a plastic bag, the initial tearing strength should be approximately as much as the continuing tearing strength. If the maximum force at initial tearing is too high, the danger exists that the plastic bag will suddenly tear completely open and the contents will spill out. The ideal behaviour is not easy to adjust because the tear resistance (as well as the tensile strength), is very direction dependent with stretched foils.



Picture 27: Seam strength test on heat sealed packaging foils

Seam strength

The seam strength test is described in the Standard, DIN 55543.
This seam strength test determines the strength of the glued or heat sealed seam on packaging bags and sacs.

Zwick / Roell

Picture 28: The device for testing the frictional behaviour, mounted

Friction test

The friction test is described in Standards, ISO 8295, ASTM D 1834 and DIN 53375.
The coefficient of friction ratio is a dimension for determination of a foils quality. However, it is also used to evaluate the behaviour of a foil in packaging or printing machines. The following can be determined:

- The static friction ratio μ_S and/or
- the sliding friction ratio μ_D

and these as coefficient of friction of foil against foil or foil against a different material.

Penetration test on packaging foil

The penetration test device was developed for the determination of the penetration resistance of elastic packaging materials. With this device, penetration tests on foils can be simply and quickly performed according to DIN EN 14477. The possibility of placing an endless strip specimen in the device ensures cost effective testing. Using a collet, different penetration dies can be exactly mounted with a few easy steps.

Picture 29: Penetration test on foil strips

Picture 30: Peel-off test on glued beaker top/ “push-out“ test on medical packaging

Customer specific test devices for functional testing on foils

On the basis of customer specific requirements, various testing units and tools for testing of plastic packaging and other components, can be developed and produced on short notice.
Examples are shown here. To the left is a unit to determine the „push-out“ force on blister packs and, to the far left, a test device to determine the peel-off force on packaging beakers.

Testing of paper packaging

Box compression test and stacking test on cardboard boxes

The box compression and stacking tests are described in Standard, ISO 12048.
Both tests serve to determine the strength and the stacking capabilities of cardboard boxes. The complete carton is loaded until failure or until its nominal loading value is reached. In the box compression test, the cardboard carton is quickly loaded to the nominal loading value or until failure. In the stacking test, an agreed upon maximum load is held constant for a determined time, or until failure of the box.

Picture 31: Box compression test on a large cardboard box

Picture 32: 4-point flexure test on cardboard

Flexure test on cardboard

The 4-point flexure test on cardboard is described in Standard, ISO 5628.
The 4-point flexure test is used to test single or multi-layered cardboard, heavy cardboard, heavy fiberboard or cardboard with fiber reinforcement, as well as testing of structural materials, e.g. honeycomb constructions. The supports integrated into the testing device are made especially for cardboard testing and do not have any influence on the measurements. Specimen from 200 to approx. 400 mm can be simply and exactly tested with this device.

Compression test on compound paper boxes

The compression test on full and empty compound paper boxes serves to determine the strength of these packagings. The most varied box shapes can be simply and efficiently tested in a special horizontal testing machine. The specimen can be placed exactly and quickly into the testing unit with two guidance units.

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Testing of metal packaging

Compression testing of metal barrels, cans, canisters etc.

The compression tests on metal barrels, canisters etc. are defined in various directives (e.g. the directive for production and test standards for packaging, large packing items, large packagings...).
Accordingly, metal containers must be loaded for 5 minutes with a force that is equal to 1.8 times the maximum gross mass weight with which such a packaging is allowed to be loaded.
The packaging is not allowed to have any permanent deformations after the test is over.
Often, it is also of interest to determine the maximum possible loading of a packaging unit. Here the packaging unit is loaded until failure and the maximum load required for this is determined.

Picture 34: Compression test on a metal barrel

Picture 35: Peel-off test on a packaging beaker

Peel-off test on a packaging beaker with aluminium cover

With the flexible testing unit for peel-off testing on food stuffs beakers (e.g. joghurt, soft cheese, coffee cream,...), the peel-off forces which are required to open a glued beaker cover can be determined.
Various sizes and shapes of beakers can be held with the variably adjustable unit. A clamp is affixed to the pull-off tab of the cover. This is connected to the load cell on the moving crosshead with a thin cord via a guide roller.
When the moving crosshead is driven upwards, the cover is peeled-off and the force required is determined.

Testing of other packaging materials

Torsion testing on packaging materials

Screw cap closings are more and more important in the packaging industry and they find increasingly more applications. Bottles, canisters, compound paper boxes etc. are fitted with screw cap closings. In order to test these closings, a testing machine is necessary for torsion testing.
In addition, torsion testing on complete packaging materials (e.g. cigarette boxes) is becoming more important.
Zwick offers a variable use test machine series exactly for these applications with various specimen sizes and the different torque moments required.

Picture 36: Torsion testing on a carton

Picture 37: Tensile and penetration tests on textiles

Tests on textile packaging materials (sacks, bags, ”Big Bag”, ...)

Tests are not performed on the end product of packaging materials made of textile, but on defined specimen.
The most important test on these materials is the tensile test. Similar to the Standards EN ISO 13934, 13935 and 13937, the specimen are loaded in a tensile test until they tear.
Another important test on such textile sheets is the die penetration test. Similar to the Standard EN ISO 12236, a penetration body is forced through a specimen. The force required, as well as the deformation determined, gives important information about the characteristics of the end product.

Pull-out test on wine bottle corks

The pull-out test on corks of wine bottles is a very special test which has been developed for a small circle of users. However, it is a good example of the flexibility and Zwick´s customer orientation.

Picture 38: Illustration of the cork pull-out test on a wine bottle

Zwick / Roell

Flexible testing components for food stuffs/ packaging testing

BasicLine Toolbox: Quick action chuck
For flexible compression and penetration tests, various penetration needles or compression dies can be simply and precisely held with the quick action chuck. The quick action chuck is adapted to the Zwick connection system which gives the customer the possibility of quickly and simply integrating his own testing tools into the system.

BasicLine Toolbox: T-Slot plates
The T-Slot plates are used for universal mounting of the most varied testing tools. Zwick Roell tools, as well as customer specific units and tools, can be adapted via these plates. For example positioning units, hinge sets, vices and many more can be used.

Picture 39: Pull-off test on a marmalade container which is held in a parallel vice. The pull-off is performed by a small screw clamp

Picture 40a/b: Penetration tests on foodstuffs packaging

BasicLine Toolbox: Vices
Several universally usable vices make possible the gripping of the most varied specimen and components. According to application, a highly precise parallel vice, an easy to open and close quick action vice, or an universal vice, can be adapted to the machine for use in many universal ways.

BasicLine Toolbox: Screw clamp
A multiple application clamp finds use in foodstuffs testing in pull-off, tensile and pull-out tests. The clamp, which is connected to the moving crosshead with a thin cord, can be used e.g. for pull-out tests on fruit stems, or as well for pull-off tests on joghurt beakers.

3. Testing machines

Zwick Roell develops and produces testing machines for forces from the mN range up to more than 6000 kN. As opposed to the often offered single-purpose testing instruments, Zwick Roell offers testing machines with individual solutions for each testing requirement. A customer specific testing machine is put together for each testing application.

Following is an overview of the different variations of load frames, the multitude of testing tools and devices, the advantages of the testing software *testXpert*®, as well as several of the options available.

We would also be happy to specify the correct testing machine for you and your application.

3.1 Load frame

Basic concept
The Zwick Roell program has table-top and floor machines with various measurement, control and regulating systems, different drives and many multi-use accessories.

In order to be able to offer the correct machine with the optimum price-performance ratio, the Zwick Roell machine concept has three machine series which are very different in their equipment, performance characteristics and in their expansion possibilities:

Picture 41a/b: Testing machines of the Standard series:
A 1-column (left) and 2-column (right) table-top machine

- The **BasicLine** is especially suited for routine and functional testing of components and for simple materials testing.

- With the **Standard series** the user who wants tests reliably performed to test requirements of Standards, receives a solid solution which is cost favourable.

- The **Allround series** is the expandable machine for demanding test requirements in research and development. It enables the connection of special sensors, allows multi-channel measurement technology and can be expanded modularly.

In each of these series we offer:
- **1-column table-top machines** („zwickis“)

- **2-column table-top machines**

- **Floor machines** (not in the BasicLine)

Picture 42a/b: Testing machine of the BasicLine:
A 1-column (left) and 2-column (right) table-top machine

Picture 43a/b: Testing machines of the Allround series:
A 1-column table-top machine (left) and a floor machine (right)

Zwick Roell

1-column table-top machines

These transportable load frames are based on a very stiff extruded aluminium profile. The working area is freely accessable from three sides which predestinates it for functional and component testing on specimen which have small front-to-back depths when mounted for testing. The lower force limits are determined by the load cell which is used: They begin in the mN range and go up to 2.5 kN.

2-column table-top machines

These load frames are outfitted with steel columns (BasicLine), or carrying and guiding columns of patented extruded aluminium profile (Standard and Allround series).

The load frames of the BasicLine are of a simple concept. That means, with fewer functions, but still with high quality, which offers an inexpensive alternative to the Standard and Allround series.

Picture 44: By equipping a testing machine with several testing positions, a maximum degree of use is achieved at low cost

Picture 45: The BasicLine offers inexpensive solutions for simple testing

The load frames of the Standard and Allround series are very light but with high bending stiffness because of the extruded aluminium profiles. The profiles also serve as guidance and protection for the spindles.
T-slots on the outer sides enable simple mounting of accessories. These load frames can be optionally equipped with profile legs for optimum positioning of the working area to a user friendly height.

Floor machines

The load frames of the floor machines are equipped with two or four chromium plated round columns and two precision ball-lead screw spindles. They are especially suitable for testing with high forces, materials with high extension, large specimen or components.

Electro-mechanical drive

All electro-mechanical drives are based on play-free and wear resistant ball-lead screws and digitally controlled drives. They are used for load frames with testing loads up to 600 kN. Together with the digital measurement, control and regulating system, they offer the following advantages:

- Extremely large, stepless, speed range
- Very small speeds can be set (from approx. 0.5 µm/min)
- Highly precise and exactly reproducible positioning and speeds

Zwick / Roell

Overview of the Zwick Roell load frame series and their specifications/functions

Specification/function	BasicLine	Standard series	Allround series
Load frames			
• Model			
- Table-top machine (Nom. force)	500 N to 20 kN	1 to 100 kN	1 to 100 kN
- Floor machine (Nom. force)	-	50 to 250 kN	50 to 600 kN
• Number of testing areas	1	1, optionally 2	1, optionally 2
• Wider and/or higher models available	-	√	√
Drive system			
• Electro-mechanical			
- Number of ball lead screws	1 or 2	1 or 2	1 or 2
- DC-Motor	√	only „zwicki“	only „zwicki“
- AC-Motor	-	√ (except „zwicki“)	√ (except „zwicki“)
Measurement, control and regulation system			
• BasicLine (Stand Alone / PC operation)	√	-	-
• *testControl* (PC operation)	-	√	√
• *testControl* Stand Alone	-	optional	optional
Test software			
• Test software *testXpert*® (for PC operation)	optional	optional	optional
- with Standard test programs	√	√	√
- with Master test programs	-	√	√
Measuring transducers			
• Strain-gauge load cell	1 (exchangeable)	1 (optional up to 2)	1 (optional up to 3)
• Digital crosshead travel monitor	integrated	integrated	integrated
Connection and control of external measurement systems	-	√	√
Control of external systems			
• Specimen grips (motor driven, pneumatic, hydraulic)	-	√	√
• Extension measurement systems	-	semi-automatic	fully-automatic
Optional accessories for special applications			
• Torsion drive	-	-	optional
• Torque transducer	-	optional	optional
• Temperature and climate chambers	-	optional	optional

Table 4: Overview of Zwick Roell load frames

3.2 Measurement, control and regulating system

The testing machine components which decide the performance capability and degree of functionality are the measurement, control and regulating system. Its performance capability determines which drive can be regulated, which sensors can be connected and which functions can be controlled. Therefore, it determines the scope of applications and the extension possibilities of the testing machine.

Picture 46: The measurement, control and regulating system for the BasicLine can be operated with or without PC

Measurement, control and regulating system of the BasicLine

The proven electronics used for the BasicLine can be used for simple tests, e.g. on components, with or without PC (Stand Alone). When used with a PC, all advantages of the Zwick Roell testing software *testXpert*®, in connection with Standard test programs, can be used.

Measurement, control and regulating system *testControl* of the Standard and Allround series

For the extensive functionality of the Standard and Allround series, the measurement, control and regulating system „*testControl*“ developed by Zwick Roell is used. Through the use of the most modern technology and the highest quality standards, *testControl* offers long-term investment security and the greatest measure of technical performance:

- Time synchronised test value acquisition with high resolution and measuring frequency.
- Real-time evaluation of the test values with 500 Hz acquisition rate.
- Adaptive regulation for exactly reproducible test speed and positioning.

When used with a PC, all advantages of the Zwick Roell testing software *testXpert*®, are available. The electronics, „Stand Alone“, is also optionally available. Here the operation can be performed simply and securely without PC, with a decade keyboard and a few function keys. A printer can be connected for output of the test results.

Picture 47: The measurement, control and regulating system *testControl* is operated via PC, or with the option „Stand Alone“ also without PC (see inset picture)

3.3 Test software *testXpert*®

testXpert® is the universal test software from Zwick for materials, components and functional testing. Its area of use reaches from material testing machines (tensile, compression, flexure and materials testing machines), hardness testing machines, pendulum impact testers, melt flow rate instruments, balances, automatic testing systems etc., up to the modernisation of testing machines of the most varied construction types and makes.

Tasks and functions

The basic functions of *testXpert*® are:

- Preparation and/or changeover to different tests of the test machine
- Parametrisation of the test or test series
- Performance of the test, evaluation and documentation
- Data management
- Quality management
- Data exchange between *testXpert*® and other applications (Word, Excel etc.)

testXpert® supports the user in all tasks with Software-Assistants and Editors, guiding pictures and video sequences, situation specific user tips, warnings, error messages and online help.

Future oriented concept

The testing software *testXpert*® uses the characteristic of object oriented programming for a clear organisation of tasks and functions. Structure and performance are determined from applications and software know-how from Zwick Roell. The *testXpert*®-concept is a guarantee of highest flexibility and functional security, as well as being simple to use. The important features are:

- Uniform basic software for all applications
- Software modules for Standards
- Software tools for operator support

Modular system

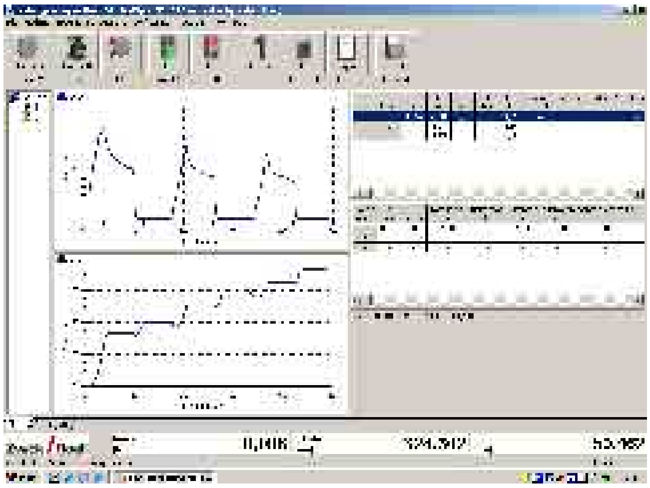
The test programs have been created by Zwick Roell with several hundred software modules. The modules are separated into classes such as test parameters, test sequence phases, screen masks etc. They are continually updated and expanded with new insights and required supplements. This makes *testXpert*®*,* an intelligent software and thereby makes it possible to realise test programmes which follow Standards exactly, but which are also practice oriented (Picture 48). Their variety makes it possible to use *testXpert*® universally for a wide applications spectrum and with most types of testing machines.

Test programs

Test programs describe how a test is to be performed. Their basis is selected software modules which are linked together and pre-configured by fixed parameters corresponding to the required functions. The user receives a finished „test template“ from Zwick Roell, into which he must only enter variable parameters.

For the various requirements in practice, the following three variations are available:

- Master test programs
- Standard test programs
- Customer specific test programs



Picture 48: Screenshot in *testXpert*®: Penetration test on bread

International Quality Standard

A software product can only meet International Quality Standards when each version has continuity, is documented in all phases of development, and is archived for 10 years. The test software *testXpert®* fulfils these requirements and even the especially strict guidelines of the Good Manufacturing Practices (GMP).

The complete developing process of software and its components is carefully documented and archived from source code up to the software tools used for each version, and for every phase of the analysis of the specification, design, implementation and finally, testing. The conformity to Standard, ISO 9000-3 is confirmed with the audit report number QM-F-96/1016.

testXpert® is available in various languages, e.g. German, English and French.

Safety in detail

testXpert® takes over a safety relevant task with the monitoring and control of machines: Machine damage and danger to people must be eliminated. For this reason, in the testing mode, *testXpert®* has no overlapping windows, as is known in Windows, which can cover important displays or buttons.

Automatic read-in of system data

Various testing tasks require testing machines with different components which are usually exchangeable. Their specific characteristics are recorded in the system data (nominal force, travel, speed range, test set-up height, calibration factors, etc.). Organisational data such as serial number or the date of last calibration is also necessary.

testXpert® automatically reads-in the data directly after programme start

- For the required settings,
- To determine the safety limit values,
- For correct evaluation of the measured values.

In addition, *testXpert®,* checks if

- The test can be performed with this configuration,
- All settings have been made,
- The data for the actual test has been changed.

The most simple operation

With standard applications, the operational effort is reduced to one-button operation, that is, the pushing of the start button. This is possible because *testXpert®* automatically acquires the test values, and depending on these, controls and monitors the test sequence and determines and documents the test results.

The preparation of a test series only requires 2 steps:

- Call-up of the test program
- Input of the variable parameters

Optimum operator information

All displays which are required for the performance of a test can be clearly collated in one screen mask. These include:

- Input fields for specimen specific test parameters
- Individual or multiple diagram curves
- Tables for test results
- Tables for results statistics

Data storage for later use

Corresponding to the requirements in the test Standard, all data, or only selected data, of a test or test series can be stored. The storage of all data offers the possibility to trace the development of the results all the way back to the configuration and set-up of the machine. In the simulation mode, the test data can be repeatedly displayed and reevaluated to other criteria.

Traceability

The system data is stored along with other test data. Then, according to ISO 9000 ff, it can be traced back as to which testing machine, in which configuration, and with which settings, the test was performed.

Video-Capturing

testXpert® supports the operator not only with „help videos“, but also with video sequences which can be taken at the same time as the test. With a video camera and a video-capture card, multimedial testing can be performed. The videos run synchronous to the respective test values. Therefore, they can be evaluated and the video can be repeated as often as desired.

3.4 Load cells

Load cells for nominal loads from 5 N to 2,000 kN can be supplied. Together with the digital measurement, control and regulation system, they offer many advantageous characteristics:

- Automatic identification and acquisition of all set-up and calibration parameters via the sensor plug. This makes the changing of load cells very simple and an input of set-up data or calibration is not necessary.
- Automatic zero point and sensitivity adjustment
- Temperature drift compensation
- High measuring frequency
- High measurement value resolution
- Measurement accuracy:
  Class 0.5 (0.5 % of measured value) from 1 to 100 % of the nominal load
  Class 1 (1 % of measured value) from 0.2 to 120 % of the nominal load (1 to 100 % for load cells with a nominal load ≤ 500 N)
- Overload protection
- Manufacturer´s test certificate for proof of factory calibration

Picture 49: A load cell from our large selection: The load cell type „KAF“ for loads up to maximum 5 kN

3.5 Test units and test tools

Test units and test tools are divided into:

- Specimen grips
- Test tools for compression and flexure tests and test tools for special applications
- Tool elements for variable specimen holding („BasicLine Toolbox“)

Since chapters 1 and 2 had information about the testing devices and tools that are often used in food stuffs and packaging testing, the following is only a basic overview.

Specimen grips

Zwick covers a multitude of applications areas with a wide spectrum of specimen grips. The quality of a specimen grip and its match to the specimen is very important to the quality of the test.

The following criteria is used to select specimen grips:

- Force-locking and form-locking specimen grips: With the force-locking principle, the specimen is held by applying a tensile force. With the form-locking principle, the form of the specimen holds it in the grip itself, therefore there is no force application from the specimen grip.
- Externally operated and self-clamping specimen grips: Specimen grips which are operated by external energy always have a parallel clamping gripping principle, whereby the gripping force is indepenent of the tensile force. Examples are screw and pneumatic specimen grips. With the self-clamping specimen grips, the clamping force is taken from the test force and amplified via levers, wedges, cams, or similar, and transferred to the jaw faces. Examples here are wedge and pincer grips.
- Nominal force: Within the various categories of specimen grips, there are also various maximum nominal forces available. For example: There are screw grips with Fmax from 20 N up to 50 kN.

An important criteria is also the selection of the matching jaw inserts. A secure and slip-free clamping of the specimen depends on the correct jaw inserts. For example: There are jaw faces with rubber smooth surface, or steel corrugated, smooth, with V-slot etc.

Test tools for compression and flexure tests and test tools for special applications

There is a multitude of testing tools of various types and dimensions, as well as of different test forces, for performing compression and flexure tests. Complete compression and flexure test kits are available, but there is also a complete line of individual elements available so that a unit can be specified to any application. There also exist test tools for special applications, which are developed explicit for a test. For example: The device for testing the frictional behaviour (see picture 28).

Picture 50: An individually specified test arrangement: Above is a specimen grip and below are elements of the BasicLine Toolbox

Picture 51: The „Mc Kee-testing machine“ contains the most varying testing units especially for packaging / paper testing

Toolbox elements for variable specimen clamping

Some „unwieldy“ specimen require a suitable specimen clamping when there is no special testing unit available. For these cases, Zwick Roell offers the „BasicLine Toolbox“. This is a product programme which contains many elements which can be combined with one another. Examples can be seen in the pictures on page 22.

3.6 Temperature and climate chambers

Foodstuffs and many packagings change their characteristics greatly depending on the humidity and environmental temperature.

According to the application of the „material“, these changes can have important effects. For example: When heated sauces are filled into containers, the temperature can effect the production process.

Zwick Roell offers a complete product range of temperature chambers corresponding to the many different requirements.

Picture 52: A temperature chamber especially for the zwicki. Used here for testing on foodstuffs

3.7 Extensometers

Crosshead travel monitors

All Zwick Roell material testing machines are equipped with a digital crosshead travel monitor. This measures the travel of the moving crosshead with high precision and exactly reproducibility. This means that many applications in foodstuffs and packaging testing can use indirect measurement of the extension (without additional extensometer direct on the specimen).

Direct extension and reduction-in-width measurement

Some tests require measurement of the extension directly on the specimen in order to eliminate any measuring errors which could occur due to machine deformation, over-run of test tools or partial slippage of the specimen.
There are various measurement systems for measuring extension:

- Mechanical exensometers for contact measurement directly on the specimen, also for long-travel lengths.
- Contact-free extensometers which do not affect the specimen and measure the extension with optical methods.
- Clip-on extensometers which measure with high resolution and are clipped directly onto the specimen.

Picture 53: Mechanical extensometer for high resolution, direct extension measurement on the specimen.