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SECTION 1: A Science to Learn From

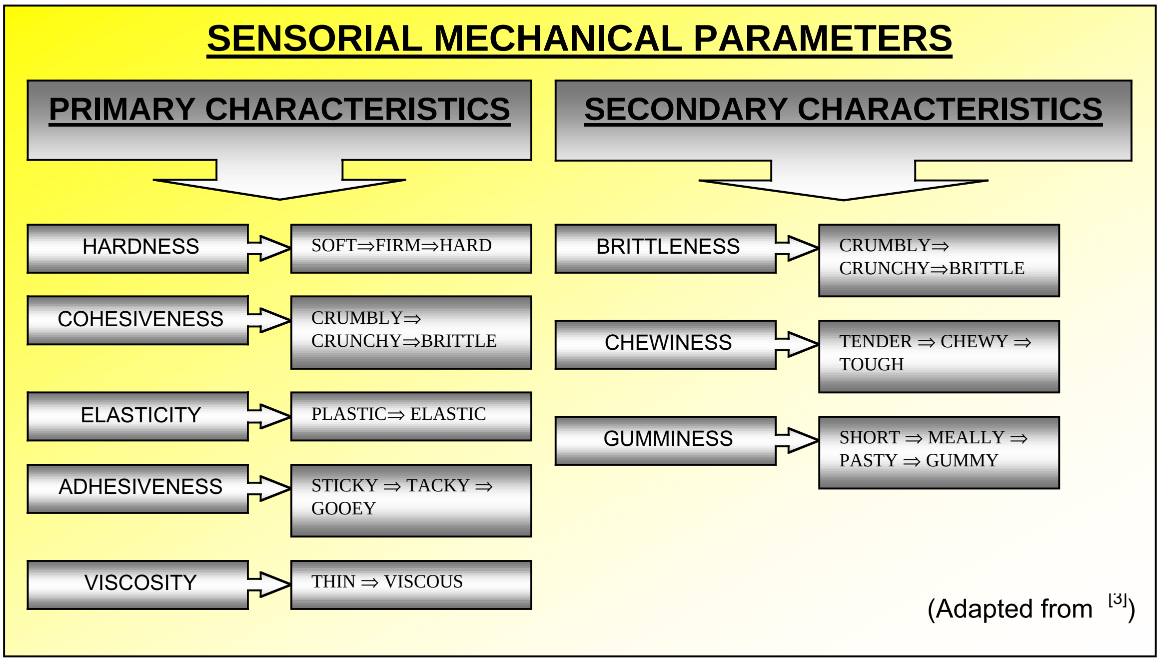
TEXTURE ANALYSIS… A SCIENCE TO LEARN FROM

Texture, appearance and flavour are the three major components of food acceptability[1]. The importance of food texture on consumer perception has undergone considerable review in recent years, where it has been categorised into three principle characteristics:

1. ***MECHANICAL:*** Relating to a food reaction to stress (force application)
2. ***GEOMETRICAL:*** Relating to the size, shape and orientation of the particles within a food
3. ***OTHER:*** Relating to the perception of moisture and fat contents of a food

[3]

Texture analysis is primarily concerned with the evaluation of mechanical characteristics where a food is subjected to a controlled force from which a deformation curve of its response is generated. These mechanical characteristics can be further sub-divided into primary and secondary sensory characteristics.



The parameters highlighted are discussed fully within our in-house publication "A Quick Reference Glossary of Texture Terminology".

Characterisation of textural parameters is bias to either sensory or instrumental procedures:

1. **SENSORY ANALYSIS:** *A scientific discipline used to evoke, measure, analyse and interpret reactions to those characteristics of food and materials as perceived by the senses of: sight; smell; taste; hearing and touch.*

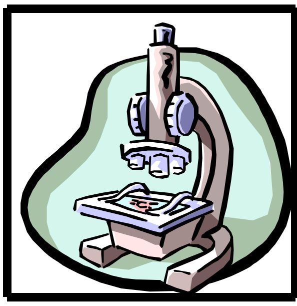
(IFT, USA)

2. **INSTRUMENTAL TEXTURE ANALYSIS:** *Is an analytical procedure which subjects a sample to known conditions (Stress or Strain) in a controlled manner from which mechanical characteristics can be interpreted.*

Instrumental procedures are generally more sensitive and reproducible than their subjective sensory equivalents where variation in results is generally attributed to variation in sample heterogeneity rather than instrumental precision.

There are two principle approaches to texture analysis adopted by the industry:

CORRELATION BETWEEN HUMAN AND INSTRUMENT.
Related to sensorial correlation between instrument and human where both parties are cross-correlated and trends or patterns observed. The most commonly employed method being Texture Profile Analysis (TPA)



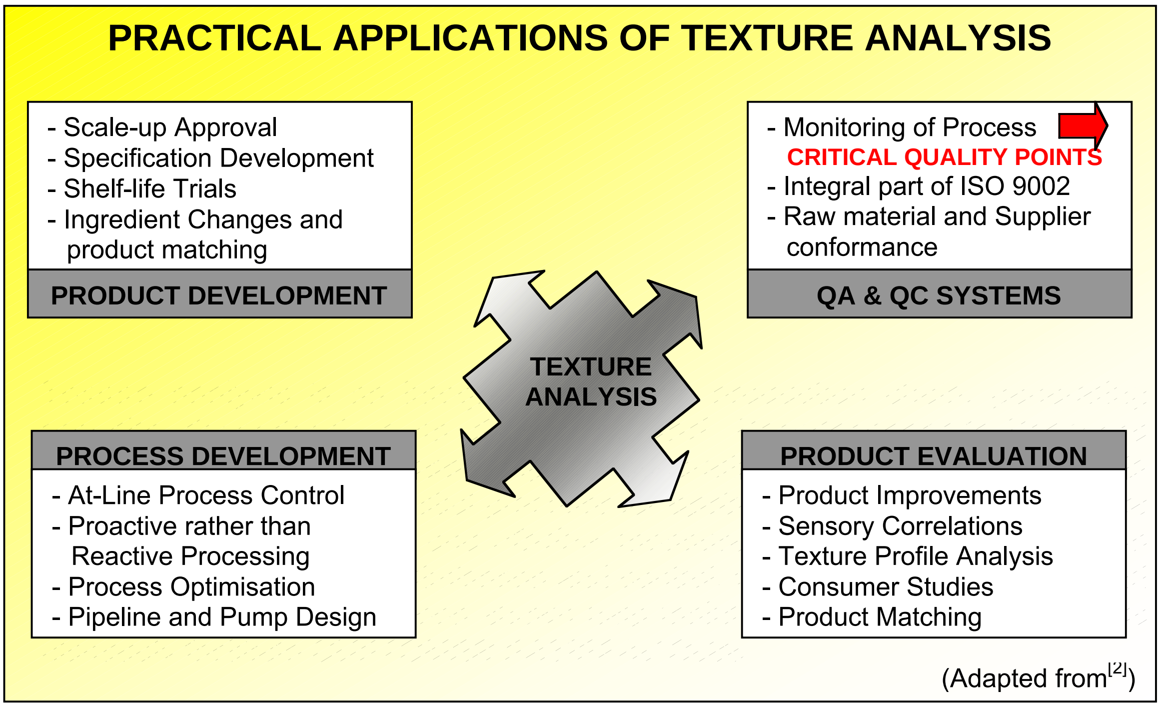
PROCESS CONTROL AND PRODUCT DEVELOPMENT.
Key fundamental characteristics which affect finished product texture (such as moisture content and compositional quality) are identified throughout the initial stages of development after which they can be selected for ***at-line*** process control measurements.

Objective mechanical texture measurements, as employed within texture analysis are subdivided into 3 categories*: Fundamental; Empirical* and *Imitative*. Full reference to such definitions can be within the "in-house" publication "**An Overview to Texture Terminology**".

Texture analysis is a versatile science which can be applied as a means of **process control**.

An Analogy

The formulation of a food product specifies the molecules which go into it. The processing of these molecules in turn leads to the development of "structures" desirable and expected by the cosumer. Most food products are manufactured from ingredients, which again have their own associated structures and a complex picture of the finished product evolves. It is here that texture analysis becomes an invaluable tool in the optimisation of product quality, characteristics and eventually process control in waste management.



Texture analysis is an integral part of the production chain, generating benefits throughout, from ***Research and Development*** to ***Process Optimisation*** and ***Production***. Key fundamental characteristics which affect finished product texture quality are identified throughout the initial stages of development after which they may be selected for ***at-line*** process control measurements (e.g. the generation of *higher* and *lower* limits of acceptance builds the initial precursor for ***optimal manufacture*** and ***waste reduction***).

These *at-* and *off-line* measures are rapidly becoming an integral part of process optimisation and control, where increased product and process knowledge has been shown to help maintain product quality and thus ultimately facilitate ***CUSTOMER SATISFACTION*** and ***REPEAT SALES.***

In conclusion, the industry as whole is **not** utilising texture analysis to its full potential as rheological indicator, where tests should be exploited to gain full advantage and optimise procative manufacture within the "***QUALITY CONTROL LOOP***" maximising production efficiency and ultimately profits through production of the *right* product at the *right* quality, *consistently.*

REFERENCES:

[1] Bourne, M. (1978). Texture Profile Analysis. *Food Technology.* **32** (7), 62-66, 72
[2] Borwankar, R. (1992). Food Texture and Rheology. In: *Rheology of Foods* (Ed. Borwankar, R. and Shoemaker, C. (1992). Elsevier Applied Science Publishers Ltd, Essex, 1-16.
[3] Szczesniak, A. (1963). Classification of Textural Characteristics. *Journalof Food Science.* **28,** 981-985.

SECTION 2: An Overview to Texture Terminology

An Overview to Texture Terminology

Food texture is considered as a human experience developed between food structure and its response or behaviour when handled. Instrumental methods are used to objectively quantify mechanical characteristics of food texture where scientific apparatus is utilised to quantify a foods reaction to imposed conditions. The conditions imposed are either related to stress (application of constant force or load and quantification of distance travelled a response) or strain (application of constant test distance and quantification of load resistance as a response). Instrumental measure may only be utilised to quantify the physical aspects of food texture and make no allowance for the influence of factors such as physiology or psychology of perception.

Instrumental or mechanical methods for texture measurement are divided into three classes (Szczesniak, 1963), *Fundamental; Empirical* and *Imitative.* Full discussion to these techniques is given within Table 1.

Table. 1. *A Breakdown of Experimental Classification*

FUNDAMENTAL	Fundamental tests measure well-defined physical properties and relate these characteristics to well defined physical properties. These measures are familiar to those used by engineers e.g. Poisson's ratio and other moduli such as Young's, Shear and Bulk moduli. Fundamental tests relate the nature of the tested food in two basic rheological prototypes: A dashpot for Newtonian liquids and a metal spring for Hookean solid. The complexity of foods means that models encompass both dashpots and springs linked in series and/or parallel, where the former allows for recoverable deformation and the latter accounts for delayed elastic effects.
EMPIRICAL	Empirical techniques are used to quantify product specific characteristics which can not be expressed in fundamental rheological quantities. Results obtained from such procedures depend on the geometry of the system used and are thus condition dependant. They cover a miscellany of tests incorporating forces such as puncture, shear and extrusion. Techniques involved, through practical experience, have been correlated with textural qualities (Bourne, 1982), many of which have become industrial standards such as the Bloom Test.
IMITATIVE	Tests which attempt to imitate with instruments the conditions to which the food is subjected in the mouth or on the plate (Bourne, 1978). These types of test may be considered as an extension to empirical techniques.

The majority of food texture analysis is empirical and specific to the application to which they are applied. Each of the recommended application studies developed within CNS Farnell are specific to the application which they have been developed, deviation from product or process recommended will significantly change the results generated and thus data is no longer cross-comparable. However, when comparisons are made like for like the data formed is invaluable as within standard quality assurance practices or in the development of new products where texture analysis becomes an integral factor in the prediction and determination of rheological characteristics.

Texture Analysis and Fundamental Measurements:

Rheology characterises forces in relation to size and direction. These vectors are termed as units of stress and strain.

- *Stress* is the intensity of force components acting on a material and is expressed in units of force per unit area (Szczesniak, 1983).
- *Strain* is the change in size or shape of a body in response to the applied force. It is a non-dimensional parameter, delineated as a ratio or percentage, and is expressed as the change in relation to the original size or shape (Giese, 1995).

A number of commonly employed fundamental tests are given in Table 2, the first four listed apply to solids, while the fifth applies to fluids. Both the QTS and LFRA TA are capable of calculating such parameters provided that deformations are made within the linear region of elasticity (1-3% for viscoelastic materials such as most foods). Samples must also be uniform in both shape and consistency e.g. are isotropic, whilst measurements are made at sufficiently low speed to permit accurate generation. Where all of these conditions are not available the modulus of deformability has been utilised where true-stress:true-strain ratios are calculated based on the expansion of the sample caused through compression.

Table. 2. Commonly Employed Fundamental Tests			
Eq. No.	Fundamental Test	Factors	Units
1	Young's modulus of elasticity (*E*) **(Longitudinal Compression or extension)**	$\frac{\text{Stress}}{\text{Strain}}$	$\frac{F/A}{\Delta L/L}$
2	Shear Modulus (*G*) **(Lateral Shear Deformation)**	$\frac{\text{Shear Stress}}{\text{Shear Strain}}$	$\frac{F/A}{\gamma/L}$
3	Bulk Modulus (*K*)	$\frac{\text{Hydrostatic Pressure}}{\text{Volume Strain}}$	$\frac{P}{\Delta V/V}$
4	Poisson's Ratio μ	$\frac{\text{Change in width per unit width}}{\text{Change in length per unit length}}$	$\frac{\Delta D/D}{\Delta L/L}$
When the volume is unchanged during test, μ = _. If volume decreases, μ < _.			
5	Viscosity		σ/•γ
Where F is applied force, A is cross-section area, L is unstressed length, ΔL is change in length caused by the application of force F, γ is displaced (shear modulus), P is pressure, V is volume, D is diameter, σ is shear stress (viscosity) and •γ is shear rate (viscosity)			

(Adapted from Bourne, 1982)

Small Deformation:

Peleg (1976) stated that a rheological model should be capable of predicting real material behaviour under any force-deformation history. To achieve this goal, the model parameters might be functions time (t) and stress (σ) or strain (ε). Provided that the magnitude of σ or ε is below certain limits, the mechanical properties may depend on time only, thus leading to so called linear elastic materials (Mancini, Moresi and Rancini, 1999). This region is thought to be at less than 1% of original sample height in foods and is the region where the food behaves as an ideal elastic material e.g. deformation (strain) occurs instantaneously when stress is applied and disappears instantaneously when stress is removed as if it possess a "memory" (Borwankar, 1992) – *This relates to the CNS Farnell Memory Parameter.*

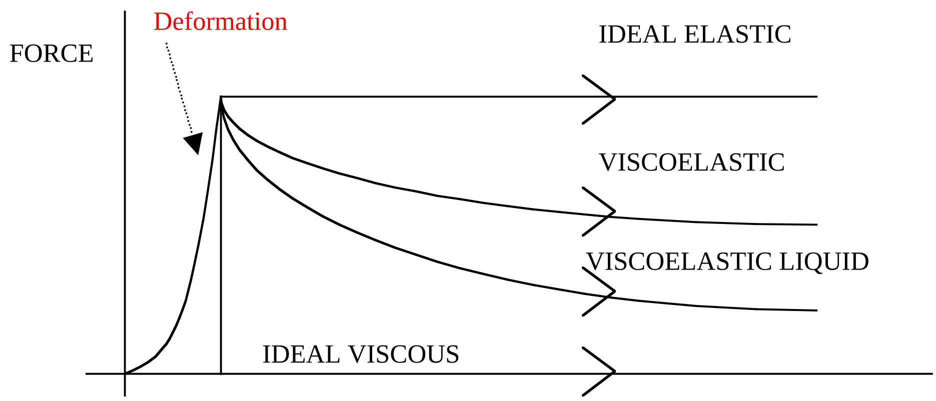
Large Deformations:

According to Borwankar (1992) large deformations relate to when stresses are applied at levels above the yield value. The original shape is not regained on removal of the applied stress and plastic deformation is exhibited involving some structural breakdown. At even larger deformations macroscopic fracture may occur, correlating with the mastication action and subsequent forces developed within the mouth.

Stress Relaxation Tests:

The viscoelastic properties of solid foods have frequently been demonstrated by relaxation curves (Peleg, 1979). Stress relaxation experiments involve the rapid deformation of a sample where subsequent stress at a constant deformation is measured as a function of time at a constant deformation. Examples of typical stress relaxation curves for various materials are given in Fig. 1. Ideally, the material is deformed in a step function, but in practice deformation always takes time (van Vilet, 1999). Fig. 1 illustrates that viscoelastic materials decay over a time period, the greater the elasticity of the sample the shallower the relaxation gradient will appear until pure elastic behaviour ensues.

Fig. 1. Stress Relaxation Curves Highlighting Various



(Adapted from Peleg, 1979)

The Usefulness of Fundamental Tests:

Fundamental tests are generally slow to perform, do not correlate as well with sensory evaluation, as do empirical tests and use expensive equipment (Bourne, 1982). The complexity of fundamental test procedures has limited their application within the food industry, although they have become an invaluable tool within the research laboratory.

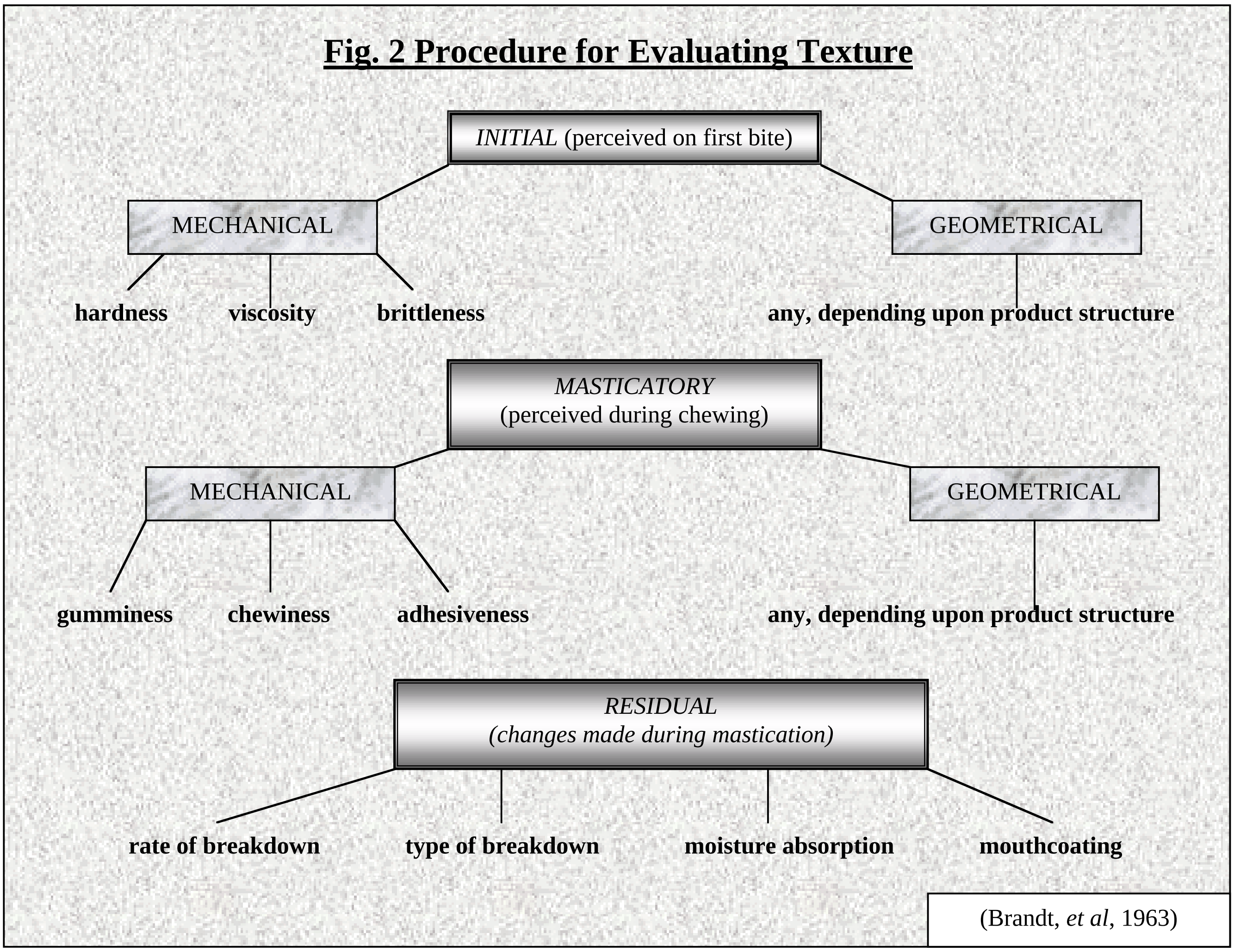
Szczesniak (1963) described the usefulness of fundamental tests as:

> *"Since most foodstuffs do not have simple rheological properties that are independent of stress and strain conditions, and since rheological properties once measured and defined are not meaningful in a practical sense unless related to functional properties, fundamental tests serve the greatest value to the food technologist by providing bases for the development of more meaningful empirical tests".*

As very few foods exhibit true elastic, viscous or plastic behaviour, but more often than not a combination of all three, when subjected to stress (Brennan, 1994) the classification of stress and strain is extremely complicated (Bourne, 1982) often showing little correlation with sensorial perception (Mohsenin, *et al,* 1977). And as Bourne (1975) aptly reported objective rheology on its own, is not enough to cover all the texture parameters of interest to the food technologist.

Imitative Measures:

Food samples inherently possess and exhibit non-dominant textural characteristics, and it is the perception and interaction of these characteristics which is unknown (Meullenet, *et al*, 1998). The perception of food texture follows a definite pattern regarding the order in which characteristics are perceived. These characteristics were sub-divided by Brandt, *et al*, (1963) into first-bite, masticatory, and residual and are illustrated in Fig. 2. Imitative instrumental measures of mechanical texture thus attempt to simulate *real-life* imposed conditions in a range of applications as diverse as assessing spreadability of margarine or the effect of extrusion on product consistency.



Texture Profile Analysis:

Texture Profile Analysis (TPA) evolved through work by General Foods in the early 60's where key textural parameters of a wide range of food stuffs were identified. Mechanical instrumental parameters read from force:deformation curves and cross compared with sensorial observed characteristics. These parameters were later adopted and applied by Bourne (1978) using uniaxial compression within the Instron Universal Testing Machine (IUTM) and in later studies by additional authors using apparatus such as the QTS-25 and LFRA TA.

TABLE 3. Bourne (1978) Seven TPA Textural Characteristics	
CHARACTERISTIC	**DEFINITION**
FRACTURABILITY	Defined as the first significant break in the first compression cycle
HARDNESS	Peak force of the first compression cycle
COHESIVENESS	The ratio of positive force during the second to that during the first compression (A2/A1)
ADHESIVENESS	The negative area for the first bite, representing the work necessary to pull the compressing plunger away from the sample
SPRINGINESS	Height that the food recovers during the that elapses between the end of the first bite and the start of the second bite
GUMMINESS **(SEMI-SOLID)**	Calculated parameter: Product of Hardness x Cohesiveness
CHEWINESS **(SOLID)**	Calculated parameter: Product of Gumminess x Springiness (equivalent to Hardness x Cohesiveness x Springiness)

The parameters listed in Table 3 have been used as the basis for practically all subsequent instrumental TPA studies using the IUTM (Pons, *et al,* 1996). It is imperative that the mechanical texture characteristics defined by Bourne (1978) are considered in relation to the sensorial definitions originally defined by Szczesniak (1963) and given in Fig 3, if valid correlations with sensory perception are to be made. Units of the seven parameters discussed are given in Table 4 as listed by Bourne (1978), the table also includes units of measure noted by Breene (1975).

Fig. 3. MECHANICAL PROPERTIES AND INTERPRETATION FROM GF TEXTUROMETER

PARAMETER	SENSORIAL DEFINITION

PRIMARY CHARACTERISTICS – 5 Basic parameters (viscosity excluded) utilised in determining the manner in which a food handles and behaves in the mouth.

HARDNESS	Force required to compress food between molars. Defined as force necessary to attain a given deformation
ELASTICITY	Rate at which a deformed material returns to its undeformed condition after deforming force is removed
COHESIVENESS	The strength of the internal bonds making up the body of the product. (Greater the value the greater the cohesiveness).

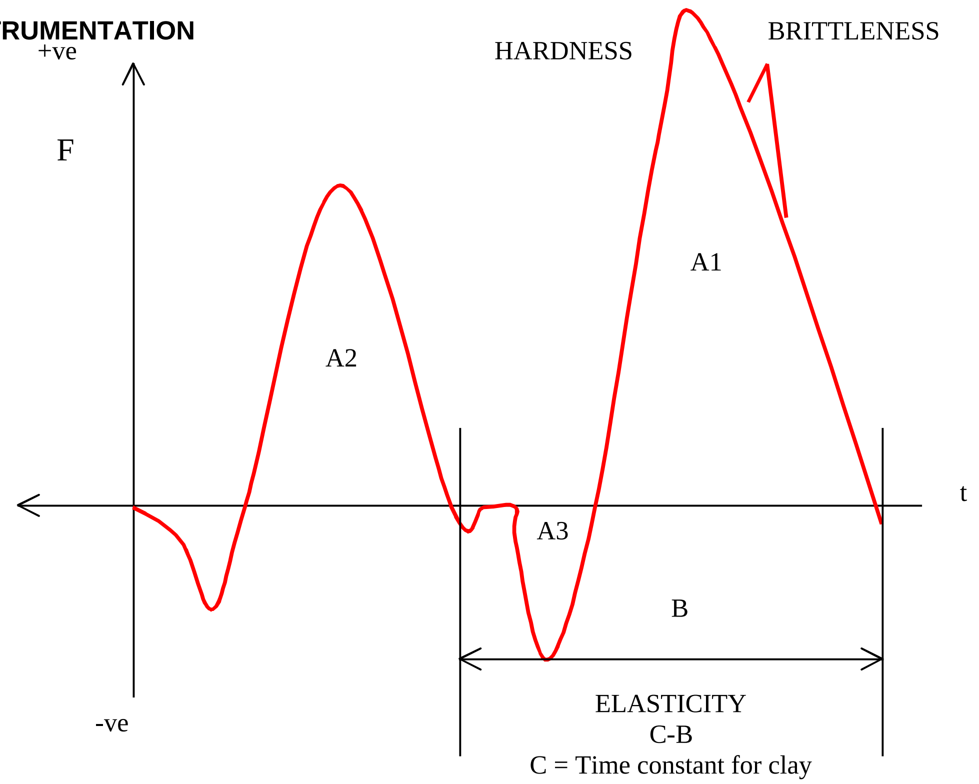
Related to the forces of attraction acting between particles of food and opposing disintegration

ADHESIVENESS	The work necessary to overcome the attractive forces between the surface of the food and the surface of other materials with which the food comes into contact (e.g. Tongue, Teeth, palate). Work required to pull food away from surface.

SECONDARY CHARACTERISTICS – 3 Additional parameters included to make characterisation as meaningful as possible to individuals accustomed to popular terminology, whilst retaining rheological principles.

BRITTLENESS	Force at which the material fractures. Related to the primary parameters of hardness and cohesiveness where brittle materials have low cohesiveness. Brittle foods are never adhesive.
CHEWINESS	Energy required to chew a SOLID food product to a state where it was ready for swallowing
GUMMINESS	Energy required to disintegrate a SEMISOLID food product to a state ready for

INSTRUMENTATION



Adapted from Rosenthal, 1999; Szczesniak *et al.* 1963; Szczesniak, 1963)

TABLE 4. Parameter Units of Instrumental TPA				
Mechanical Parameter	Measured Variable	Bourne (1978) Unit	Unit Name	Breene (1975) Unit
HARDNESS	Force	mlt^{-2}	Newton	kg
COHESIVENESS	Ratio	Dimensionless		
SPRINGINESS	Distance	l		mm
ADHESIVENESS	Work	$ml^{-2}t^{-2}$	Joule	
FRACTURABILITY	Force	mlt^{-2}	Newton	kg
GUMMINESS **(SEMI-SOLID)**	Force	mlt^{-2}	Newton	kg
CHEWINESS **(SOLID)**	Work	$ml^{-2}t^{-2}$	Joule	kg mm

Since their original development an expansion and indisputable improvements to the original terminology has been made. However care should be given to use of these expanded parameters, where the addition of new ones (e.g. Hardness 2 (Meullenet, *et al*, 1997)), have been made without demonstrating their usefulness (Szczesniak, 1998). It is therefore imperative that all additional parameters are considered with direct reference to food sample being evaluated, as was the case with the original classification (Szczesniak, *et al*, 1963; Brandt, *et al.* 1963) and thus retain a defined quantitative method of evaluation of the mechanical parameters of texture.

Expanded Parameters at CNS Farnell:

The development of the new QTS TexturePro™ software has incorporated a number of expanded textural parameters identified by previous authors. These measures have been shown to have a valid baring on the evaluation of commercial food products adopting the principles of fundamental, empirical and imitative techniques in order to facilitate the application of simple and reproducible tests. The use of such methods marks our continuos dedication to improving the practical benefits of food textural assessment, whilst understanding the limitations as well as functional benefits of instrumental mechanical texture evaluation.

References:

Bourne, M. (1978). Texture Profile Analysis. *Food Technology.* 32(7), 62-66, 72.

Bourne, M. (1982). Food Texture and Viscosity: Concept and Measurement. Academic Press INC, New York.

Bourne, M. (1975). Is Reheology Enough for Food Texture Measurement? *Journal of Texure Studies*, 6, 259-262.

Borwankar, R. (1992). Food Texture and Rheology. In *Rheology of Foods* (Ed. Borwankar, R. and Shoemaker, C.(1992). Elsevier Applied Science Publishers Ltd, Essex, 1-16.

Brandt, M., Skinner, E. and Coleman, J. (1963). Texture Profile Method. *Journal of Food Science,* 25, 404-409.

Breene, W. (1975). Application of Texture Profile Analysis to Instrumental Food Texture Evaluation. *Journal of Texture Studies,* 6 (53-82).

Fiszman, S., Pons, M. and Damasio, M. (1998). New Parameters For instrumental Texture Profile Analysis: Instantaneous and Retarded Recoverable Springiness. *Journal of Texture Studies,* 29, 499-508.

Giese, J. (1995). Measuring Physical Properties of Foods. *Food Technology,* Feb, pp 54-63.

Mancini, M., Moresi, M. and Rancini, R. (1999). Uniaxial Compression and Stress Relaxation Tests on Alginate Gels. *Journal of Texture Studies,* 30, 639-657.

Meullenet, J., Lyon, B., Carpenter, J. and Lyon, C. (1997). Bi-cyclical Instrument for Assessing Texture Profile Parameters and its Relationship to Sensory Evaluation of Texture. *Journal of Texture Studies*. 28 101-118.

Meullenet, J., Lyon, B., Carpenter, J. and Lyon, C. (1998) Relationship Between Sensory and Instrumental Texture Profile Attributes. *Journal of Sensory Studies*. 13, 77-93.

Peleg, M. (1976) Texture Profile Analysis Parameters Obtained by an Instron Universal Testing Machine. *Journal of Food Science*, 41, 721-722.

Peleg, M. (1979). Characterisation of the Stress Relaxation Curves of Solid Foods. *Journal of Food Science,* 44, 277-281.

Pons, M. and Fiszman, S. (1996). Instrumental Texture Profile Analysis with Particular Reference to Gelled Systems. *Journal of Texture Studies*. 27, 597-624.

Smewing, J. (1996). Determination of a Shear Modulus from Penetration Tests on Gelatin Gels. Mphil Thesis, University of Nottingham, 1996.

Szczesniak,A. (1963). Classification of Textural Characteristics. *Journal of Food Science,* 28, 981-985.

Szczesniak, A., Brandt, M. and Freidman, H. (1963). Development of Standard Rating Scales for Mechanical Parameters and Correlation Between the Objective and Sensory Texture Measurements. *Food Technology*. 22, 50-54.

Szczesniak, A. (1968). Correlations Between Objective and Sensory Texture Measurements. *Food Technology*, 22, 981-985.

Szczesniak, A. (1975). General Foods Texture Profile Revisited – Ten Years Perspective. *Journal of Texture Studies*, 6, 385-409.

Szczesniak, A. and Hall, B. (1975). Application of the General Foods Texturometer to Specific Food Products. *Journal of Texture Studies*. 6, 117-138.

Szczesniak, A., Humbaugh, P. and Block, H. (1970). Behaviour of Different Foods in a Standard Shear-Compression Cell and the Effect of Sample Weight on Peak Area and Maximum Force. *Journal of Texture Studies,* 1, 356-387.

Szczesniak, A. (1983). Physical Properties of Foods: What they are and their Relationship to Other Food Properties. In: *Physical Properties of Foods*. ed. M. Peleg and E. Bagley. pp. 1-42. AVI Publishing Co., Inc., Westport, Conn. (As quoted by Giese, 1995).

Szeczesniak, A. (1987). Review Paper: Correlating Sensory with Instrumental Texture Measurements – An Overview of Recent Developments. *Journal of Texture Studies*, 18, 1-15.

Szczesniak, A. (1998). Letter to the Editor: Issues pertaining to the Texture Profile Analyisis. *Journal of Texture Studies*, 29, vii-viii

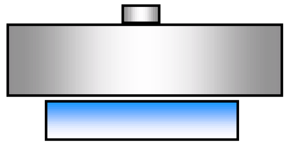
van Vilet, T. (1999). Rheological Classification of Foods and Instrumental Techniques for their Study. In: *Food Texture Measurement and Perception* (Ed. A. Rosenthal) Aspen Publishers, Inc. USA, 1-17.

SECTION 3: Probe Specifications

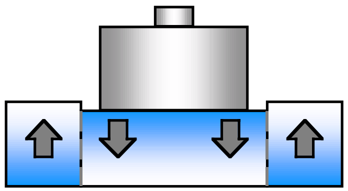
TECHNICAL NOTE

ACCESSORIES AND GENERAL APPLICATIONS

CYLINDER PROBES



Compression where sample contact area is smaller than that of probe.



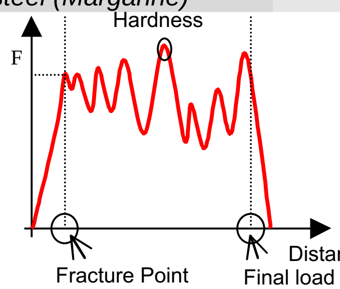
Penetration where sample contact area is greater than that of probe.

A group of flat ended probes of varying diameter between 2mm and 50mm. Cylinder probes are used to perform puncture and penetration tests in dairy, bakery, fruits and vegetable, meat and meat products, confectionery and many other applications where they are used to quantify product Hardness, Firmness, Yield Points and other profile information. Puncture tests impose both compression and shear forces and are commonly employed in the identification of properties such as:

- Visco-elastic creep
- Compliance (elasticity)
- Stress relaxation
- Rigidity
- Plasicity
- Viscosity

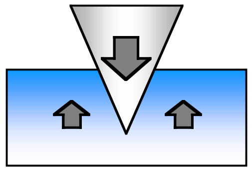
Probes are manufactured from stainless steel, perspex or delrin. Our comprehensive range includes:

PROBE	REF:
1mm ∅ stainless steel	TA 45
2mm ∅ stainless steel	TA 39
3mm ∅ stainless steel	TA 42
4mm ∅ stainless steel	TA 44
5mm ∅ stainless steel	TA 35
6mm ∅ stainless steel	TA 41
7mm∅ stainless steel	TA 36
10mm ∅ Kobe(1cm^2 std. for agar gels)	TA 19
_” (6.35mm) ∅ Delrin	TA 6
_” (12.7mm) ∅ Perspex (with radius BS 757)	TA 5
_” (12.7mm) ∅ Delrin (No radius AOAC Bloom)	TA 10
1” (25,4mm) ∅ Perspex (with radius BS 757)	TA 3
1” (25,4mm) ∅ Perspex (No radius AOAC)	TA 11
1_” (38.1mm) Perspex	TA 4
4.5mm ∅ stainless steel (Margarine)	TA 40



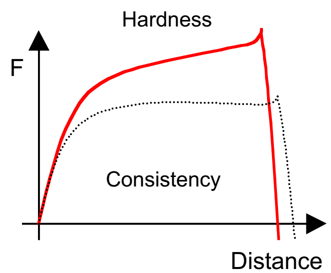
Cylinder Biscuit fracture profile using cylinder probe

CONICAL PROBES



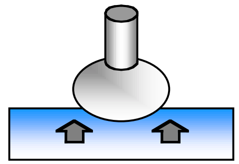
A range of seven conical probes with angles ranging between 15° to 90° is available for cone penetration tests on samples such as butter, margarine, soft cheese and other similar products. Results generated correlate well with sensory perceived spreadability and consistency.

PROBE	REF:
15° stainless steel	TA 29
20° Perspex	TA 27
30° Perspex	TA 17
40° Perspex	TA 16
45° Perspex	TA 15
60° Perspex	TA 2
90° Perspex	TA 32



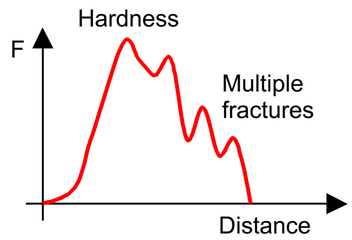
Conical Comparison of butter and

SPHERICAL PROBES



Spherical or ball probes are available with 1mm to 25.4mm ∅. The range incorporates a number of industrial standards such as the 1” ∅ nylon Avery adhesive test probe. They are utilised in the assessment of fracturability characteristic of crisp type products. Such probes are also used in the assessment of surface hardness characteristics through indentation of cheeses, fruits and packaging materials.

PROBE	REF:
1mm ∅ stainless steel	TA 31
2mm ∅ stainless steel	TA 28
3mm ∅ stainless steel	TA 33
10mm ∅ stainless steel	TA 38
_” ∅ stainless steel	TA 8
_” ∅ stainless steel	TA 18
1” ∅ Nylon (Avery test)	TA 43
1” Hemispherical Perspex	TA 49



Spherical Measurement of fracturability of tortilla type snack product

MISCELLANEOUS

NEEDLE PROBE:

The needle probe is used within puncture tests on foods such as fruit, vegetables and various confectionery products. These tests quantify parameters such as skin strength or bio yield in fruit or hardness within chocolate bars.
10° taper stainless steel TA 9

COMPRESSION PLATEN:

Used for compression tests of structured products such as bread or cheese where no containing vessel is utilised. Compression test denote that the sample surface area is smaller than that of the probe.
50.8mm (2”) ∅ Perspex TA25

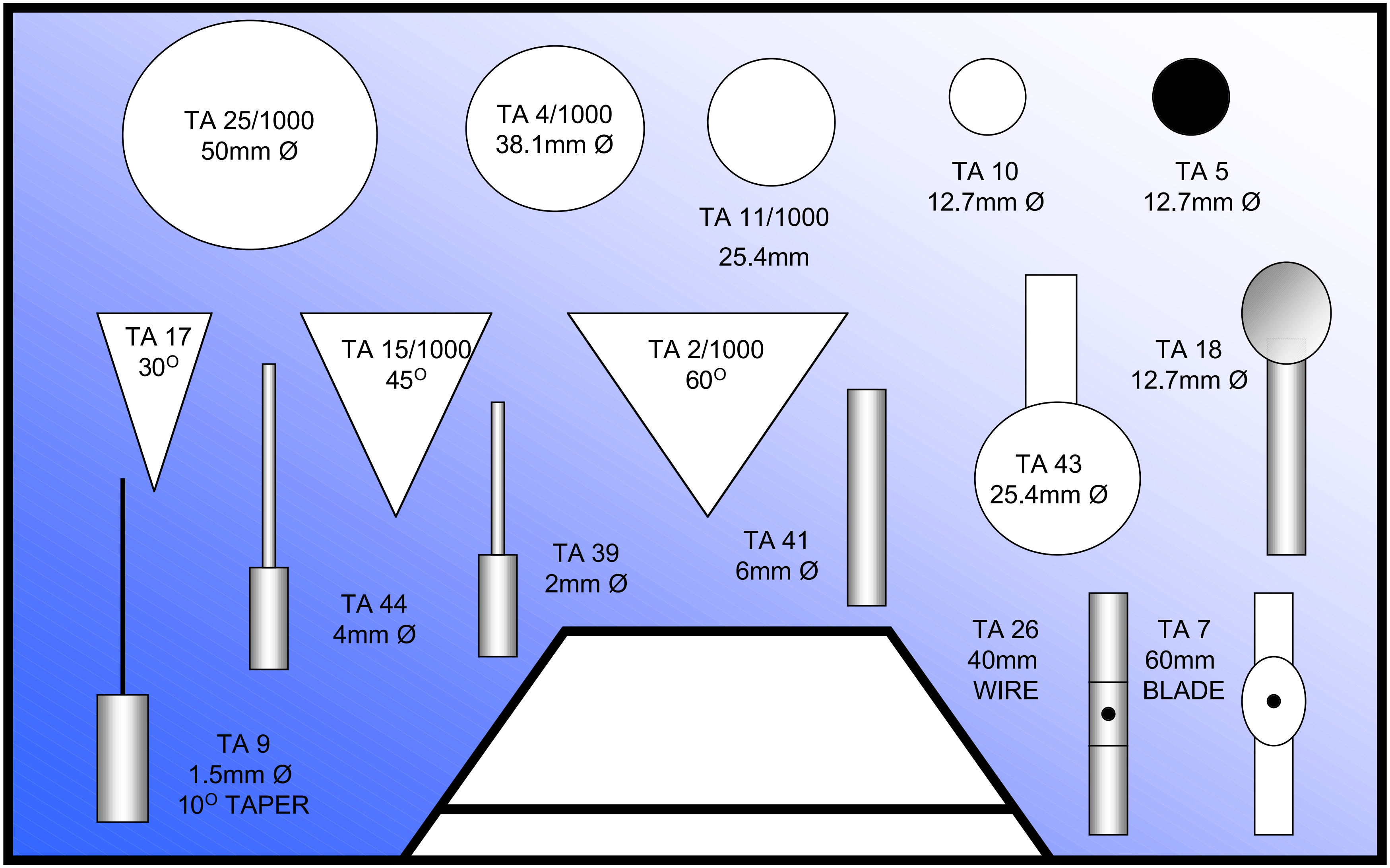
NARROW EDGE CUTTING:

Range of shear force probes that may be used to determine cut characteristics of foods such as cheese, butter, pastes and pâté.

PROBE	REF:
Perspex Knife Edge	TA 7
Bar (1.8mm ∅ 39mm wide)	TA 22
Cutting Wire (40mm	TA 26

TECHNICAL NOTE - GENERAL PROBE KIT

ACCESSORIES AND GENERAL APPLICATIONS



SPECIFICATION OF PROBES
within General Probe Kit

PROBE TYPE	DIMENSIONS	DESCRIPTION	USE
CYLINDERS			
TA11	25.4 MM DIA 35MM LONG	CLEAR PLASTIC.	AOAC BLOOM TEST ON GELATIN, YOGURTS AND DAIRY
TA4	38.1MM DIA 20MM LONG. RAD .35- .43MM	CLEAR PLASTIC.BS757	GENERAL USE, YOGURTS, SAUCES, WHIPPED CREAM, MOUSSE, DESSERTS.
TA25	50MM DIA . 20MM LONG. RAD .35 - .43MM. BS757.	CLEAR PLASTIC	LARGE COMPRESSION PLATEN. USED IN TPA TYPE ASSESSMENT, STRESS RELAXATION etc.
TA5	12.7MM DIA 35MM LONG. RAD .35 - .43MM. BS757.	BLACK ACETATE.	GENERAL USE, FRUIT PRESERVES, JAMS. BS757 BLOOM TEST
TA10	12.7MM DIA AOAC 35MM LONG.	CLEAR PLASTIC.	GENERAL USE, FRUIT PRESERVES, JAMS. AOAC BLOOM TEST
TA39	2MM DIA 20MM LONG. FLAT END	STAINLESS STEEL.	GENERAL USE, STANDARD MARGARINE TEST
TA44	4MM DIA 35MM LONG. FLAT END.	STAINLESS STEEL	GENERAL USE, LIPSTICK PENETRATION etc.
TA41	6MM DIAM . 35MM LONG.	STAINLESS STEEL	GENERAL USE. PENETRATION TESTS
CONICAL			
TA17	30º. 25MM DIAMETER	CLEAR PLASTIC	GENERAL USE MARGARINE, BUTTER, MEAT PASTES, ICE-CREAM, SOFT CHEESE
TA15	45º . 30MM DIAMETER.	CLEAR PLASTIC	GENERAL USE MARGARINE, BUTTER, MEAT PASTES, ICE-CREAM, SOFT CHEESE
TA2	60º. 30MM DIAMETER.	CLEAR PLASTIC	GENERAL USE, MARGARINE, SPREADS (PRODUCT FLOW)
SPHERICAL			
TA18	12.7MM DIA	STAINLESS STEEL.	GENERAL USE, CRISP FRACTURE, SAMPLE HARDNESS
TA43	25.4MM DIA	NYLON.	GENERAL USE, AVERY ADHESIVE STANDARD
GENERAL			
TA7	KNIFE EDGE 60MM WIDE.	CLEAR PLASTIC	GENERAL USE, THREE POINT BEND, SNAP TESTS, CUTTING
TA9	NEEDLE PROBE . 1.5MM DIAM. 46MM LONG. 10º MAXIMUM TAPER.	STAINLESS STEEL	BITUMEN, TOFFEE, CHOCOLATE HARDNESS, CONFECTIONARY, FRUIT/VEG PUNCTURE, PHARMACEUTICAL TEST.
TA26	40MM WIDE CUTTING WIRE	ALUMINIUM FRAME	GENERAL CUTTING TESTS, CHEESE, BUTTER, PASTES.

ALL PROBES ARE PRECISION MANUFACTURED TO TOLERANCES OF 0.1% OR BETTER

SECTION 4: Glossary of Common Terminology

<table>
<tr><th>TERM</th><th>DEFINITION</th><th>VISUAL INTERPRETATION</th></tr>
<tr><td>YIELD POINT</td><td>Minimum stress at which the sample initiates flow e.g. Bingham Plastic where the fluid behave as a Newtonian Fluid once minimum stress is reached. At stresses below this minimum level the sample behaves as an elastic solid (Fig. 1.1).

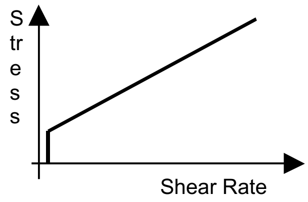
Few materials behave in the simple manner of Bingham plastics, and flow above the Yield point is non-Newtonian. It thus very difficult to determine the exact point of yield, where most consider that these materials are fluid at all stresses and that the deformation is too small to have been observed in the time available. Fig. 1.2. illustrates that when flow above the yield point is far from Newtonian it is very difficult to identify the point at which flow commences.</td><td>


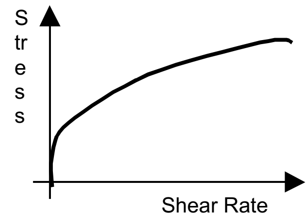
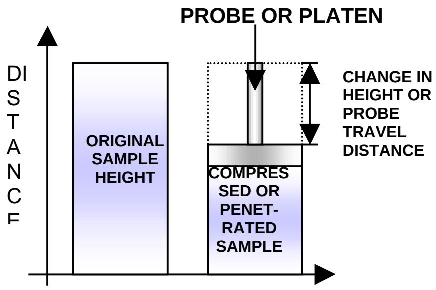
Fig. 1.1. Bingham Plastic


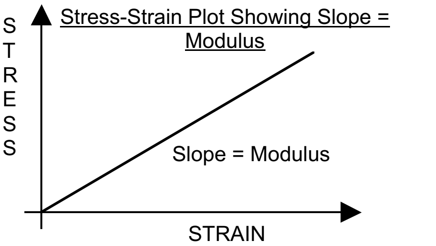
Fig. 1.2. Herschel and Bulkey Body

One practical definition would be:
Yield stress is the stress below which no observable deformation occurs within the time available for making the observation (Prentice, 1995)</td></tr>
<tr><td>FRICTION</td><td>Resistances between two surfaces when parallel plates are moved.</td><td></td></tr>
<tr><td>DEFOR-MATION</td><td>The change in height of a sample when a force is applied.

This is simply the height of the original sample minus the distance travelled by the probe.

3 types of deformation:
1. Compressive
2. Tension
3. Shearing</td><td>


DEFORMATION = ORIGINAL SAMPLE HEIGHT - DISTANCE TRAVELLED BY PROBE</td></tr>
<tr><td>VISCOUS</td><td colspan="2">Material which follows ideal liquid or viscous behaviour
Viscous materials start to flow at a certain rate when a stress is applied, retaining the shape attained at the moment the force was removed</td></tr>
<tr><td>ELASTIC</td><td colspan="2">Material which follows ideal solid or elastic behaviour
Elastic materials deform instantaneously to a certain extent when stress is applied and regain their original shape once the stress is removed</td></tr>
<tr><td>VISCO-ELASTIC</td><td colspan="2">Material which cannot be classified as either viscous or elastic as possesses the properties of both</td></tr>
</table>

An Analogy of Sample Viscosity: Layers persist within liquids as in a deck of cards, the first layers is the fastest moving with each proceeding layer moving at a slower rate creating "*drag*". It is this "*drag*" between the parallel plates which is responsible for sample viscosity.		
STRESS	The intensity of force components acting on a material expressed in units of force per unit area.	
STRAIN	The change in unit size or shape of a body in response to an applied force.	
SHEAR RATE	Velocity gradient within a fluid generated as a result of an applied stress. This parameter is expressed in units of reciprocal seconds (sec $^{-1}$).	

Is there anything else you think should be added? Email us at info@TextureAnalysis.com and we'll gladly include your suggestions.

SECTION 5: Quick Reference Glossary of Texture Terminology

QUICK REFERENCE GLOSSARY OF TEXTURE TERMINOLOGY.

PARAMETER	SENSORIAL DEFINITION	INSTRUMENTAL DEFINITION	UNITS
PARAMETERS AS DENOTED WITHIN ORIGINAL SZCZESNIAK *et al* (1963) AND BOURNE (1978) TPA WORK			
PRIMARY	5 basic parameters utilised in determining the manner in which a food handles and behaves in the mouth.		
HARDNESS	Force required to compress a food between the molars. Defined as force necessary to attain given deformation.	Peak force of the first compression cycle. *Max force may occur when sample breaks, or it may occur later in the cycle as the sample is flattened and deformed to a high given deformation.*	Newtons (N)
SPRINGINESS	Rate at which a deformed material goes back to its undeformed condition after the deforming force is removed	Height that the food recovers during the time that elapses between the end of the first bite and the start of the second bite.	Meters (m)
ADHESIVENESS	The work necessary to overcome the attractive forces between the surface of the food and the surface of other materials with which the food comes into contact (e.g. tongue, teeth, palate). Work required to pull food away from a surface.	The negative area for the first bite, representing the work necessary to pull the compressing plunger away from the sample. *Positioning of probe must ensure break is formed on retraction.*	Joules (J)
COHESIVENESS	The strength of internal bonds making up the body of the product (greater the value the greater the cohesiveness)	The ratio of positive force during the second to that of the first compression cycle (downward strokes only)	Ratio Dimensionless
VISCOSITY	Force required to draw a liquid from a spoon over the tongue	Rate of flow per unit force	
SECONDARY	3 additional parameters included to make characterisation as meaningful as possible to individuals accustomed to popular terminology, whilst retaining rheological principles.		
FRACTURABILITY (BRITTLENESS)	Force at which a material fractures. Related to the primary parameters of hardness and cohesiveness, where brittle materials have low cohesiveness. Not all foods fracture and thus value may relate to hardness if only single peak is present. **Brittle foods are never adhesive.**	The first significant break in the first compression cycle. Taken as first peak force prior to force dropping by at least 5%.	Newtons (N)
GUMMINESS	Energy required to disintegrate a **SEMI-SOLID** food product to a state ready for swallowing. Related to foods with low hardness levels.	Calculated parameter: Product of Hardness x Cohesiveness **Semi-solid products undergo permanent deformation and have no springiness.**	Newtons (N)
CHEWINESS	Energy required to chew a **SOLID** food product to a state where it is ready for swallowing. Attribute is difficult to quantify precisely due to complexities of mastication e.g. saliva at body temp. with a variety of force actions (shear, compression, grinding, tearing and penetration).	Calculated Parameter: Product of Gumminess x Springiness (essentially primary parameters of Hardness x Cohesiveness x Springiness)	Joules (J)

EXPANDED TPA PARAMETERS (VARIOUS AUTHORS)			
PARAMETER	**SENSORIAL DEFINITION**	**INSTRUMENTAL DEFINITION**	**UNITS**
ADHESIVE FORCE (Fiszman and Damasio, 2000)	Force required to pull probe from sample	Maximum negative force generated during upstroke of probe.	Newtons (N)
SPRINGINESS INDEX	Ratio of height that the sample springs back after the first compression to the maximum deformation selected.	Springiness value divided by deformation. Enables the comparison of samples of different lengths. Interpreted as a recovery property such as relaxation, where: *Values of 1* ➔ Complete recovery e.g. elastic material. *Values of 0* ➔ No recovery of e.g. viscous material.	Ratio Dimensionless
CHEWINESS INDEX (Evolved from DRAKE, 1966)	Gumminess and chewiness are mutually exclusive therefore must not confuse.	Gumminess multiplied by springiness index. Will be zero when cohesiveness is zero.	Newtons (N)
AREA (CYCLE 1 and 2) (BOURNE, 1968, 1974; MASSEY, 1968; BREENE, *et al*, 1973)	Internal strength of bonds within a product. **ENCOMPASSES TOTAL POSITIVE AREAS**	The work done (energy) during a specified part of the test e.g. total positive area of either cycle 1 or 2.	Joules (J)
HARDNESS 1 WORK DONE HARDNESS 2 WORK DONE	Internal strength of bonds within a product, related to parameter of consistency. Gives good sample differentiation in relation to sample firmness at high strains when probe:sample contact area is small.	Calculates work done (energy) required to obtain given deformation to target value e.g. distance or force. Representative of work invested by instrument in deforming sample e.g. opposite to Recoverable Work Done.	Joules (J)
RESILIANCE (PELEG, 1976)	Measurement of how a sample recovers from deformation in relation to speed and forces derived *Not included within TexturePro but can be calculated*	Ratio of Recoverable Work Done 1 to Hardness Work Done 1. Representing ratio of recoverable and non-recoverable work necessary for deformation of sample.	Ratio Dimensionless
STRINGINESS LENGTH	The distance a sample is extended during compression before separation from compression probe.	Distance to peak negative force from point where load crosses 0 value in decompression cycle. *Provided break between probe and sample is formed*	Meters (m)
STRINGINESS WORK DONE	Amount of work exhibited by a sample as it clings to contact probe during decompression	Negative area between 0 value in decompression cycle and peak negative force.	Joules (J)

PARAMETER	SENSORIAL DEFINITION	INSTRUMENTAL DEFINITION	UNITS
MODULUS OF DEFORMABILITY Calzada and Peleg (1978); Sanderson, *et al*, (1988); Tang, *et al*, (1995).	Acts as an indication of rigidity or stiffness of the material at selected points within stress-strain curve. Traditionally low deformations (less than 10%) are utilised. $E_c = \sigma_c/\varepsilon_c = \sigma T/\varepsilon T$ = *Modulus of Elasticity from Compression*	Ratio of the stress divided by strain during initial part of first compression. Gradient of curve between 20 and 80% (or percentages selected in *Control Window*) prior to sample fracture. If no fracture is shown gradient will be recorded to hardness value. Derived from True Stress-Strain data. (variant of **Young's Modulus**) True Strain = $\varepsilon T = -\ln(ho/ho-\Delta h/ho)$ True Stress = $\sigma T = F_t/A_0{*}ho-\Delta h/ho$ (ho = original height; Δh change in height during compression (Pons, *et al*, 1996).	Pascals (Pa)
CORRECTED COHESIVENESS (PELEG, 1976)	Network invested in the non-recoverable deformations of the first and second bites.	Positive area of first compression cycle e.g. where the probe acts upon the sample minus the positive area of the decompression cycle where the sample acts upon the probe. Calculation is repeated for second cycle to give corrected values for both A_1 and A_2 after which revised A_2 is divided by A_1.	Ratio Dimensionless
CORRECTED PARAMETERS	Corrected parameters of chewiness and gumminess may be calculated utilising revised cohesiveness values based upon network invested in compression.		
HARDNESS CYCLE 2	Force necessary to attain given deformation on second chew. Not fully defined in relation to sensorial and instrumental correlation.	Peak force of the second compression cycle, post first decompression. *The specimen which is subjected to the second bite is the same specimen at the end of the first bite, its length is the sum of the residual length after the predetermined deformation and the recovered deformation after the first bite.*	Newtons (N)

EXPANSION OF FRACTURABILITY PARAMETERS → ONLY APPLICABLE IF FOOD EXHIBITS FRACTURE CHARACTERISTIC. PARAMETERS GIVE DIRCT INDICATION OF BIOYIELD VALUES IN FRUITS AND VEGETABLES, AND CRISPINESS AND CRUNCHINESS ATTRIBUTES OF HIGH FRACTURE FOODS e.g. BISCUITS, HONEYCOMBE etc.			
PARAMETER	**SENSORIAL DEFINITION**	**INSTRUMENTAL DEFINITION**	**UNITS**
QUANTITY OF FRACTURES	Related to *fracturability* parameter, giving good indication of sample cripiness and crunchiness.	Number of occasions that the load drops off by 5% prior to reaching target value within *cycle 1*.	Dimensionless
1^{ST} FRACTURE LOAD DROP OFF	Decrease in load resultant of initial fracture e.g. force required to puncture skin of fruit etc.	The amount load decreases at the first fracture point e.g. related to 5% force decrease criteria.	Newtons (N)
1^{ST} FRACTURE DEFORMATION (D_{rup} Munoz, *et al*, 1986)	Strain or distance required to impose initial fracture of sample.	Amount of deformation (probe distance travelled) to reach first fracture force	Meters (m)
1^{ST} FRACTURE % DEFORMATION	% Strain or distance required to impose initial fracture of sample relation to original sample height.	1^{st} Fracture Deformation divided by original sample height, multiplied by 100. Must enter original sample dimensions.	% value
1^{ST} FRACTURE WORK DONE (A_{rup} Munoz, *et al*, 1986)	Related to the amount of work required to achieve fracture of sample.	Positive area generated between start of compression and first fracture.	Joules (J)

FUNDAMENTAL AND ASSOCIATED MEASURES				
PARAMETER	**SENSORIAL DEFINITION**	**INSTRUMENTAL DEFINITION**		**UNITS**
YOUNG'S MODULUS (**Unaxial Compression**)	Measure of rigidity or stiffness of a material based on the ration of stress, below proportional limit, to corresponding strain	STRESS / STRAIN	F/A / ΔA/L F = Applied force; A = Cross-section area; ΔL = change in legth caused by application of force; L = Unstressed length	Pascals (Pa)
STRESS RELAXATION (PELEG, 1979)	Samples are deformed through the application of stress to a pre-determined deformation very quickly and the ensuing stress is measured as a function of time at a constant deformation. Viscoelastic materials exhibit stress decay as time increases where resistance of sample to probe gradually decreases.			Seconds (s)
CREEP	A constant force (stress) is applied to the sample at t=0 and the deformation is measured as a function of time. The system exhibits an instantaneous increase in deformation (strain) as stress is applied. On removal of force ideal elastic materials instantaneously gain full recovery of their original dimensions. Viscoelastic materials exhibit elastic response as well as steady-state flow and gradually recover former shape and size over time, thus the greater the elastic component the quicker the recovery.			
HENCKY TRUE STRESS	True Stress = $\sigma T = F_t/A_0 * ho-\Delta h/ho = F/\prod r^2 = F(ho-\Delta h)/\prod ro^2 ho = \sigma_c$ (ho = original height; Δh change in height during compression, A_0 = Original contact area; F_t = Force at Time; r = Radius at compression; ro = Original radius; c = Compression)			Pascals (Pa)
HENCKY TRUE STRAIN	True Strain = $\varepsilon T = -\ln(ho/ho-\Delta h/ho) = \varepsilon_c$ (ho = original height; Δh change in height during compression)			Ratio Dimensionless
SHEAR MODULUS (**Shear Deformation**)	Also known as the rigidity modulus, it is the ratio of shear stress to the relative sideways displacement of parallel surfaces (shear strain).	STRESS / STRAIN	F/A / ϒ/L F = Force applied; A = Cross-section area; ϒ = Displaced shear modulus; L = Unstressed length	Pascals (Pa)

DEFORMATION RELATED MEASURES			
PARAMETER	**SENSORIAL DEFINITION**	**INSTRUMENTAL DEFINITION**	**UNITS**
% DEFORMATION	Change in sample dimensions as a result of application of compressing or extension forces. Related to *STRAIN* applied to sample	Distance travelled in compressing the sample during cycle 1, divided by original sample length multiplied by 100. *Must enter original sample height into test set-up prior to commencing compression.*	% value
DEFORMATION	Change in height of sample when force is applied.	Original height of sample minus distance travelled by probe from trigger. Expressed as % *strain* in relation to original height e.g. distance travelled as 5 original height.	Meters (m)
RECOVERABLE DEFORMATION 1	Height recovered by sample on removal of compressing force.	Return distance travelled by probe during decompression cycle from hardness to zero. MUST MAKE SURE HARDNESS IS ACTULLY AT THE POINT OF PROBE REVERSAL	Meters (m)
RECOVERABLE DEFORMATION 2			
RECOVERABLE WORK DONE 1	Representative of *recoverable* work invested in deformation where sample is acting on probe e.g. work performed by the sample to the instrument during decompression.	Positive area of return stage of compression cycle related to sample springiness. Recoverable Deformations and Work Done from each cycle will be equal if sample is ideal elastic. Visco- elastic properties of foods dictates that 2nd value might be slightly greater and dependant upon time elapsed between bites.	Joules (J)
RECOVERABLE WORK DONE 2			

<table>
<tr><th colspan="4"><u>ADDITIONAL MEASURES CALCULATED THROUGH USER DEFINED OPTION</u></th></tr>
<tr><th>PARAMETER</th><th>SENSORIAL DEFINITION</th><th>INSTRUMENTAL DEFINITION</th><th>UNITS</th></tr>
<tr><td>INSTANTANEOUS SPRINGINESS</td><td>S_{ins} acts as an index of ideal elastic materials where values near or equal to 1 indicate the presence of a high elastic component and almost “instantaneous recovery” of their initial height.</td><td>Defined from first compression cycle as:

Ratio of distance (or time) recorded during decompression of a sample to that recorded during its initial compression.</td><td>Ratio Dimensionless</td></tr>
<tr><td>RETARDED SPRINGINESS</td><td>S_{ret} reflects the characteristics due to viscous behaviour of the sample. In true elastic materials S_{ret} will be equal to S_{ins}.

The value of S_{ret} will always be greater than that of S_{ins} for a specific percentage of a given system as S_{ret} includes S_{ins} plus recovery. Where greater S_{ret} to S_{ins} values persist viscous elements are thought to predominate.</td><td>Defined from both compression cycles as:

Ratio of distance (or time) recorded during the second compression cycle to that of the first. It is therefore indicative of the height recovered during the time elapsed between the two cycles.</td><td>Ratio Dimensionless</td></tr>
<tr><td>SLOPE INITIAL
(Meullenet, et al, 1999)</td><td rowspan="2">Slope gradients give a direct indication of internal bond strength, and thus can be related to cohesiveness characteristics. Slope values represent initial resistance to strains applied at low deformation and as a predictor of internal bonding at higher deformations.

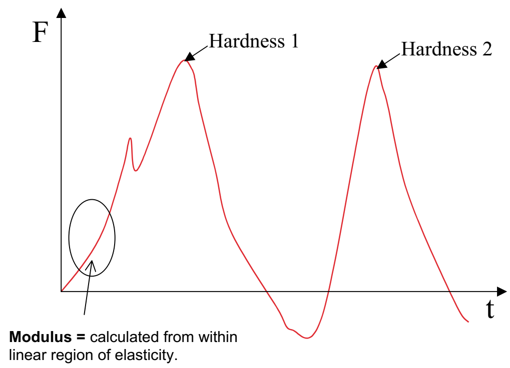
Problem with Slope Max at high deformations where base effects arise through probe compression against texture analyser bed.

Slope max also represents sample hardness where it acts as a projection of what max load would be if strain was continued to be applied.</td><td>$S_{initial}$ = Slope calculated at the beginning of first compression cycle (The first 25 (0.5mm displacement) data points acquired)

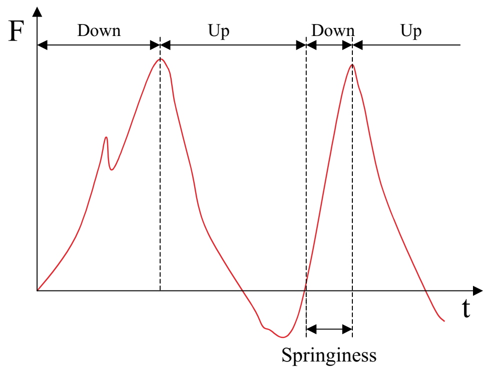
High slope initial values indicate greater resistance to small strains, with increased likelihood of breaking when higher strains are applied.</td><td>Rate of change</td></tr>
<tr><td>SLOPE MAX
(Meullenet, et al, 1999)</td><td>S_{max} = Max slope calculated from first compression cycle (Selection of data points made through visual assessment: Samples exhibiting yield prior to max load 2mm displacement utilised and 100 points collected; Samples exhibiting no yield utilised 100 points prior to max force).

High slope max values indicate to greater resistance to high strains and therefore do not readily break apart e.g. greater cohesiveness</td><td>Rate of change</td></tr>
</table>

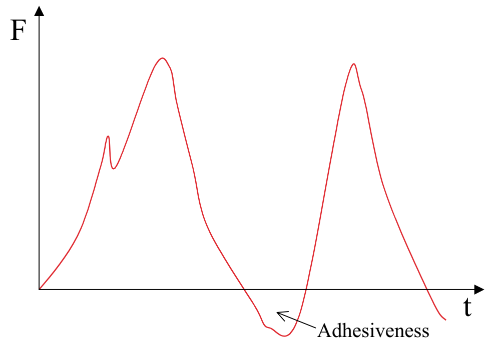
SECTION 6: Illustrated Parameters



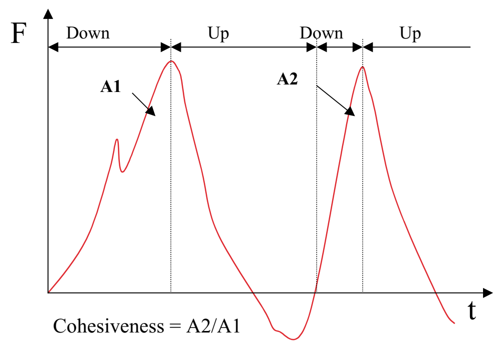
HARDNESS PARAMETERS



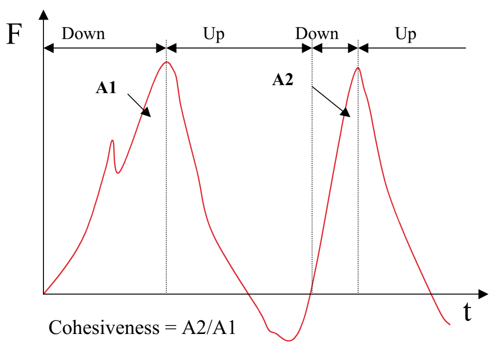
TRADITIONAL BOURNE (1978) SPRINGINESS



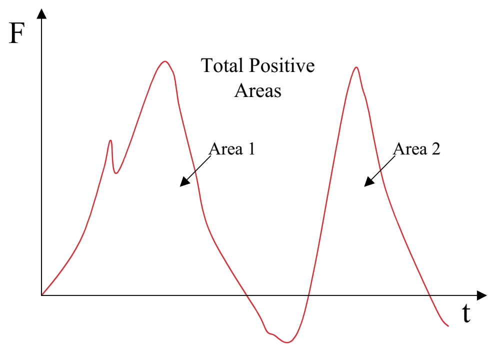
TRADITIONAL BOURNE (1978) ADHESIVENESS
(TOTAL NEGATIVE AREA)



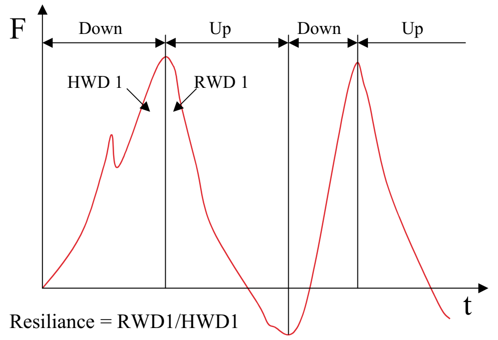
TRADITIONAL BOURNE (1978) COHESIVENESS



ADHESIVE FORCE e.g. Peak Negative Value
Indicative of Surface Tackiness



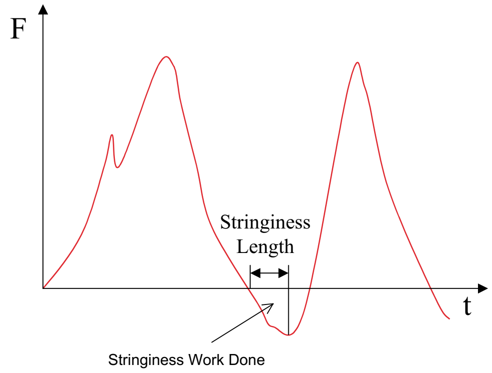
POSITIVE AREAS REPRESENTATIVE OF WORK
REQUIRED TO ATTAIN DEFORMATION



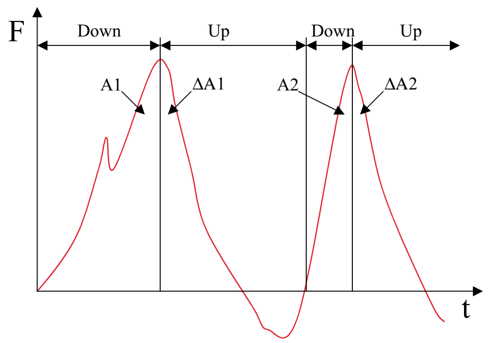
Resiliance = RWD1/HWD1

RESILIANCE

Not included with Version 1 of Texture Pro, however easily within User Defined Functions Option



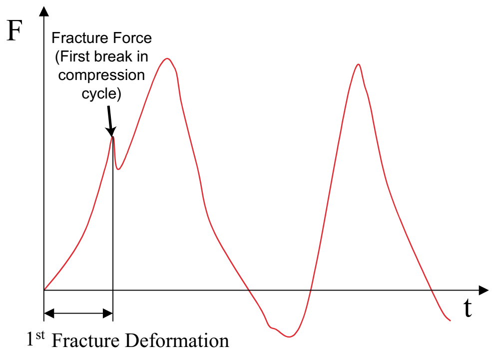
STRINGINESS PARAMETERS



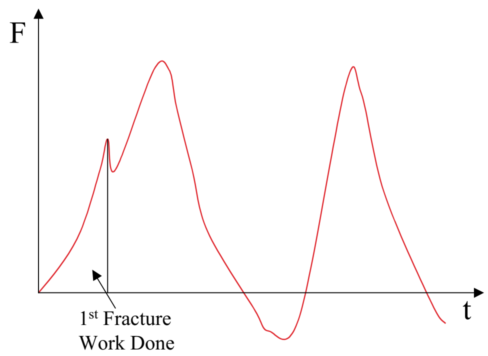
Corrected Cohesiveness = (A2-ΔA2)/(A1-ΔA1)

PELEG (1976) CORRECTED COHESIVENESS

Network Invested by Apparatus

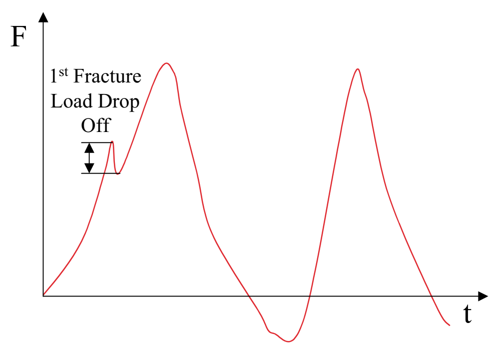


FRACTURE CHARACTERISTICS



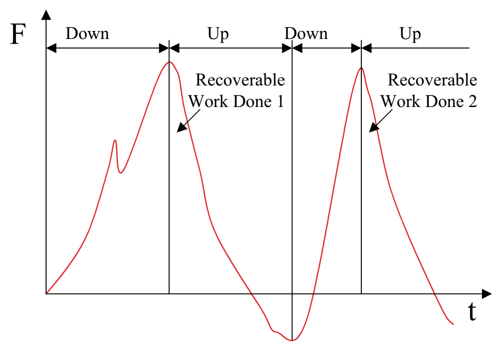
FRACTURE CHARACTERISTICS

(Fracture Work Done, e.g. Work Necessary to Rupture Specimen)

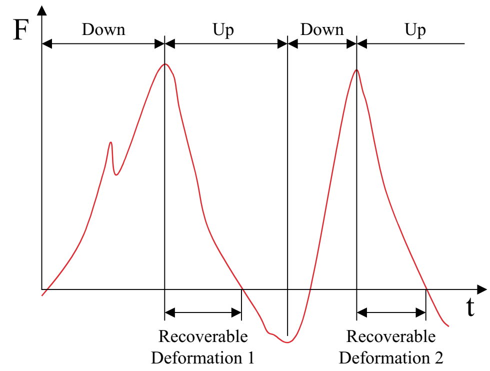


FRACTURE CHARACTERISTICS

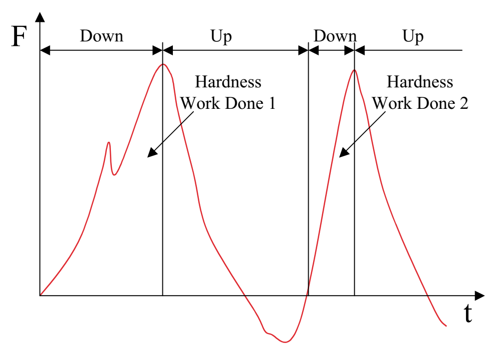
(FRACTURE LOAD DROP OFF)



PELEG (1976) RECOVERABLE WORK PARAMETERS

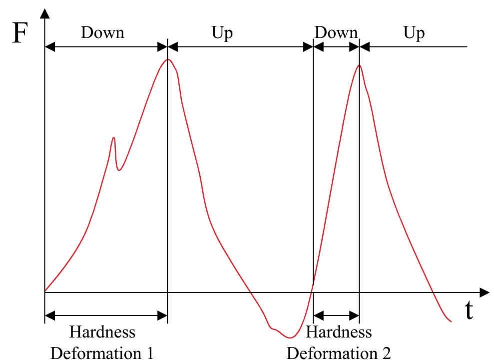


PELEG (1976) RECOVERABLE WORK PARAMETERS



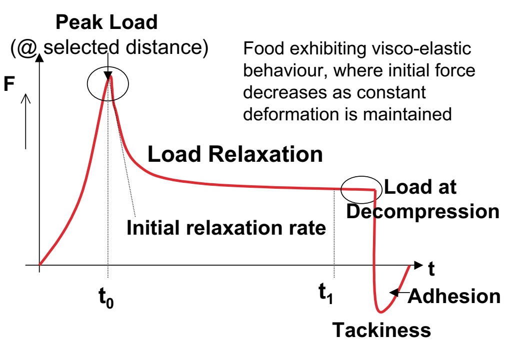
WORK INVESTED PARAMETERS

(Work Invested by Machine During Compression Cycle)



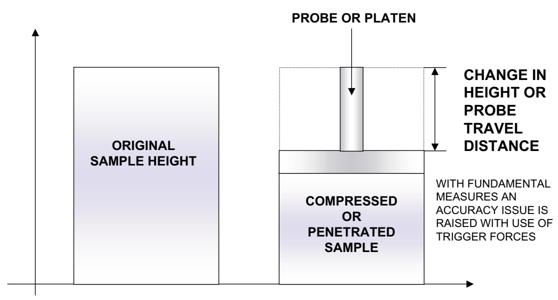
WORK INVESTED PARAMETERS

(Work Invested by Machine During Compression Cycle)

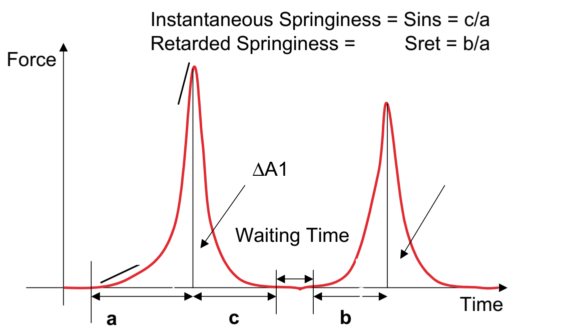


The load after 1 minute (t_1 - t_0) is expressed as a percentage of peak load, where it provides an indication of system elasticity

STRESS RELAXATION CHARACTERISTICS



DEFORMATION = ORIGINAL SAMPLE HEIGHT - DISTANCE TRAVELLED BY PROBE



(Pons *et al,* 1996; 1998)

ADDITIONAL PARAMETERS CALCULATED
THROUGH USER DEFINED OPTION