emtec TSA Tissue Softness Analyzer

A test device that objectively measures the softness and other haptic parameters of a tissue product.

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Agenda

Introduction

In the past there have been many trials to develop devices for the determination of the softness of tissue, but none of them delivered satisfying results. 2004 a completely new measuring method was invented by Dipl.-Phys. Giselher Gruener, which simulates the human feeling to a great extent during the testing of a tissue sample by hand. During the following years and based on this invention a measuring device was developed by Emtec Electronic Leipzig. The results of this measuring device deliver a great correlation to the subjective testing results of a human panel and also all advantages of an objective measuring method, like

- » high accuracy and a very good correlation to the subjective feeling
- » high reproducibility
- » excellent stability
- » very easy handling.

Additionally, the device provides individual results for each of the three basic parameters of the human feeling (softness, smoothness and stiffness). Humans only feel a combination of these three, which is the so-called hand feel. This opens a huge amount of possibilities for process optimization, complaint management, product development as well as QA. Over the years, the device has become industrial standard in the tissue paper industry.

Terminology

Before getting deeper into the topic, it is important to clarify what we understand under the different terms that we use in this booklet. A good example that shows, why this is necessary is that a product of a good haptic quality is often called "soft", but the softness of a tissue product is only one of the three basic haptic parameters, which determine the overall haptic quality.

1. Softness

   Micro-surface variations, e.g. the stiffness or flexibility of fibers sticking out of the material (free fiber ends)

   Can be influenced for example by the pulp mix (long and short fiber ratio), refining, use of softener, calendaring, application of lotion and others.

2. Smoothness/roughness

   Macro-surface variations, e.g. creping or embossing as well as everything else that influences the surface structure of the material

   Can be influenced mainly by the creping blade and embossing.

3. Stiffness

   In-plane stiffness, how can the material be deformed in z direction under a defined load. The results of the TSA stiffness measurement correlate very well with the TEA Tensile Energy Absorption, but not with the bending stiffness.

   Can be influenced by the pulp mix (long and short fiber ratio, production technology and chemical additives)

4. Hand Feel (HF) value

   The hand feel value is what humans feel while touching any kind of surface. It is the combination of the three parameters explained above as well as others.

The TSA is able to measure the three basic haptic parameters softness, smoothness and stiffness individually. From these three parameters and others, such as thickness of the material, number of plies, base weight, and the environmental conditions temperature and rel. humidity, a hand feel value can be calculated, which can correlate up to almost 100%, if the right algorithm is used.

The softness of tissue

To determine whether a tissue product is functional, reliable information about the overall hand feel value, which is a combination of the three single parameters, of the respective material needs to be available. The consumer can directly sense this parameter so that it influences the purchasing behavior decisively. However, the commonly used term "softness" is not correct. The words “hand feel” or “grip” or “haptics” should be used as the softness is only one of several factors that influence the individual evaluation of tissue. There is no clear physical definition and a measuring unit for the “hand feel”.

The human brain combines several sensations to a “hand feeling” in a very individual way: On the one hand the unconscious detection of vibrations, which mainly depend on the fiber softness (stiffness of the free fiber ends) and surface/bulk structure, perceived by the sensors in the fingers when they slide over the sample applying a specific pressure and velocity. On the other hand, the subjective sensation of the stiffness and shear resistance of the material when it is crumpled. Therefore, the result does not only depend very much on the individual tester but also on the test method (number of sheets tested at one time, Z-fold or U-fold and by that only top side or top side and back side together, stroking or crumpling). The individual perception of the hand feel is therefore mainly determined by the following characteristics: the actual fiber softness/fiber stiffness (which is determined by the fiber material itself, but also by added chemicals like softeners, wet strength agents or lotion); the surface and internal structure, which depend on the manufacturing technology and on the "creping" and "embossing", if applicable; and the stiffness, which is mainly determined by the fiber material, the manufacturing technology and the used chemicals. Furthermore, the thickness, the grammage and the number of plies come into play. This makes clear that it is, similar to the evaluation of the taste of wine or whiskey, a very complex and extremely subjective and therefore unreliable parameter. This parameter is further influenced unconsciously by the color, the smell, printed patterns, the tester's current mood and motivation, even the weather and the season as well as personal preferences. Some people prefer for example a smooth and "cool" (higher thermal conductivity) surface which they perceive as "softer" and others prefer a velvet, voluminous and "warmer" (lower thermal conductivity) surface like the one of TAD. These preferences also depend on the market and the user behavior (North America, Asia, Europe differ very much).

All the mentioned reasons make clear that there is not one good/soft tissue, but that a certain quality is preferred or rejected depending on the individual preference (see ref. 3).

The human feeling

How do humans feel

Four different cells, which are located in the skin of the finger tips (but also at all parts of the human body), are mainly responsible for the human feeling.

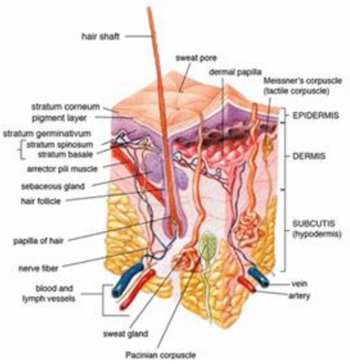
These four cells are the:

- Lamellar / Pacinian corpuscles*
- Tactile / Meissner corpuscles*
- Tactile / Merkel cells*
- Ruffini bodies

* The papillary lines on the finger tips – in combination with the sample surface – generate different vibrations, which come from the different characteristics of the material: real

softness, smoothness / roughness, stiffness. The four different sensors detect the different vibration frequencies.

In the following, these four cells are explained in depth:

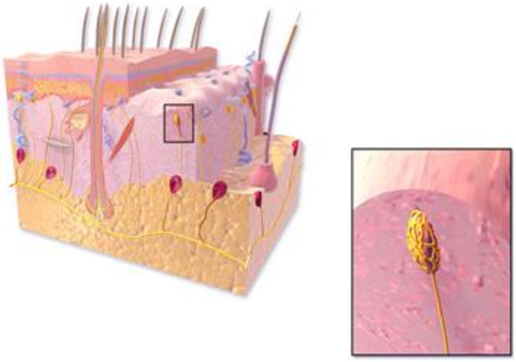


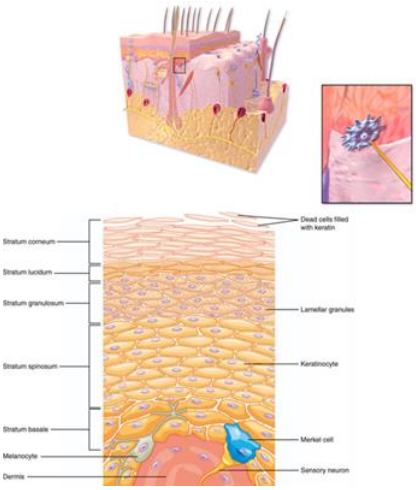
Lamellar or Pacinian corpuscles

The Lamellar corpuscles are located in the lower skin and belong to the fast adapting receptors. They have their highest sensitivity at around 300Hz. The lamellar corpuscles measure the softness or better micro-surface variations of the material

Tactile or Meissner corpuscles

The tactile corpuscles are receptors of the glabrous skin and are concentrated in the finger tips. These cells react to pressure changes between 10 and 50Hz. The Meissner bodies are responsible for the feeling of roughness/macro-surface variations. Blind people depend on the Meissner bodies to be able to read the Braille-Alphabet.



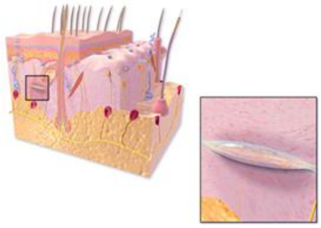


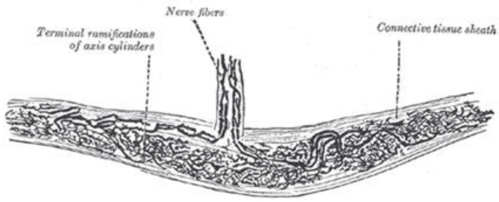
Tactile or Merkel cells

These are special sensory cells, which are located in the deeper parts of the epidermis and act as pressure receptors. They belong to the mechanoreceptors of the tactile sense. They are sensitive to a frequency of 0.3 – 3Hz. These cells are responsible to feel the stiffness of a material.

Ruffini bodies

Belong to the slow adapting mechanoreceptors. They are located in the very deep layers of the skin and register mechanical deformation in the joints (angle change and continuous pressure states. Similar to the Merkel cells, the Ruffini bodies are responsible to feel stiffness and compressibility.





The traditional hand test

As the pictures below show, there are different ways to test a piece of tissue: it is possible to touch the material from just one side, from two sides at the same time or it can be crumpled. Independent from the test method, different vibrations and forces are generated against the deformation. These depend on the softness, roughness and stiffness of the material. Sensors, which are located in the skin and joints of the fingers, are responsible to feel the three basic parameters, softness, roughness and stiffness.

Hand moves over the sample surface

Sample is crumpled by the hand

Generation of different vibrations, shear forces and resistance against the deformation, which depend on:

- micro-surface variations (feeling of softness)
- macro-surface variations (feeling of roughness)
- stiffness

These different signals (the vibrations in the different frequency areas) are detected by the four sensors in the human skin and transported to the brain via the nerves. In the brain, these signals are combined to an overall impression of touch, comfort, hand feel.

The human feeling is determined by the following three parameters:

» softness / micro-surface variations

» roughness / macro-surface variations

» stiffness / in-plane stiffness.

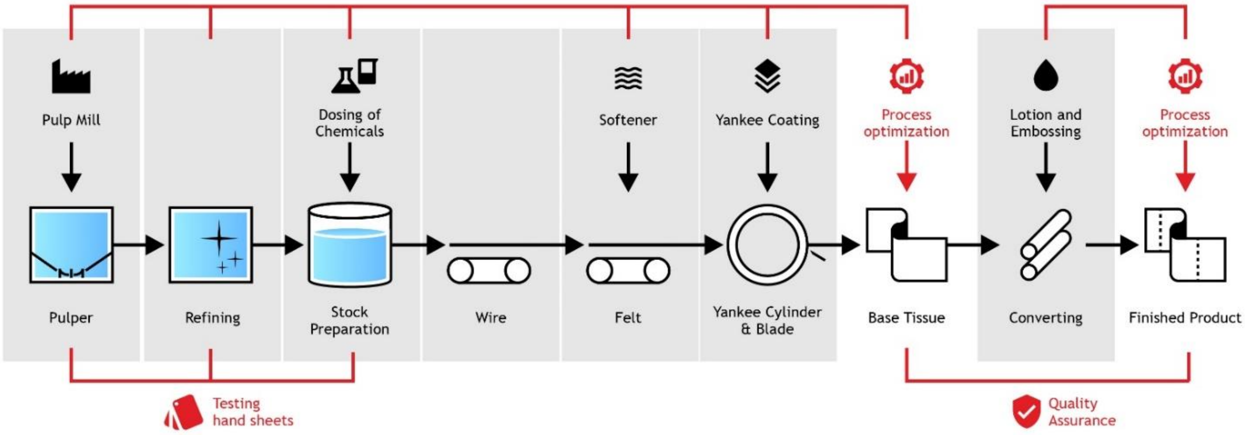
Due to the fact that a hand panel is done by a group of humans, who are influenced by subjective factors, hand panels have several disadvantages. First of all, the sensitivity of different testers varies, in some cases a lot. Besides this, humans cannot satisfyingly distinguish between the three parameters, softness, roughness and stiffness. Humans only get an overall impression of the haptic quality (hand feel). And, the results depend on the testing procedure, the daily mood, the culture and personal as well as market specific preferences.

Which process parameters influence the "hand feel" or the "softness" of tissue during production?

There are several steps during manufacturing and processing that influence the softness or the grip of tissue crucially:

- » Source material pulp (fiber type, fiber quality, fiber mixture, refining)
- » Chemicals (softeners added in the wet-end or lotion applied in the converting, wet strength agents and other additives, which are used might influence the haptic quality indirect and unwanted.
- » Manufacturing technology (i.e. TAD, ATMOS, conventional)
- » Machine speed
- » Retention
- » Fiber fractionation (TS/BS)
- » Yankee coating
- » Drying conditions
- » Wire type and condition

» Blade type and angle, blade condition



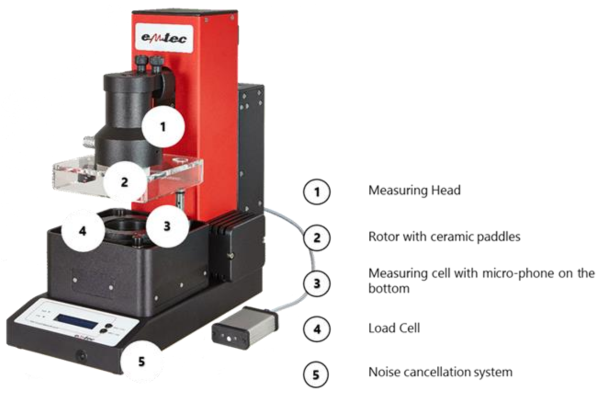
TSA in the process

The fiber quality decisively influences the hand feel of the finished product (according to pulp manufacturers about 30 %). But the remaining parameters sum up to a contribution of about 70 % it is important to know the influence of each parameter to optimize the process effectively. The problem is that the impact of specific single parameters to the quality of the base tissue off machine can be small, and it is impossible to detect it by hand. For that purpose, it is of course necessary to apply an adequate and objective measuring method that gathers the softness, the texture, and the stiffness as selectively as possible.

Technical principle of the TSA

Micro-surface variations (softness), macro-surface variations (roughness) and the in-plane stiffness are measured with the device. Softness and roughness are measured by a sound analysis in the first step. In the second step, the in-plane stiffness is measured.

Important parts of the device



Measuring principle

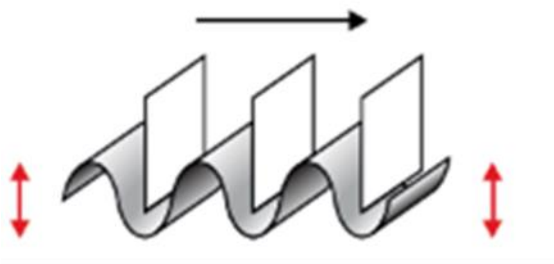
As already mentioned, the TSA measures the three haptic parameters within two separate steps.

1. Step one: sound measurement (softness and roughness)

   To measure, the measuring head incl. rotor and blades moves down to the sample until a load of 100mN is applied. Once the load is reached, the rotor starts to rotate over the sample with a constant load of 100mN. The rotation of the blades over the material cause two different types of vibrations. One is the vibration of the sample and the other one is the vibration of the blades.

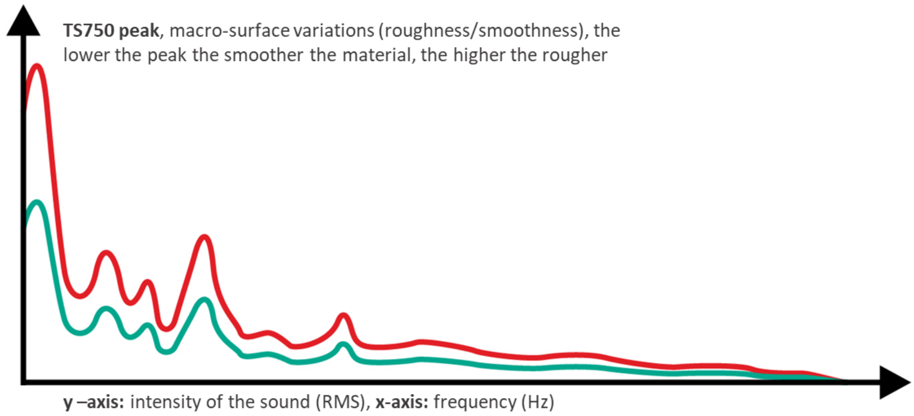
   The vibration of both, the sample and the blades, causes a sound. This sound is recorded by a microphone, which is located underneath the sample. Both parameters are measured at the same time in two different frequency areas. But, which vibration represents which parameter?

   Vibration of the sample

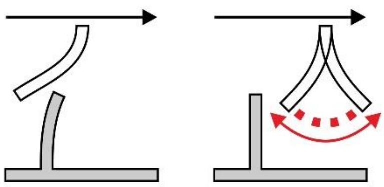
   Vertical vibration of the sample

   While the blades move over the sample, the measuring head incl. the moving rotor and blades are fixed in vertical direction. But, the sample has a certain surface topography (“hills” and “valleys”) and according to these hills and valleys, it needs to go somewhere. This up and down of the sample according to its surface topography is a vibration, which causes a sound. The sound is recorded by the microphone underneath the sample. The result is shown in the PC software, either as a graph or as a value in the data fields. The vibration of the sample represents the macro-surface variations, which define the roughness of the material. The picture below is an example of a sound spectrum. The first peak (TS750 peak) represents the macro-surface variations (roughness) of the material, normally it can be found between 200 and 2000Hz.



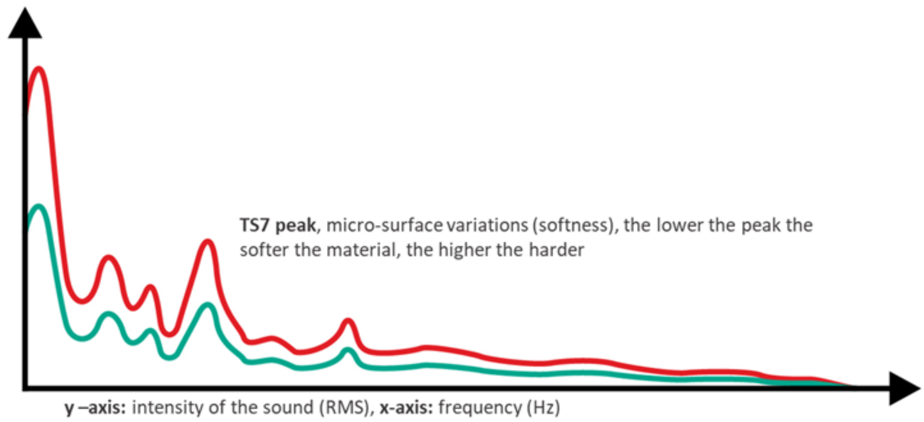
TSA sound spectrum

Vibration of the blades



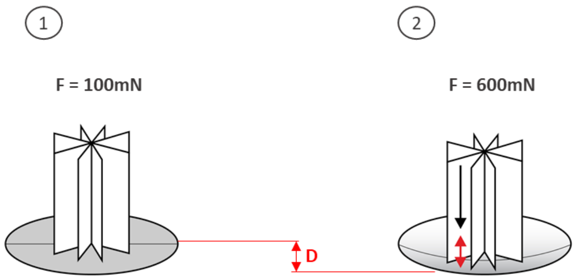
By zooming into a tissue paper sample, single fibers that stick out of the material and other micro-surface variations can be seen. When the blades move over these fibers and other micro-surface variations, they will get into vibration, e.g. according to the stiffness or flexibility of these fibers (stick and slip principle). Stiff and hard fibers cause a strong vibration of the blades and thus more sound. Soft and flexible fibers cause much less vibration and thus less sound.

The peak at approx. 6500Hz is called TS7 and represents the micro-surface variations (softness).



2. Step two: deformation measurement (in-plane stiffness)

   In the second step, a load between 100 and 600mN is applied to the sample and the deformation is measured in mm/N. For the measurement, the measuring head is moving down to the sample until a load of 100mN is applied. From that point, the load increases to 600mN.



The way between 100mN and 600mN is measured and represents the deformation of the sample (stiffness, flexibility).

Results

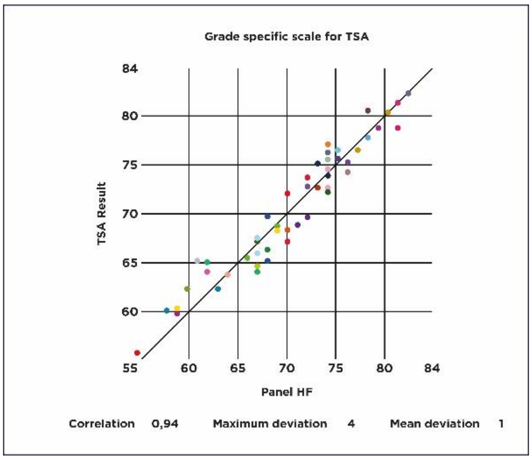
Measured

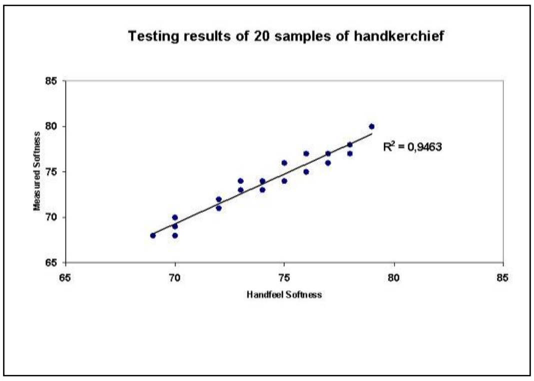
- Micro-surface variations (soft vs. hard)
- Macro-surface variations (smooth vs. rough)
- Stiffness (stiff vs. flexible)

Calculated

- HF value

Correlation between the TSA results (single parameters and calculated hand feel value) with the hand panel

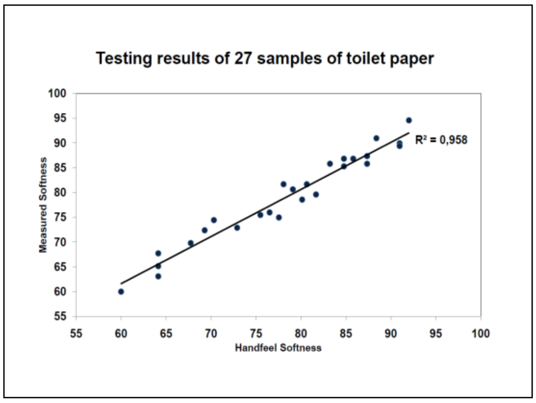




The excellent correlation of the TSA-Values with the testing results of good panels has its cause in the fact, that the TSA simulates the human hand and via mathematical formulas and calculations by PC the human brain. Due to the measuring principle the three essential influencing factors to the human feeling are captured: fiber softness, surface structure/texture (= roughness/smoothness) and stiffness, which – together with the entered values for thickness, grammage and number of plies by complex formulas in the “brain”, the PC – are calculated to measuring values, the “HF”.

Especially advantageous for the application of the TSA for the process- and product optimization is the fact, that the three main factors (contrary to the human hand) are separately ascertainable.

The emtec R&D realized several very comprehensive projects with partners from the industry in which we tested thousands of different samples for which there are known panel hand feel values (base tissue, facials, toilet tissue). We achieved correlations of the TSA values with the panel values of 90-98 %, partly even up to 100 %, especially for base tissue. Here, it has to be taken into account that the precision of the panel evaluation was subject to decisive insecurities when comparing different embossed toilet tissues due to the partly differing embossing. In general, it is true that: **the better the panel is configured and the more precisely it works, the better correlate the TSA values and the panel values.**



One interesting result of the extensive process analytical tests realized by emtec is that the influence of the smoothness/roughness of embossed toilet tissue to the hand feel/haptic is less and less, the softer the tissue actually is.

Users, application areas, products

Users

- » pulp producers
- » chemical suppliers
- » tissue makers/converters
- » tissue machine builders (tissue production and converting)
- » retailers
- » universities and institutes

Application areas

- » R&D
- » process and product optimization
- » incoming control
- » quality assurance
- » complaint management and trouble shooting
- » benchmarking

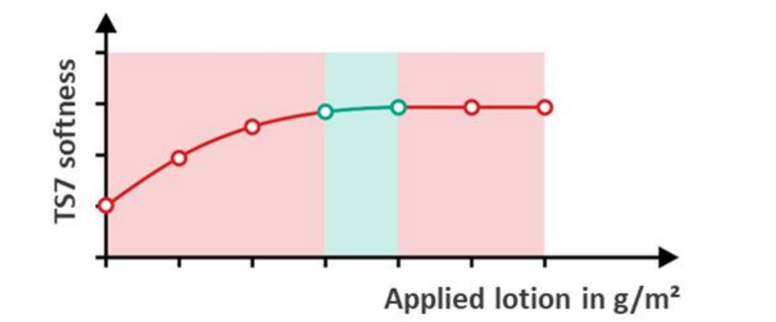
- » marketing and sales

Products

- » base tissue
- » facials/handkerchiefs
- » toilet tissue
- » kitchen towels
- » napkins
- » also, non-woven, fabrics, and any other flat materials, even cosmetic pads can be measured

Application examples

Example 1: *Optimization of the application of lotion in the tissue converting*



The target of the trial: optimization of the production and converting process, without losing softness:

Often, there are many different possibilities to optimize the process without losing quality. An example for what can be done is illustrated on the left side. The tissue converter was interested to see the effect that the applied lotion has to the tissue paper.

The procedure that we recommend for this kind of trials is the following:

1. Measuring the softness of selected samples (tissue raw material) by using the TSA, setting delivery specifications

2. Determining the optimal amount of lotion to be applied by using TSA measurements (carry out machine testing with increasing application quantity and use tissue of which the softness is on the lower limit of the agreed specification) or hand sheet tests.

3. Choosing the softener with the best cost-performance ratio

4. Incoming control of the raw material

5. Cost saving by process optimization to avoid overdosing and « overquality »

Model calculation

Return on investment (ROI) for a tissue converter, example – optimized application of lotion:

Annual production of 2-ply facials (30g/m²) with appliedlotion:	10,000 t
Amount of applied lotion: the	approx. 3 g/m² (1.5 g/m2 on each side) = 10 % of basis weight
Annual use of lotion:	approx. 10% of 10,000t = approx. 1,000 t = 1,000,000 kg
Price of lotion (depending on quality):	aapprox. 2-5 Euro/kg
Annual costs for lotion:	approx. 2-5 Million Euro

Potential to save money about 10 - 50% = 200,000– 2,500,000 Euro/year

Price of the device (including accessories):	approx. 65,000.00 Euro
Personnel costs for the measurements (dependent on cost structure and the area of the company):	Approx. 30,000.00 Euro /per year

Return on investment within approx. 5 months down to only 2 weeks

Example 2: *Optimization of the creping blade life time*

The lifetime especially of steel blades is limited. Generally, depending on the target quality of the base tissue, 1 − 8 rolls are produced, then the blade will be changed, which requires about 2-3 minutes while of course no tissue can be produced. As with the previously used hand test neither an accurate nor a fast test is possible, one is forced to drive on safety and to change the blade periodically according to set cycles. With the TSA as an accurate and objective method, the blade change can be carried out “on demand”. Respectively, by determining the optimal number of cycles an increase of the produced rolls per blade can be achieved without the risk of quality reduction.

ROI example

Annual production:	45,000 t
Production time per reel:	approx. 30 min
Time for blade change:	approx. 3 min
Number of rolls per blade cycle before optimization:	4 = 120 min = 12 Blade changes/day = 36 min/day
Number of rolls per blade cycle after optimization:	6 = 180 min = 8 Blade changes/day = 24 min/day

Saving of time for blade change

350 days x 12 min = ca. 4200 min/year = **140 Rolls á approx. 4 t = approx. 560 t additional production = approx. 1.25 % increase in production** without substitutions in machines or Equipment

Plus, cost savings through saving of blades

Price/Steel blade ? **42.50 € /Steel blade** (approx. 5m machine width) 4 Blades/day * 350 days = 1400 Blades x 42.50 € = **Saving of 59,500 €**

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Mr. Hans-Jürgen Lamb, SCA Hygiene Products GmbH, Germany

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