NordDesign 2018
August 14 – 17, 2018
Linköping, Sweden

Affective surface engineering- using soft and hard metrologhy to measure the Sensation and perception in surface properties

Lars Eriksson[1], B-G Rosen[2], Martin Bergman[3]

[1]Jönköping University, Industrial Design, Product Development Department
Lars.Eriksson@ju.se
[2]Halmstad University, Functional Surfaces Research Group
Bengt-Goran.Rosen@hh.se

[3]Halmstad University, Functional Surfaces Research Group,
martinbergman85@gmail.com

Abstract

New surface treatments, novel material developments, and improved quality control procedures and advanced metrology instrumentation create a possibility to further develop competitiveness by the selection of "optimal" surface features", to a product.
The customers first apprehension of a product and the creation of desire is a very complex, but tempting process to learn more about. The interaction between the added quantitative- and the qualitative direct impressions with the customers known and unknown functional demands, social background, and expectations results in sensation and perception, partly possible to quantify and to great extent impossible to pin-down as numbers. Customer sensation and perception are much about psychological factors. There has been a strong industrial- and academic need and interest for methods and tools to quantify and linking product properties to the human response but a lack of studies of the impact of surfaces.
This paper aims to introduce a novel approach to develop and join a human sensoric inspired metrology frame-work with qualitative gradings of apprehended impressions of products with varying surface properties.
The aim is to establish the metrology framework to link measurable- and unmeasurable impressions of product surfaces to customer FEELING as exemplified by a set of industrial applications.
In conclusions of the study, future research in *Soft metrology* is proposed to allow understanding and modelling of product perception and sensations in combination with a development of the Kansei Surface Engineering methodology and software tools.

Keywords: *Surface Texture, Affective Engineering, Industrial Design, Kansei, Surface Perception.*

1 Introduction

The fact that surface properties gives character to a product is nothing new. The surfaces create together with shape, choice of material and color, an overall total experience of the product. The trend that surface properties play an increasingly important role in designing products is

clear. In the automotive industry, for example, it is estimated that about 30% of today's car buyers decide on purchases based on the interior appearance (design language, color and pattern, buttons and controls quality, etc.).Percieved quality has become very important though it is sometimes hard to measure. A designer has an idea of what a product should express. This can be summarized in a number of words, Kansei words. For these reasons, the designer creates a product with a certain expression. When the product reaches its production phase, much of the work is focused on ensuring that the right quality is obtained throughout the production phase. The Industrial Designer har mainly responsible for creating surfaces that has a meaning and an expression, while Design Engineers has the responsilitiy for maintaining the quality trough the whole process. Produced plastic surfaces are measured towards samples and what is measured is similarity. There is a need for improvement in using same or compatible measurement methods in order to measure percieved quality.
Many vehicle components are currently manufactured from injection molded plastics, as plastic injection molding offers cost-effective manufacturing, great design freedom, easy integration of features, great color and pattern flexibility etc. It is however difficult to achieve components with perfect color and texture through the whole process. perfect good sound absorption components, etc. However, injection molding of components with perfect color and pattern is difficult and the purpose of the proposed project is to increase the knowledge of efficient injection molding of patterned vehicle components.
The aim of the paper is to present the importance and context of “Affective Engineering” and to give example as cases on the application for engineering surfaces to support the discussion of continued research in the field –addressing the problem of the absence of a current joint approach to affective surface engineering in general. Also to give focus on the link between specific and intentional knowledge of surface properties, and the universal and existing knowledge of surface properties.

2. Emotions and product experience

2.1 From stimuli to sensation

The combined sensation of a products’ surface gloss, colour, haptic properties like “friction”, “elasticity”, “hardness”, and “temperature”, create an intended message to the customer received as a stimuli (R) by the human five senses, transformed to psychological sensation (S). The Psychological Sensation (S) was expressed in “*Fechner’s law*” as:

$$S=k \log R \tag{1}$$

where k is a constant and the Sensation following a logarithmic function where small differences in stimuli create a larger variation of sensation than for changes of stimuli at higher values [3].

Later S.S. Stevens at Harvard developed a similar model – “*Stevens’ power law”*, sensitive to that different types of stimuli follow different curve shapes to Psychological sensation:

$$S=aI^b, \tag{2}$$

where a is a constant, b is a stimuli exponent varying with the type of stimulation (visual, haptic, smell, taste, or audio) and I is the stimulus energy related to Stimuli (R) the “Fechener’s law” in eq.1 above [4]. So to convey a “message” strong enough to the customer, thresholds for the lowest detection level of changes in stimuli and the function relating the stimuli to psychological sensation are important to understand.

Questions needed to be answered related to surface engineering are *the minimum roughness* of a handle the customer can sense and *the differences of texture roughness* allowing a handle with two textured parts to be perceived as having the same haptic roughness sensation, i.e defining thresholds for texture sensation and tolerance in relation to customer expectations and satisfaction.

2.2 Aesthetics and semantic scales to rate attitude

Aesthetics can be explained as the human perception of beauty, including sight, sound, smell, touch, taste, and movement, and the interpretation of the impression. But can also be explained as how a product present itself, its expression. Hidden factors controlling appreciation of beauty have been discussed by philosophers since the Ancients and was established as a subject of science when Osgood et al introduced the semantical differential method used to quantify people's perception of a product [5]. Here, a semantic scale composed of polar opposite adjective pairs separated by a five to seven point rating scale is used. For example, a customer could rate the perception and interpreted attitude to a product by grading adjective pairs (*rough* to *smooth, cold* to *warm, dark* to *bright*) on 7 grade scales. Semantic scales could then be evaluated using e.g. principal component analysis (PCA), to draw general conclusions of attitudes and separate them from more specific and subjective interpretations of surface properties.

2.3 Motivation and need

However, one important component affecting the Aesthetics and attitude to the products is the customers' *need* or *motivation*. Motivation and need of a customer was discussed by Maslow [6]. Here, 5 levels of motivation (*Biological-* and *psychological needs*, *Safety needs*, *Belonging* and *love needs*, *Esteem needs* and *Self actualisation*) were accentuated. If the psychological sensation (S) triggered by the physical stimuli matches the customers' expectation at the present motivation "level", the attitude to the product would be positive. I.e, the message of the product design would create a positive perception of the product and its properties to the specific customer including both the psychological sensation e.g. from surface roughness level and the customers' current "level" of motivation from a position of wanting to satisfy basic biological needs, e.g. having simple eye glass frames without requirements of *expensive-*, *exclusive-, and luxury* signalling high gloss polished roughness.

3. The intended product message

3.1 Designing the customer motivation

Schutte [7] added to the discussion of needs of the customer also the pleasures of motivation by Jordan's "4 pleasures" [8] -*Physio* – to do with the body and the senses. *Psycho* – to do with the mind and the emotions. *Socio* – to do with relationships and status and *Ideo* – to do with tastes and values. Jordan's 4 groups complete Maslow's five steps and their fulfilment at the different motivation levels is of importance when designing customer motivation into the product.

3.2 Design parameters and intention –the Affective Engineering Equalizer

Our motivation for- and how we perceive a product is strongly linked to the customers' "buy" decision. Industrial design methodology aims at creating this motivation and pleasurable product experience including meaning and message for the customer [9,10,11].

The aesthetic and pleasing properties of a product are of major importance in order to create motivation, interest, meaning and relevance of a specific product for the customer. Since there almost always exist alternative competitive products that fulfil basic required functionalities, the intended design of product properties towards increased customer motivation is one way of "making a difference" and standing out from the competition. The "Equalizer" introduced by Bergman et al. [12] in fig. 1 below, is a tool to visualize the relative importance of design element properties (form, material, colour and surface); how they are used and tuned for a given product to create the intended motivation, meaning and message, i.e. the aesthetics and core values, intended by the industrial designer.

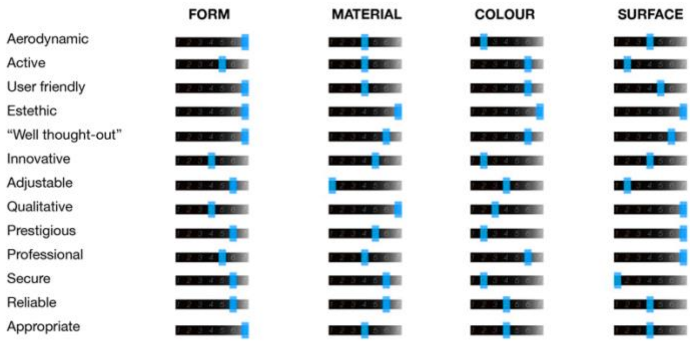

Figure 1. The Equalizer with the design elements (horizontal scale) and the product intended core values or "product message" (vertical scale) and how the "tuning" of the "equalizer" setting creates the total perception and aesthetics of a product [12].

In the example from figure 1 above, the 13 core values are adjectives decided by the industrial designers to define the product message of a roof-mounted bicycle carrier for the automotive industry [13]. The design element *surface* is decided to have its highest importance on "user friendliness", "aesthetics", "well-thought out", "quality", "prestige", and "professional" and consequently surface properties like gloss, average roughness, texture, on the final product needed to be verified towards those core values for the successful product.

3.3 Ideaesthesia, and semantics, connecting design elements and product experience

Ideaesthesia can be defined as the phenomenon in which activations of concepts results in a perception-like experience [14] To objectively and transparently judge and measure how the specification of physical design elements create the expected subjective customer perception i.e. creating *ideaesthesia,* is a complex task involving both physical metrology and perceptual evaluations. An example of ideaesthesia is the experiment made by the psychologist Wolfgang Köhler in 1929 [14], showing the strong correlation between the visual shape of an object and the speech sound (see below figure 2, top and middle) named the "Bouba-Kiki" effect. The word *Lumumba* is normally connected to the top and middle right "soft-large radii contour shape" image and the word *Takete* with the top and middle left "sharp angle, straight line contour shape" image. Today, a strong belief in the industrial designers' expertise and intuitive ability to make judgement exists and is regarded as "tacit" knowledge based on skills, ideas and experiences hard to formalise for an organisation.

A tool used frequently within the discipline of industrial design and strongly related to the ideaesthesia, to explain and formalise aesthetic knowledge is "Semiotics" , -the study of signs, and "Semantics" ,- the study of meaning and the relation between design elements and signifiers, like words, and symbols, and the correlation in between.

As an example of design semantics connecting design elements to core values –adjectives, is the "softening" of the perceived visual sensation in figure 2 from a sheet metal surface by mimicking a "soft" natural hair texture (bottom left) with the Angel Hair™ texturing[1] (bottom mid), compared to the more traditional "hard" "Taketeteish" brushed steel texture (bottom right).

Figure 2. Lumumba–Takete or Bouba-Kiki words (top and middle) and the meaning of form which has a strong connection to product experience. Takete to the left and Lumumba to the right. Beside is a typical soft hair texture (left) and the Angel Hair™ (middle) steel texture, mimicking hair and a brushed uni-directional steel texture (right).

3.4 Perceptual Product Experience, modelling the products' intended message Perceptions involve any or all of the five senses. Understanding the structure of how this works can create a more robust and controlled process when designers create new concepts for a predicted user experience. The Framework of Perceptual Product Experience (PPE framework) [9,16] considers perceptual product experience as composed of three core modes; *the sensorial mode* including perceptions of stimuli experienced with any of the receiver senses, *the cognitive mode*, we understand, organise, and interpret and make sense of what we perceive, and finally *the affective mode* concerns itself with experiences that are affective: feelings, emotions, and mood states, as result of product perceptions (see fig. 3, mid, below).

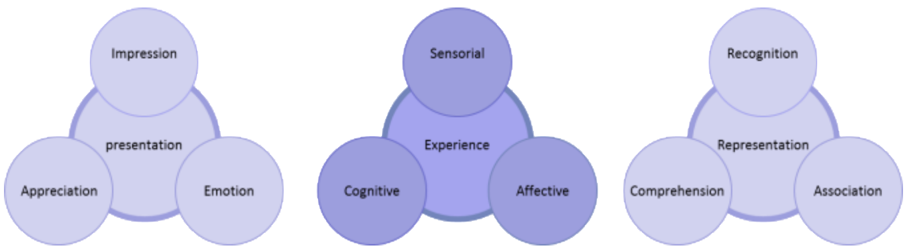

Figure 3. The Framework of Perceptual Product Experience (PPE), after [9,16].

The PPE model in figure 3 below, illustrates a model for the intended product communication between the Producer and the Consumer. I.e. how the industrial designers' intended product message, s*emantics*, expressed as *core values*, *adjectives* and converted into design elements with controlled properties creating consumer sensations, and ideally results in *ideaesthesia*, a pleasurable experience of the product at the customers motivation level.

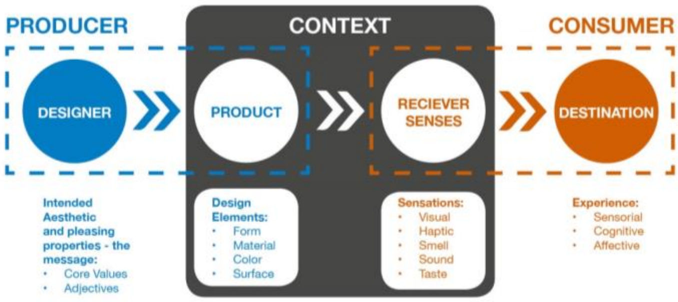

Figure 4 The figure illustrating a model for Intended product communication linked to the PPE Framework.

The PPE model in figure 3 above, illustrates a model for the intended product communication between the Producer and the Consumer. I.e. how the industrial designers' intended product message, s*emantics*, expressed as *core values*, *adjectives* and converted into design elements with controlled properties creating consumer sensations, and ideally results in *ideaesthesia*, a pleasurable experience of the product at the customers motivation level.

4. A "Soft metrology" framework to measure total appearance

4.1 Soft metrology –the measurement of customer satisfaction

Soft Metrology, is defined as "the set of techniques and models that allow the objective quantification of certain properties of perception, in the domain of all five senses" [17].
Soft metrology addresses a broad range of measurement, outside of the traditional field of physical metrology [17].
- psychometric measurement or perceived feeling (color, taste, odour, touch),
- qualitative measurements (perceived quality, satisfaction, comfort, usability),
- econometrics and market research (image, stock exchange notation), sociometry (audience and opinion),
- measurements related to the human sciences: biometrics, typology, behavior and intelligence.

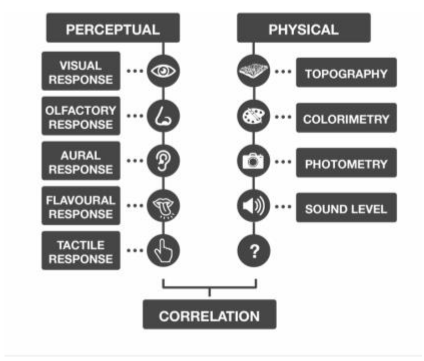

Figure 5. Soft metrology, correlating the objective physical measurements to human subjective perceptions, after [17].

Here the human would be considered as a measurement system defining sensitivity, repeatability and reproducibility and comparing the results with those obtained by methods from traditional "hard" physical metrology.

The notion of subjectivism can of course be discussed further related to figure 4 above. Parts of what is described as subjective, specific human responses in the figure above, can actually be described as universal and general perception, though subjective. For instance, the Bouba-kiki effect, in which the subjective perception are shared by all respondents, and therefore can be seen as a general perception, and not notified as a personal opinion of what is perceived. Perceptions that can be generalized and therefore universal can be explained as "agreements" of how things are, like a clear distinction between milk, yoghurt and wine, not to be mixed up with preferences of the same in different contexts or time of the day.
The area of *soft metrology* has got a lot of attention and departments was formed both at the standards institutes NIST in USA and NPL in England [17,18,19] an European project - Measuring the Impossible (MINET) 2007-2010 with 22 partners from Europe and Israel including industries and academia as well as the national standards institutes in Great Britain, NPL and in Sweden SP [20]. In 2013 also L. Rossi published her doctoral thesis – "Principle of Soft Metrology and Measurement procedures in humans" stating the importance of the field [21].

4.2 Total appearance

Appearance is according to American Society for Testing and Materials (ASTM) [22] defined as "*The aspect of visual perception by which objects are recognised".*

The visual appearance of an object is a result of the interaction between the object and the light falling upon it. *Colour* appearance is a result of the light reflection and adsorption by the pigments. *Gloss* is created by the reflection of light from the surface, and *translucency* is a result of the light scattering while the light passes through the object (fig. 5). The described complexity of the object's appearance causes different measurement technologies and instruments to be employed when attempting to quantify it [17]. Texture is a complementary component of the visual appearance and also needs to be considered.
The concept of *total appearance*, has been introduced to extend the concept of the appearance of an object. The *total appearance*, however, would require a description of the shape, size, texture, gloss and any other objects' properties possible to detect by our 5 senses (visual, haptic, smell, sound and taste) and interpreted by the brain as a "total appearance" of an object [17,23].

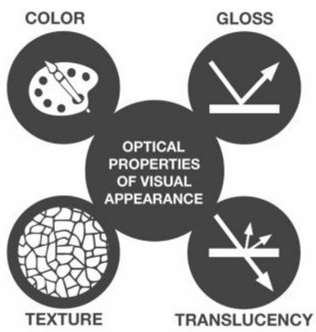

Figure 6. Visual appearance is one aspect of the total appearance. Here, the four basic optical properties (colour, gloss, texture and translucency) of visual appearance are grouped together.

The total appearance (fig. 6) could also be described as a combination of three aspects of appearance:
Physical (object properties physically detectable by our senses, modified by the surrounding, properties of the illumination, individual factors like ageing, handicap, etc., affecting our sensibility)
Physiological aspect (the neural effect when human receptors are subjected to the physical stimuli and convey signals to the cerebral cortex), creates a sensation
Psychological aspect created when sensations are interpreted by the cortex, recognised as an object and combined with inherited and taught response modifiers (Memory, Culture, Fashion, Preferences). Figure 8 below summarise the factors affecting the total appearance, resulting in two appearance images.

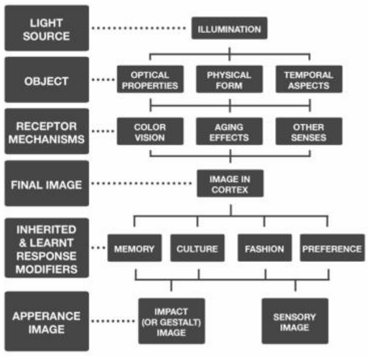

Figure 7. The concept of *total appearance*, after [17].

-*the impact image*, and *the sensory image*. The *impact image* is the initial recognition of the object or scene (the gestalt), plus an initial opinion or judgement. For the *sensory appearance image*, three viewpoints are used to create the total appearance, sensory, emotional and intellectual. The sensory viewpoint describe thoughts associated with the colours, gloss etc. of the object. The emotional viewpoint associates the emotions connected with colours, gloss, etc. while the intellectual viewpoint covers other aspects associated to the object and situation rather than sensory- or emotional associations [24,25].

Total appearance is closely related to the models of Intended product communication, and the Perceptual Product Experience (PPE) framework and could be used when quantifying customer perception and satisfaction using soft metrology to correlate physical- and human factors contributing to products appearance images.

5. Affective engineering, - to measure total appearance and control the customer satisfaction

5.1 Quality Function Deployment and Kano to understand psychological sensation

After Osgood's publications [5] more methodologies e.g. Quality Function Deployment, QFD, and the Kano model were developed with similar motivation [26,27]. Those methods are very capable of dealing with psychological sensation but not as capable when it comes to translating the subjective sensation into design parameters i.e. real product features influencing the perceived sensation.

5.2 Kansei engineering –from subjective sensations to design parameters and total appearance

Nagamachi developed the method "Affective-" or "Kansei-" Engineering (KE) in the 1970's which has its roots in the Japanese concept of Kansei, "intuitive mental action of the person who feels some sort of impression from an external stimulus" [28,29,30,31]. By using the framework of KE as an approach and focusing on finding correlations between the functions; customer requirements, function requirements, design requirements and process requirements; a higher level of user quality and a methodology for soft metrology as discussed above could be obtained.

According to Nagamachi the Kansei concept includes; "a feeling about a certain something that likely will improve one's quality of life". KE can also be defined as a customer-oriented approach to product development. The basic idea is that; the client's feelings shall be observed already at the phase of idea generation in the product development process, which then facilitate the project later on when a concept reaches the production stage.

Kansei engineering handles 6 different phases/steps [12, 28,29,30,31]., starting with the definition of the products' domain and context, see figure 7 below

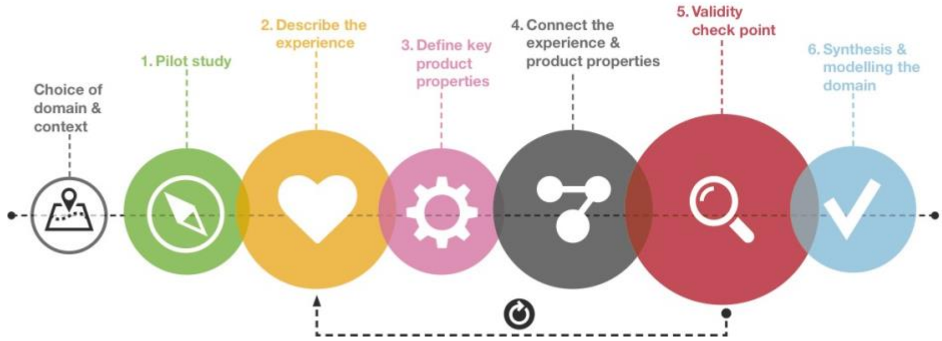

Figure 8. The Kansei based research approach and 6 different phases.

The 6 phases range from a pilot study where the product or service is defined including specification of the product and market, to synthesis and modelling the result of the given study.
A full project ranging over all the 6 phases of Kansei engineering will result in a model or prediction of the total appearance or a limited sector of the total appearance, e.g. visual appearance or *total appearance of the texture* of a product within the domain selected in phase 1 of the project. *Visual appearance* is limited to optical factors of the product appearance while the total appearance of the texture of a product includes visual-, haptic- and other sensory aspects of the total appearance of the micro- or nanometre texture experience.
Below in following sections the Kansei methodology briefly described generally in the sections above will be detailed and exemplified with results from current and past cases and studies to illustrate the potential of an application of affective engineering concepts on product surfaces.

5.3 Phase 1, The Pilot study, defining the domain

In this phase it is important to define product domain and users. Define and analyze: WHAT, WHO, WHERE, WHY, WHEN & HOW.

In the Pilot study The Design Compass and *persona* studies as well as *mood boards* are used in order to make the definitions right.

5.4 Phase 2, Describe the experience

Define the Product experience (Span the semantic space) – In this phase it is important to find psychological emotions and expected total appearance and perception related to a product expressed as adjectives -"Kansei words", and grouped in logical clusters (see fig.10).

The idea of describing the product experience using adjectives is about framing the emotional functions, i.e. defining the expected perception and total appearance. To be able to do that there is a need to "span the semantic space", collect the expressed "emotions", by collecting adequate describing words, which the user expresses when interacting within the product domain. By using describing words it is possible to find appropriate expressions and clusters of Kansei words expected to be associated with (and not!) a product designed to evoke an intended perception or *Ideaesthesia*.

5.5 Phase 3, Define key product properties

Define Key Product Properties (Span the space of properties) – In this phase it is important to find physical product properties that affect the user. Analyse the properties of the domain • Define properties that affect • Isolate significant properties.

When the identification of the core-values and Kansei words is made, the next step is to identify properties of the existing product that can be controlled and affect the product towards those core values, The design elements should be appropriately measurable using standardized methods and parameters like the surface texture field-, stratified- and feature parameters in accordance with acknowledged ISO 25178 series of standards.

5.6 Phase 4, Connect the experience and product properties

Connect the experience,-the Kansei adjectives, and Product physical properties– By using qualitative studies on focus groups connections between Kansei words and design elements can be made. An important tool to visualize the connection between Kansei words and design elements contributing to the total appearance is the "equalizer".

For a given domain identified in step 1, the key product properties –design elements from phase 3 are connected to the Kansei words from phase 2, in this 4'th step by, for example, using focus groups (

5.7 Phase 5, Validity checkpoint

Validity Checkpoint – When the correlation in the Synthesis in step 4 is established, it is important to verify the results by statistical tests, experiments or virtual simulations.

The validity checkpoint is about an overall validation of the concepts total appearance, verifying quantitatively the Kansei words from phase 2 and their connection to the design elements obtained in phase 4. Practical testing of concepts are made and quantitatively evaluated by the correlation of "soft" judgements of Kansei words to "hard measurements" of design element properties.

5.8 Phase 6 - Synthesis and modelling the domain , – Design and validation of a "prediction model".

The final step is intended to create a model that combines, refines and describes the results from the previous five phases in the Kansei methodology. Hence, to assemble a model bridging the emotional semantic- and product properties' space.

In this step a *designmanual* can be made in order to link design elements with Kansei words. The design manual basically linked surface geometrical properties (the significant design elements and properties) to the Kansei words according to the results demonstrated in step 5 above. . In practice this resulted in designer rules collected in a physical booklet for the context

The designer rules and the equation above are examples where affective engineering and soft metrology results are synthesized into tools able to predict customer perception and aspects of total experience supporting organisations' possibilities to maintain customer focus and competitive advantage.

6. Conclusions and future

The aesthetic and pleasing property of products is one of the major design dimensions in order to create a meaning and relevance of a product.

The correlation of objective characterization of material properties in relation to human response is the main component in *Soft Metrology,* a concept previously introduced and known, naming the methodology with the power of enabling affective surface engineering.

- *Total experience* can be used when quantifying customer satisfaction using *Soft metrology* correlating physical- and human factors contributing to products appearance images.
- *Soft Metrology* allows the objective quantification of certain properties of perception, in the domain of all five senses, i.e, a quantification method for measuring total appearance.
- *Affective surface engineering* using the *Kansei* method is effective to connect the expected sensation, using *Soft metrology* methods, to validated design parameters.
- Appearance and perception of product surfaces *visual-*, *haptic-* and *other functional requirements* like visual requirements on *external building– and sauna panels* and perceived haptic roughness of *tissue paper* as well as clean ability of *surfaces for the medical industry* can be taken into account using the Kansei “6 phase” engineering approach.
- The Affective-, Kansei surface engineering methodology has a great potential to help organisations to maintain customer focus by allowing industrial designers to understand and model a desired perception and total appearance of a product.

The results from the paper discuss a current direction in product development and industrial design where surface engineering and the concepts of soft metrology, total appearance and affective, Kansei, engineering are combined and exemplified.

Future possibilities to increase the generality and applicability lies *firstly* in the development of soft metrology to enable detailed understanding and modelling of the customer perception and total appearance.

Secondly, the development of software tools supporting and optimizing the 6 phases of Affective-, Kansei-, surface engineering will increase the accessibility and interest for the method and increase the number of performed case studies, thus increasing the knowledge in this emerging research area.

Thirdly, there exist a possibility and a need of further research into the development of the word “metrology” in soft metrology, where multisensorial physical data will be linked to human multisensorial perceptual data. *Finally,* the question of “How and to what level can we quality assure soft metrology data in turn assuring the quality of affective-, Kansei engineering approaches?” need to be addressed in future studies.

Acknowledgements
The authors wish to thank the companies *A.Zahner Company* MO USA, *Tylö AB* Sweden, *Getinge Sterilization* Sweden, for financial support as well as expert input. We would also like to thank *Digital Surf* France for the support with the Mountain Map software. The conducted research is financed and part of the *Vinnova*, The Swedish Governmental Agency for Innovation Systems, project "Robust injection moulding of automotive components with desired surface properties (SW: Robust formsprutning av fordonskomponenter med önskade ytegenskaper).

References

[1] ISO 9001:2015 (2015) Quality management systems — Requirements.
[2] Nagano H, Okamoto A and Yamada Y (2013) Visual and Sensory Properties of Textures that Appeal to Human Touch International *J. Affective Engineering* **12** 3 pp 375-384
[3] Fechner G T (1897) *Vorschule der Aesthetik* (Leipzig, Germany: Breitkopf & Härtel)
[4] Stevens S S, Galanter E H (1957) Ratio Scales and Category Scales for a dozen perceptual continua, *J. Exp. Psycol.* **56** pp 328-334
[5] Osgood C E, George J S and Tannenbaum P H (1943) *The Measurement of Meaning* (Urbana IL USA: University of Illinois Press)
[6] Maslow A H (1943) A theory of human motivation *Psychological Review* 50 **4** pp 370–96
[7] Schütte S (2013) Evaluation of the affective coherence of the exterior and interior of chocolate snacks *Food Quality and Preference* **29** pp 16-24
[8] Jordan P W (2002) *Designing Pleasurable Products: An Introduction to the New Human Factors* (London, England: Taylor & Francis) (ISBN 041529887-3)
[9] Monö R (1997) *Design for Product Understanding* (Stockholm, Sweden: Liber) (ISBN 9789147011056)
[10] Krippendorf K (2006) *The Semantic Turn – a New Foundation for Design* (Boca Raton, Florida, USA: CRC Press) (ISBN 9780415322201)
[11] Vihma S (1995) *Products as Representations: A Semiotic and Aesthetic Study of Design Products* (Helsinki Finland: Helsinki University of Art and Design)
[12] Bergman M, Rosén B-G and Eriksson L (2012) Surface appearance and impression *Proc. Int. Conf. on Kansei Engineering and Emotion* Research (KEER 2012) (Penghu, Taiwan 22-25 May) ed Feng-Tyan Lin (ISBN 978-986-03-2488-4)
[13] Claesson O (2008) Nästa generation takmonterad cykelhållare (SW: Next generation roof mounted bike carrier for cars) Master thesis (Jönköping University, Jönköping Sweden)
[14] Köhler, W (1929) *Gestalt Psychology* (New York: Liveright)
[15] Gómez M E, Iborra O, de Córdoba M J, Juárez-Ramos V, Rodríguez Artacho M A and Rubio J L (2013) The Kiki-Bouba effect: A Case of Personification and Ideaesthesia *J. Consciousness Studies* **20** 1-2 pp 84-102
[16] Warell A (2008) Modelling Perceptual Product Experience – Towards a Cohesive Framework of Presentation and Representation in Design *Design & Emotion 2008 Proc. 6th Int.Conf. Design & Emotion* (Hong Kong, Hong Kong Polytechnic University, 6-9 October)
[17] Pointer M R (2003) New Directions – Soft Metrology requirements for Support from Mathematics, Statistics and Software: recommendations for the Software Support for Metrology programme 2004-2007 *NPL Report CMSC 20/03* (Teddington: National Physical Laboratory) (ISSN 1471-0005)
[18] Krynicki J C (2006) Introduction to "soft" metrology: A CIE challenge of Soft Metrology, *18'th IMEKO World Congress Metrology for a sustainable development*, (Rio de Janeiro, Brazil, 17–22 September)

[19] Eugéne C (2008) Measurement of "Total Visual Appearance": A CIE Challenge of Soft Metrology *12th IMEKO TC1 & TC7 Joint Symposium on Man, Science & Measurement* (Annecy, France, 3–5 September)

[20] European Commission (2007) *Measuring the Impossible* EUR22424 European Communities (ISBN 92-79-03854-0)

[21] Rossi L (2013) *Principle of Soft Metrology and Measurement Procedures in Humans Ph.D. Dissertation* (Politecnico di Torino, Turin, Italy)

[22] ASTM E284 (2002) Standard terminology of appearance, American Society for Testing and Materials

[23] McKnight M E, Martin J V, Galler M, Hunt F Y, Lipman R R, Vorburger T V and Thompson A (1997) Workshop on advanced methods and models for appearance of coatings and coated objects, *J. Res. of the National Institute of Standards and Technology* **102** (4) pp 489-498

[24] Hutchings J B (1977) The Importance of visual appearance of foods to the food processor and the consumer I, *Journal of Food Quality*, **1** (3) pp 267-278

[25] Hutchings J (1995) The continuity of colour, design, art, and science I, The philosophy of the total appearance concept and image measurement, *Color Research & Application*, **20**(5) pp 296-306

[26] Akao Y (1994) *Development History of Quality Function Deployment The Customer Driven Approach to Quality Planning and Deployment* (Minato, Tokyo Japan: Asian Productivity Organization) p 339 (ISBN 9283311213)

[27] Kano N Nobuhiku S Fumio T and Shinichi T (1984) Attractive quality and must-be quality *J. Japanese Society for Quality Control* (in Japanese) **14** 2 39–48 (ISSN 0386-8230)

[28] Nagamachi M and Lokman A M (2011) *Innovations of Kansei Engineering* (Boca Raton, Florida, USA: CRC Press) (ISBN 1439818665)

[29] Nagamachi M (1997) Kansei engineering and comfort *Int. J. Ind. Ergonomics* 19 pp 79-80

[30] Nagamachi M (2002) Kansei engineering as a powerful consumer oriented technology for product development *Applied ergonomics*, **33** 3 pp 289-294

[31] Lokman A M (2010) Design & Emotion: The Kansei Engineering Methodology *Malaysian J. of Computing* **1** 1 pp 1-12 (ISSN: 2231-7473)

[32] Rosén B-G, Bergman M, Skillius H, Eriksson L and Rake L (2011) On Linking Customer requirements to Surfaces – Two Industrial- and Engineering Design Case Studies *Proc. 13th Int. Conf.on Metrology and Properties of Engineering Surfaces (Twickenham Stadium, Teddington, UK, 12-15 April*) ed R Leach pp 131-135

[33] Bergman M, Rosén B-G, Eriksson L and Anderberg C (2014) Surface design methodology: challenge the steel *J. Phys.: Conf. Ser. 483 011001* doi:10.1088/1742-6596/483/1/011001

[34] Bergman M, Rosén B -G , Eriksson L and Anderberg C (2014) Surface Design Methodology – The Cleanability Investigation *KEER2014 Proc. 5th Kansei Engineering & Emotion Research (Linköping Sweden 11-13 June)* ed S Schutte

[35] ASME (2009) Bioprocessing Equipment (BPE)

[36] Bergman M, Rosén B-G and Eriksson L (2015) Affective Surface Engineering – the art of creating emotional response from surfaces. *Proc. 15th Int. Conf. on Metrology and Properties of Engineering Surfaces (Charlotte, USA, 2-5 March)* ed C J Evans

[37] Rosén B-G, Fall A, Rosén S, Farbrot A, Bergström P (2013) Topographic modelling of haptic properties of tissue product *J. Phys.: Conf. Ser.* **483** 011001 doi:10.1088/1742-6596/483/1/012010.