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Surface design methodology – challenge the steel

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Abstract. The way a product or material is experienced by its user could be different depending on the scenario. It is also well known that different materials and surfaces are used for different purposes. When optimizing materials and surface roughness for a certain something with the intention to improve a product, it is important to obtain not only the physical requirements, but also the user experience and expectations. Laws and requirements of the materials and the surface function, but also the conservative way of thinking about materials and colours characterize the design of medical equipment. The purpose of this paper is to link the technical- and customer requirements of current materials and surface textures in medical environments. By focusing on parts of the theory of Kansei Engineering, improvements of the companys' products are possible. The idea is to find correlations between desired experience or "feeling" for a product, -customer requirements, functional requirements, and product geometrical properties -design parameters, to be implemented on new improved products. To be able to find new materials with the same (or better) technical requirements but a higher level of user stimulation, the current material (stainless steel) and its surface (brushed textures) was used as a reference. The usage of focus groups of experts at the manufacturer lead to a selection of twelve possible new materials for investigation in the project. In collaboration with the topical company for this project, three new materials that fulfil the requirements -easy to clean and anti-bacterial came to be in focus for further investigation in regard to a new design of a washer-disinfector for medical equipment using the Kansei based Clean ability approach CAA.

1. Introduction

It is well known that a proper material selection is important when designing a new product; a minor mistake can cause terrible consequences to its user. An outcome could only be a success if the person who matters understands the message [1] and [2]. Nevertheless, material selection is not only about ensuring safety in a construction or optimising weight in a car for instance. Zoom into the material beyond what we can see with th enaked eye, and the micro structure will expose a landscape which affects us as users more than we can understand.

Professor Mitsuo Nagamachi (Hiroshima International University) had a vision about improving products on a more detailed level than before. Hence, he developed the method Kansei Engineering (KE) in the 1970's which has its roots from the Japanese concept of Kansei, ("intuitive mental action of the person who feels some sort of impression from an external stimulus") [3]. According to Professor Nagamachi the Kansei concept includes; "a feeling about a certain something that likely will

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improve one's quality of life". KE can also be defined as a customer-oriented approach to product development [4], [5], [6] and [7].

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 could be obtained.

The perceived quality is related to the experience of the product, and the experience is directly connected to the interaction and stimulation of the senses [8]. The customer describes their experience of a product with descriptive words such as; elegant, plastic or stylish and so on [9]. Yet, what they describe is their feeling, nothing else! By focusing on the material selection and surface processing (which is controlled by us, described with numbers/parameters) the experience of the product could vary, and by that also the customers feeling [9]. Now, is it possible to link those parameters to the customer's feelings and experience (and put a number onto it), but at the same time fulfil the technical requirements of the product?

2. Method

The project is basically implemented by the framework of KE, although it is modified to fit into the topic. The adapted method has been used systematically in the research work as a reference to obtain qualitative data but also to be able to develop a tailor made toolbox for designers where special tools for product optimization are possible. The approach is briefly described in this paper, the reader is recommended to read "Surface appearance and impression" [9] for a deeper understanding of the method.

The research approach used in this project handles 6 different phases/steps, initially though, the domain and the context has to be defined;

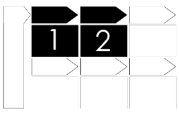
1. Pilot Study – In this phase it is important to define the questions what, who, where, how, why, and when. But also to implement a market analysis.
2. Describe the Experience, "*feeling*"– In this phase focus is lying on the description of the experience, which is possible by firstly collecting adequate describing words, *adjectives*, which the user expresses when interacting with the domain.
3. Define Key Product Properties – In this phase it is important to know the product and its features. It is about finding properties that affect the user, yet it is important that the properties are measurable and adjustable.
4. Connect the Experience,-the adjectives, and Product physical properties – By gathering typical users into a focus group whose mission is to analyse and evaluate the domain; it is possible to obtain information about the experience. In this phase focus is lying on finding connection between the describing adjectives and the key product properties.
5. Validity Check Point – When the correlation is established, it is important to verify potential other domains tested in the project. This is possible by measuring and comparing the key product properties, either the competitive domain fails the test or it will proceed to the next level.
6. Synthesis and Modelling the Domain – When the experience is evaluated towards a number of different product properties and the correlation is verified, the development of a new domain is possible using the research work as a solid ground to reach a higher level of quality.

However, the main issue in this project mainly handles the "clean ability" of the material and surface. Focus is both lying on finding a novel approach, which facilitates the confirmation of what a clean surface is or not but also finding correlations between the clean ability, and bacterial growth prevention, i.e. "Clean Ability Approach" (CAA). The CAA is about analysing the material and surface, which is directly linked to the product properties of the domain [10]. However, verification of an analysed material is difficult without a reference. Hence, the topical company´s trademark surface, the stainless steel with brushed texture, will be used as a comparison reference.

3. Result

The result is based on a literature study and measurements of the company´s reference surface, but also external materials. The analysed theoretical material is handling medical- and food contact surfaces, but also surfaces of different coatings. The thirteen (13) selected materials which were tested in a focus group were; *Anodized aluminium, Bronze, Aluminium/plastic sandwich material, Stainless steel (reference), Copper/aluminium, Tinted glass, Acrylic plastic, Zinc, White plastic, Active glass (coated), Spray painted aluminium, Fibre cement* and *Glass*.
The limitation with a wide range of tested materials was positive in terms of provoking different experiences by the users in an initial phase. The function requirements on the other hand, obviously affected the material selection as well. However, three materials came to be selected for further investigation; *glass, spray painted aluminium* and *acrylic plastic*, which all passed the focus group and the function requirements.

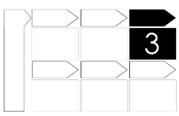
3.1. Pilot Study and Describe the Experience



Now, the domain and the context were already defined by the company. The domain is a washer-disinfector for medical equipment, focusing on the material of the front of the product, figure 2. The context is the medical environment the product is located in. Nevertheless, by defining the target audience, possibilities of finding user centred experiences were possible, and by that also correlation between the experience and the selected material samples. By converting the experience to describing words such as adjectives, it is easier to understand and analyse the outcome of the focus group. Words that continuously arose and were discussed in regard to a visionary product were; *robust, resistant, clean, warm, sleek* and *elegant.*

Figure 1. The washer-disinfector units are complex industrial products with medical demands on clean ability and bacterial resistance among several other demands like scratch resistance and chemical resistance. The current material in most of the product is today stainless steel.

3.2. Define Key Product Properties



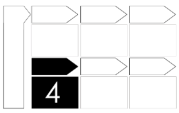
The functional requirements (table 1) and the physical design features responsible for the functions are in focus in phase 3, -*Correlation between expectations of the experience adjectives and the functional requirements*. The CAA is here a subset of all the functional requirements of the products. In this phase measurable functions and physical product properties are in focus; what is possible to measure is possible to modify, and by that providing a possibility of correlation between the experience adjectives and the CAA functional properties [10].

Table 1. The relation between functional requirements and judged texture related design parameters for CAA (crosses).

			Physical product properties, Design parameters **DP's**						
			Panel qualitatively judged properties						
			Surface texture	Chemical resistance	Color suitability	Darkness of color	Gloss	Heat conductance	Hardness
Functional requirements, **FR's**	Other	Shock resistance							
		Scratch resistance							
	Clean Ability Approach, **CAA**	Cleanability	x						
		Bacterial resistance	x						

The selection of functional demands and product properties were made by consulting the company R&D department in order to limit the study towards surface associated functions (see table 1). By judging the different functional requirements, the FR's and connecting them to product physical properties, the Design parameters DP's, the focus group considered CAA components to be: *bacterial resistance*, and *clean ability* as directly connected to surface texture.

3.3. Connect the Experience adjectives and Product Properties



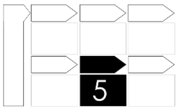
To be able to gather information about a certain product and its material, a survey is a powerful way to go forward [11]. This may lead towards the result that new products may be designed to create desirable, enjoyable and meaningful experiences. The main idea with the focus group (figure 3) was to obtain their thoughts about the current design of the product [12], focusing on the materials and the surfaces. By observing the focus group and obtaining words, adjectives, that describe their experience of the materials, correlation between the materials/surfaces and the experience was possible to find (table 2.). In this phase the functional requirements were on hold to give the focus group unbiased possibility to explore new materials purely in relation to the adjectives of experience.

Figure 2. The focus group consisting of company experts connecting the adjectives describing the "feeling" and experience of the surfaces of the 12 judged surfaces, resulting in table 2 below.

The words from phase 2, *robust, warm, sleek, elegant, resistant,* and *clean,* were now in focus. The valuation was simple, although significant. Using sight and tactile senses the focus group participants evaluated and compared to the reference stainless steel the surfaces towards the describing adjectives, either better or worse in comparison. For instance; correlation between the material *fibre cement* and the describing word *clean* was not very high in comparison with the lower texture amplitude in the reference stainless surface.

The result of the 4'th phase was that the focus group decided to choose three (3) surfaces for the next phase. The three surfaces chosen were *Acrylic plastic, Spray painted Aluminium,* and *Glass* (see table 2). All the three surfaces were considered as fulfilling the emotional response related to not only the CAA adjectives *resistant* and *clean* but also the other 4 adjectives found in phase 2.

3.4. Validity Check Point



The validity check provides the opportunity of a check point where selected materials are measured and analysed. The material samples which advanced through the focus group were measured using a MicroXAM phase shifting- and coherence scanning interferometry instrument[5] and analysed in Mountains Map Premium 6[6] to establish quantitative measures of the surface texture (see table 3). Initial focus was concentrated on the surface texture arithmetical mean height**,** *Sa*, according to ISO 25178:2011. *Sa* is considered as the surface texture property closely connected in internal company standards to the legislative demands on *bacterial resistance*, and *clean ability* i.e. connecting *Sa* and CAA. The CAA is considered "OK" when the Sa value for a given surface is <0.8µm [10]. NOTE: *Originally the "0.8µm rule" was determined for the profile ISO 4287:1997 Ra parameter, in this study replaced by the areal defined Sa parameter.*

Now, the correlation in between the experience and "feeling" (psychological requirements) and the function requirements (physical requirements) have to be established as well. It is obvious that the describing adjective words (*robust, resistant, clean, warm, sleek* and *elegant*) are possible to link to the function requirements. For instance, the adjective *clean* is directly connected to the demands; *clean ability* as discussed earlier but also secondly related to *chemical resistance,* and *scratch resistance*

Table 3. The relation between functional requirements and focus group judged as well as physically measured design parameters for CAA.

			Physical product properties, Design parameters **DP's**						
			Focus group qualitatively judged properties				Measured Properties		
			Surface texture	Chemical resistance	...	...	**Surface texture**	Haptic friction	Hardness
Functional requirements, **FR's**	Other	Shock resistance							
		Scratch resistance							
	Clean Ability Approach, **CAA**	Cleanability	**x**				**Sa<0.8um**		
		Bacterial resistance	**x**				**Sa<0.8um**		

while the material used will deteriorate in function if it is affected negatively by chemical agents and mechanical wear by surface scratching.

To further indicate the complexity, the functional demand on *scratch resistance* is regarded as linked to the adjectives *robust* and *elegant* by the focus group. Hence, it is obviously correlation not only between one describing word and a functional demand or property but also between several of the words and different demands and properties. It is therefore important to be aware of the complexity of reaching a certain experience or "feeling" for a product, without losing another experience when selecting between different product properties.

[5] ADE Phase Shift MicroXAM Optical interferometric profiler characteristics [online]. http://www.tcd.ie/CMA/misc/MicroXam.pdf
[6] Digital Surf, Besançon, France, http://www.digitalsurf.fr

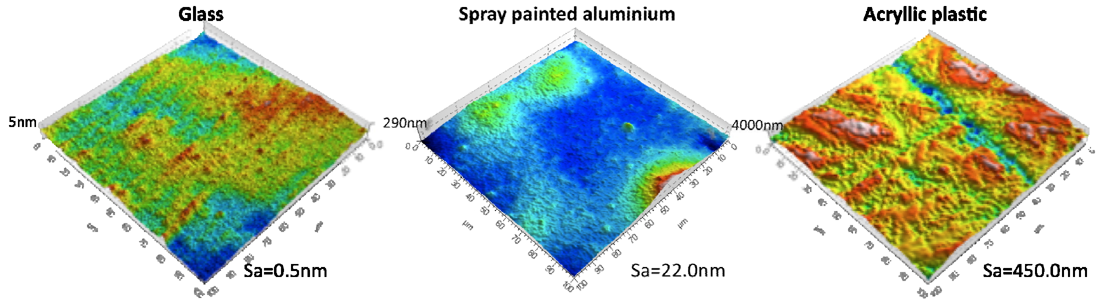


Figure 3. Coherence scanning interferometer 0.101x0.101mm measurements of the three candidate materials for replacing the stainless steel for washer-disinfector units. Arithmetic mean height (*Sa*) of the surfaces varies from below one nanometer to about 0.5µm –a factor of 900. All surfaces pass the current regulations for clean ability and bacterial resistance demands.

From figure 3 it is clear that all the three selected surfaces meet the requirements of CAA, *clean ability*, and *bacterial resistance*, as defined by the criteria *Sa*<0.8µm but two questions arise when considering this. Firstly, two of the surfaces have a *Sa*<<800nm and what does this mean for the function. Is an almost atomically flat scratch free surface like the *Glass* and *Spray painted aluminium* more beneficial? Secondly, is the *Sa* criterion valid for both functional CAA requirements? *Sa* is only one sub set of "field parameters" defined in ISO 25178:2 describing the mean amplitude of the surface texture. Spatial- or hybrid (combinations of vertical- and horizontal geometrical properties like slope and material distribution) geometrical information provides additional significant surface texture information.

By committing additional functional tests on CAA response by bacteria cultivation and cleaning tests in combination with more advanced surface texture characterisation more detailed models for the understanding of the function in relation to texture can be made. Optimizing models would be possible to design for detailed control of *clean ability* and *bacterial* growth and answers of the first question above could be given.

The fact that many surface texture parameters are closely correlated is also important to consider when answering the second question. Different physical explanations of CAA function could be masked by correlations between texture parameters describing different significant geometrical features. The *Sa* parameter correlates to 15 of the 20 ISO parameters in table 4 below. The possibility is high that some of the 15 parameters other than *Sa* have a more close relation to the physical reasons behind *clean ability* and *bacterial growth*.

Linear Correlation, R, between Surface texture parameters according to ISO 25178:2

Measured properties – Areal surface texture	Sq	Sp	Sv	Sz	Sa	Smr	Smc	Sxp	Sdq	Sdr	Vm	Vv	Vmp	Vmc	Vvc	Vvv	S10z	S5p	S5v	Sda	Sdv
	µm	µm	µm	µm	µm	%	µm	µm	-	%	µm	µm	µm	µm	µm	µm	µm	µm	µm	µm	µm
Sv	**0,94**	**0,87**	1,00																		
Sz	**0,96**	**0,91**	**1,00**	1,00																	
Sa	**0,99**	**0,95**	**0,90**	**0,92**	1,00																
Smr	-0,66	**-0,82**	-0,60	-0,65	-0,65	1,00															
Smc	**0,98**	**0,95**	**0,86**	**0,89**	**1,00**	-0,66	1,00														
Sxp	**0,98**	**0,90**	**0,96**	**0,96**	**0,95**	-0,62	**0,92**	1,00													
Sdq	**0,94**	**0,87**	**1,00**	**0,99**	**0,90**	-0,59	**0,87**	**0,95**	1,00												
Sdr	**0,93**	**0,85**	**0,97**	**0,97**	**0,91**	-0,49	**0,87**	**0,94**	**0,98**	1,00											
Vm	0,61	**0,81**	0,54	0,60	0,62	**-0,95**	0,63	0,54	0,54	0,44	1,00										
Vv	**0,98**	**0,95**	**0,86**	**0,89**	**1,00**	-0,66	**1,00**	**0,92**	0,87	**0,87**	0,63	1,00									
Vmp	0,61	**0,81**	0,54	0,60	0,62	**-0,95**	0,63	0,54	0,54	0,44	1,00	0,63	1,00								
Vmc	**0,97**	**0,95**	**0,86**	**0,89**	**0,99**	-0,64	**0,99**	**0,91**	**0,87**	**0,88**	0,62	1,00	0,62	1,00							
Vvc	**0,95**	**0,94**	**0,80**	**0,84**	**0,98**	-0,66	**0,99**	**0,87**	**0,81**	**0,82**	0,65	**0,99**	0,65	**0,99**	1,00						
Vvv	**0,97**	**0,88**	**0,96**	**0,97**	**0,94**	-0,58	**0,91**	**1,00**	**0,96**	**0,96**	0,50	**0,91**	0,50	**0,90**	**0,85**	1,00					
Spd	-0,36	-0,39	-0,35	-0,36	-0,35	0,37	-0,35	-0,35	-0,33	-0,30	-0,40	-0,36	-0,40	-0,35	-0,35	-0,34					
Spc	0,61	0,75	0,57	0,61	0,61	**-0,92**	0,62	0,57	0,57	0,47	**0,84**	0,61	**0,84**	0,62	0,62	0,53					
S10z	**0,88**	**0,80**	**0,97**	**0,96**	**0,83**	-0,50	0,79	**0,90**	**0,97**	**0,95**	0,47	0,79	0,47	0,79	0,73	**0,91**	1,00				
S5p	**0,95**	**0,84**	**0,93**	**0,93**	**0,93**	-0,45	**0,90**	**0,95**	**0,94**	**0,97**	0,40	**0,90**	0,40	**0,90**	**0,86**	**0,97**	**0,92**	1,00			
S5v	**0,80**	0,74	**0,94**	**0,92**	0,75	-0,49	0,70	**0,83**	**0,94**	**0,91**	0,48	0,70	0,48	0,71	0,64	**0,84**	**0,99**	**0,85**	1,00		
Sdv	**0,93**	**0,83**	**0,99**	**0,98**	**0,89**	-0,50	0,85	**0,94**	**0,99**	**0,99**	0,45	**0,85**	0,45	**0,85**	**0,80**	**0,96**	**0,97**	**0,96**	**0,94**	0,64	1,00
Shv	0,78	0,76	**0,91**	**0,90**	0,71	-0,60	0,66	**0,83**	**0,88**	**0,82**	0,58	0,66	0,58	0,65	0,59	**0,82**	0,91	0,75	**0,93**	0,75	**0,87**

Areal surface texture

Measured properties

Table 4. Correlation table expressing the linear correlation, R, between Areal surface texture parameters measured using optical interferometry. Figures in bold indicate a correlation higher or equal to 0.8 (R^2>=0.64).

4. Conclusions

- Kansei engineering is a strong product developing method generating information about the customer expectations and "feelings" of a sterilisation unit, its functional requirements and the connection to geometrical texture properties.
- Clean ability and bacterial growth are the main surface related requirements of the sterilisation unit.
- *Glass*, *Spray painted aluminium* and *Acrylic* plastic are all strong possible candidates to replace stainless steel for sterilisation units.
- The arithmetic amplitude of the surface texture, *Sa*, is closely historically related to clean ability and bacterial growth factors of the washer-disinfector unit.
- *Sa* is highly correlated to at least 13 of 20 ISO 25178:2 surface texture parameters.
- There exists a potential to closely study surface texture parameters to isolate in more detail other geometrical properties than mean amplitude to explain and model clean ability and bacterial growth of washer-disinfector units.

5. Future

Phase 6, Synthesis and Modelling the Domain Discussion needs to be preceded by a rigorous study to deepen the knowledge about the CAA requirements of a clean and bacterial free surface. Practical tests will be carried out to enable detailed modelling of surface texture as a variable creating desired "feelings" and user experiences from the introduction of new materials and surface textures in the washer-disinfector unit domain.

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