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CREATING AWARENESS ON NATURAL FIBRE COMPOSITES IN DESIGN

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1. Introduction

There are more than 2,000 different plant fibres in the world (such as abacá, bamboo, cane, coir, corn, cotton, flax, etc.) processed into long continuous threads mainly for weaving and textile production; or chopped as a filler material and combined with a resin to create Natural Fibre Composites (NFCs). The use of natural fibres particularly within composite materials is predicted to be a growth market [Rognoli et al. 2011]. In literature, the most important properties of NFCs are listed as follows [Brosious 2006], [Taekema 2011]: (a) they have low density, resulting in higher specific strength and stiffness; (b) natural fibres are from a renewable source, (c) NFCs can be easily recycled (depending on the type of the matrix and the properties of the fibres after the treatment) and thermal recycling is possible, (d) natural fibres have high thermal and acoustic insulation, (e) natural fibre parts consume 60% less energy in production (for average car parts), and (f) NFC parts are producible with low investment and straightforward technology, ideally suited to low wage and developing countries. NFCs are largely applied in automobiles and structural engineering. Although they have noteworthy envrionmental, cost and performance related superiorities for products, they are not widely recognised and applied in product design. This might occur mainly due to the lack of knowledge and awareness on these materials.

Stemming from this argument, Delft University of Technology, with a support from Dutch Government (AgentSchap NL), has initiated a foundation of a knowledge platform for creating awareness on Natural Fibre Composites among Dutch designers to increase the application possibilities of NFCs. As an initial activity of the NFC Design Platform (www.nfcdesign.org), an online questionnaire has been conducted with 46 Dutch designers to explore (a) if they are familiar with NFC materials; (b) if they use NFC materials in their designs and (c) what reasons are behind their positive/negative answers (regarding the use of NFCs in design). The results of the questionnaire revealed that 34 out of 46 designers have heard about NFC materials but only 9 of them applied them in their designs. Most of the designers did not have a chance to use NFCs (17) or they stated that they were not familiar enough with the material (8). The designers who have applied NFCs in their designs related their motivation to environmental and aesthetic qualities of NFC materials (9). Most of the designers would like to learn more about NFCs (39) (for the detailed explanation of the questionnaire results see [Taekema 2011]). This quick overview confirmed our prediction regarding the lack of use and awareness among Dutch designers with regards to NFCs and motivated us to pursue with a next step in our study which was to develop a NFC Design Tool Kit. The aim of the developed NFC Design Tool Kit was two-fold: (1) to provide product designers with variety of information regarding different types of NFC materials in a short period of time (e.g. within a workshop setting which we aimed to conduct in the 1st NFC Design Event) and (2) to inspire them to consider NFC materials in their designs. In the following section, the background of the Tool Kit idea is explained. In Section 3, the development and the application of the Tool Kit with 30 participants of the 1st NFC Design Workshop are thoroughly explained.

2. Background

Traditional approaches to materials selection often rely on previously used materials, which results in safe however limited solutions [Karana 2011]. *Inspiration* in materials selection plays an important role on the innovative and effective use of materials in different applications. The existing databases usually lack the inspiration designers need at the conceptual design phase [Ramalhete et al., 2010]. At the concept creation, the designer requires preliminary data for selection of the widest possible range of materials [Ashby 1999]. Here designers mostly prefer images (of *sample materials* and *example products*), supported with minimal text-based information from a source to support the preliminary selection [Karana et al. 2008], [Van Kesteren 2008]. In a first encounter with a material designers touch and feel the material, seek for the opportunities to apply the material in a design, and try to understand what makes this particular material different than other materials (i.e. *unique material properties*). A material can differ from another material with its specific sensorial properties (e.g. with its velvet like texture, with its transparency, etc.), technical properties (e.g. with its specific tensile strength, with its heat conductivity, etc.), its formability/processability (e.g. it can be injected moulded, or it can be painted), etc. This process of understanding the unique properties of materials usually takes place at the *conceptual design phase*. Thus, in the first acquaintance, designers would like to get an overview of these key properties which might inspire and stimulate them to prefer a particular material among others.

Unless technical requirements are defined at the outset of the project, product designers consider technical properties at an overview level and not in detail at the conceptual design stage [Ashby and Johnson 2002], [Karana et al. 2008], [Van Kesteren 2008]. On the other hand, the *intangible characteristics of materials*, involving the perceived values and cultural meanings, trends, associations and emotions evoked by materials play an important role in the product designers' decisions on materials in their first encounter [Karana 2009]. Following this background information from the literature and from the previously conducted studies [Karana 2009], we came up with a NFC Design Tool Kit concept, which is explained in the following section.

3. NFC Design Tool Kit

The above described background information helped us to list a number of requirements we aim to achieve through the NFC Design Tool Kit:

- The Tool Kit, which will be the 1st acquaintance of designers with NFC materials in a workshop setting, should avoid giving detailed information which is required more in embodiment and detailed design phases
- On the other hand the Tool Kit should provide sufficient information regarding the varieties of NFC materials
- It should include material samples and example applications to touch & feel
- Provided samples should present a diversity of sensorial and technical properties. In addition, samples should exemplify different manufacturing processes to assure that designers get an overview of possible manufacturing processes applicable to NFC materials
- The Tool Kit should encourage designers to think about different applications for NFC materials

We expect that focusing on the conceptual design phase where designers create ideas will generate further curiosity regarding more detailed information of NFC and processing opportunities.

3.1 Method

In order to present NFC materials in an informative and inspirational way and to stimulate designers to consider NFC materials in various design applications, we came up with an idea of a *creative game* where designers who attend the NFC Design Wokshop are asked to create different concepts within a limited time slot. They are given a design brief which is created based on the Meanings of Materials

(MoM) Model by [Karana 2009] (Figure 1). The MoM Model shows the various aspects considered by designers in user-material interaction in order to create a particular meaning through a material. All main components (User, Material, Product, Context and Meaning) of the MoM Model are used to create a design brief which encourages designers to think various aspects of NFC materials in a design process. Asking designers to come up with ideas (by using the given material samples) with their own intuition was considered more time consuming in a workshop setting where the aim is to make designers familiar with NFC materials through variety of samples and to make them considere these samples withing a product context. This was the main motivation behind giving more refined design briefs based on a developed material interaction model.

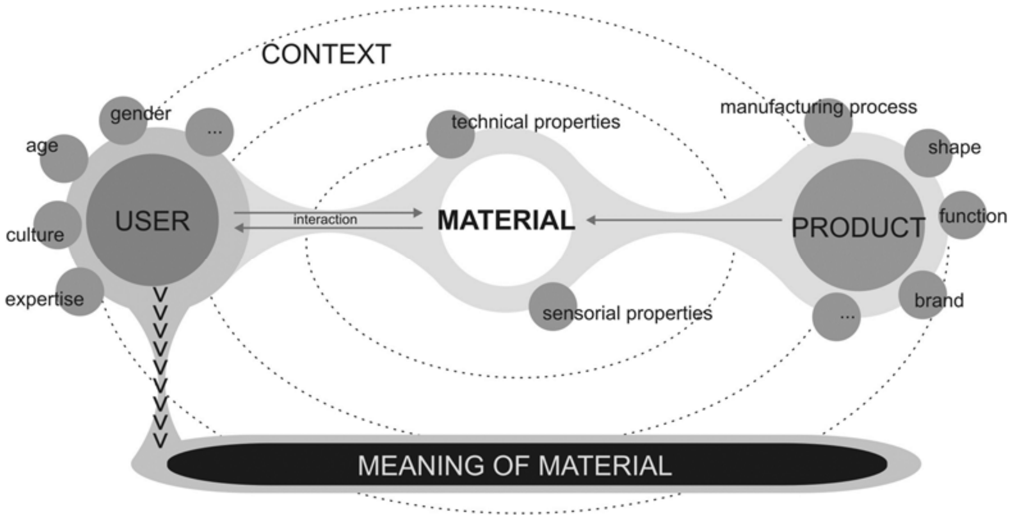

Figure 1. The Meanings of Materials Model [Karana 2009]

In the design brief, aspects (or specifications) related to a particular component are written on individual cards which we name 'aspect cards' (Figure 2, left above). Product component of the MoM Model is represented with a 'function' in the design briefs to broaden the possibilities in designs (i.e. instead of asking 'design a chair', we ask 'design a sitting element'). Next to aspects cards, a 'material card' is presented by using the MoM Model with a specific NFC material on the 'material component' of the model (Figure 2, right). Designers are provided with a short explanation (with emphasized keywords) and a material sample regarding NFC Material on the material cards. A design brief is completed when designers stick the given aspect cards on a material card. These altogether make the final design brief, for instance: *Design an aggressive product made of the 'given NFC material' to be used by males for keeping touch in a locker room. You are expected to emphasize the* ***key material properties*** *presented in the given material explanation.* Key material properties emphasized in the material cards are grouped under three main categories: sensorial properties, technical properties and manufacturing processes. These three categories are represented with pictograms on the material cards (Figure 2, left below). A number of material suppliers and NFC product manufacturers were approached to create the material cards for the Tool Kit. The collected materials that have been used in the final workshop and the given material information have been finalized after the pilot study which will be presented in the following section.

3.2 Pilot Study

The pilot study was conducted to explore the following questions: Is the proposed method comprehensible? How much time should we give to participants for a design brief? Should participants create ideas individually or as a group? Is the given information regarding a material sample sufficient? Six master students from the Faculty of Industrial Design of TU Delft participated in the pilot session. None of them were experienced in designing with NFC materials. First a short introduction about the Meaning of Material Model was given and the aim of the workshop was explained. In total, four rounds with four different design briefs have been played. Participants were asked to create ideas individually for the first two rounds. In the first round, they were given eight minutes. In the second round, we divided the eight minutes into two parts as three minutes for brainstorming and five minutes for visualizing the ideas. Then in the third and fourth rounds they were asked to make two groups (three students per group). We followed again the similar time setting for the last two rounds (eight minutes in the third round, and 3+5 minutes in the last round).

Figure 2. The Tool Kit Components: Four selected aspect cards of the Tool Kit to create a design brief (left above); A material card (right); Three pictograms (manufacturing process, sensorial properties, technical properties) used on the material cards (left below)

Results of the Pilot Study

All participants found proposed method comprehensible and informative. They added that the method was enjoyable and given design briefs encouraged them to create ideas. They emphasized that the method as a creative design game was useful to get acquaintance with a number of materials. Although they found the given time sufficient for creating an idea, they stated that the textual explanation provided on the material cards was too long to be read in the given time span. They suggested giving the related information in keywords. When they were asked if they required more time for creating ideas, they emphasized that the given time was sufficient and it was convenient for a game setting where they preferred to design with variety of samples instead of spending too much time on one sample. On the other hand, they found the time division as 3+5 very helpful for making a systematic process to finish the idea creation in time. They also emphasized that they found the group sessions more useful and enjoyable than the individual sessions. In the group sessions they were able to make short discussions on material properties and they stimulated each other in the design process. They wished to see more material samples (at least 6-8 rounds) to become more familiar with NFC materials. Based on the results from the pilot study, the following decisions were taken to be applied in the main study:

- the method is comprehensible and enjoyable to be applied in the workshop setting as it is
- material information on the material cards should be rewritten as keywords
- participants will be asked to design as groups
- in total 8 minutes will be given for an individual round with 3+5 division
- the procedure will be repeated 8-10 rounds, with new design briefs and new material cards in each round

After workshop, the material samples collected from the NFC manufacturers and material suppliers have been reanalysed to decide on what kind of properties can be emphasized for each sample. Figure 3 depicts the 10 material samples and corresponding explanations (with emphasized keywords) presented on the material cards.

Figure 3. Ten material samples and corresponding explanations written on the material cards

3.3 Application

The final version of the Tool Kit was applied in the 1st NFC Design Event on April 2011. In total 30 people participated in the workshop (professional designers (17), design academics (2), master design students (8), material suppliers (3)). Except for three material suppliers, the participants were not experienced in designing with NFC materials. All participants visited the morning session of the program where various presentations were given on potentials of NFC for design applications.

First a short introduction about the Tool Kit was given. The participants were asked to form groups of three persons. Tables were prepared beforehand to ensure a smooth process. All groups got: 10 material cards; 10 envelops (for each 10 round one envelop containing four aspect cards); One NFC Material sample that matches with the first material card on the table; Drawing materials (markers, fine liners and blank papers); and a leaflet with an explanation of the toolkit and extra material information on the samples. During each round all groups handled one material sample, the accompanying material card, and one set of aspect cards. All groups got the same aspect cards but a different NFC material in a round. This helped us to compare the results more easily after the workshop. Table 1 shows the given aspect cards to the groups in different rounds. The aspect cards were printed on stickers, and therefore could be easily attached to the material cards.

Table 1. User, Context, Function, Meaning aspect cards making 10 design briefs

Round	User	Context	Function	Meaning
1	Family	Garden	Eating	Cosy
2	YUP	Bedroom	Storing	Feminine
3	Children	Outdoor	Playing	Strange
4	Backpacker	Nature	Cooking	High-tech
5	Teenagers	Beach	Protecting	Masculine
6	Singles	Train station	Listening	Flashy
7	Couples	Festival	Sitting	Sexy
8	Business men	Fair	Writing	Elegant
9	Women	Office	Communicating	Retro
10	Students	Party	Socializing	Toy-like

As explained earlier, each round was divided into a brainstorming part of three minutes, and visualising the ideas part of five minutes. After each round the samples were passed to the next group, and the groups were told to open the next envelop and stick the aspect cards on the next material card. The previous assignments and accompanying drawings were collected. After the 5th round groups were slightly rearranged to create new acquaintance opportunities for participants. We asked one person of each group to move to the next group. In total, eight rounds were "played" (within the allocated time for the workshop). At the end of the workshop, the collected drawings (or written ideas) were exhibited to workshop participants. Figure 4 shows an overview from the workshop.

Figure 4. Group settings in the workshop

Results

At the end of the workshop 80 ideas for NFC applications (eight ideas per material sample) were generated. To be able to analyze the results, all drawings and accompanying design briefs were scanned and grouped based on rounds and based on given samples. The efficiency of the Tool Kit was examined by the following criteria: (1) Did participants use the given information of the material card in their designs? (2) Did participants use all the aspect cards in their designs? The results are summarized into two graphs (Figure 5). The first graph (on the left) depicts for which NFC material samples participants applied the given material information and the given aspect cards in their designs. In the second graph how the information and aspect cards use change per round (same aspect cards, different samples) is showed.

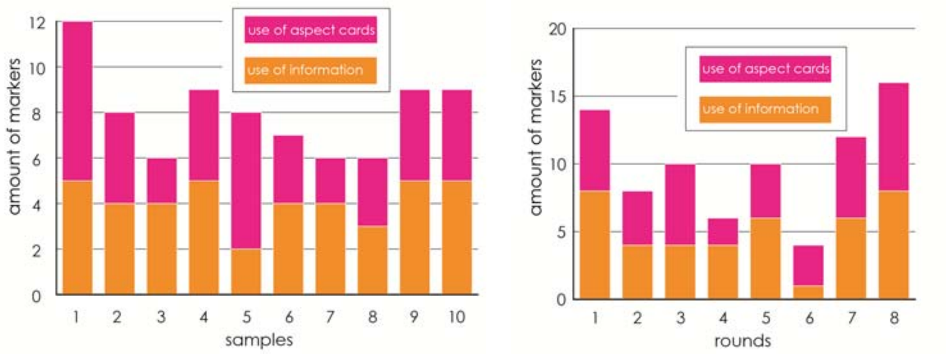

Figure 5. Use of the Tool Kit material information and aspect cards per sample (left) and per round (right)

In total, material cards were used in 54 % of the proposed design ideas. The provided material information for the samples 1, 4, 9, 10 was used in a higher rate (63 %) in comparison to the other material cards (Figure 6). The least used information (29 %) was of the sample 5. For the use of the aspect cards, the first sample had the highest score. In 88 % of the ideas the aspect cards were used for this sample. The ideas proposed for samples 3 and 7 showed the use of aspect cards in lowest degree (29 %). In total the aspect cards are used in 51 % of the proposed applications. The aspect cards were used in a higher rate in round 8 (80%). In addition, the provided information of the material samples was in a higher rate used in this round (80%). Round 6 was the least efficient round, where only in 33 % of the designs all the aspects cards were applied. Moreover in this round only 11 % of the material information was applied.

3.4 Discussion

In informal discussions with workshop participants, we were able to conclude that the Tool Kit was successful in introducing variety of NFC materials to designers in an *enjoyable* and *inspiring* way. The provided material information on material cards was used in more than half of the created ideas in the workshop. It is hard to determine definitive reasons on why information of some material cards was used more effectively than others. On the other hand, when we grouped the highly or least used material information (with correspond to samples), we could find some common patterns to discuss these results further.

Use of material information

What we commonly see in all four cases of highly used material information cards (1, 4, 9 and 10) is that the given material information can easily be detected in the corresponding material sample. Material information - material sample match might play an important role on the comprehensibility of the provided information. In addition, the information given in the above mentioned four cards was relatively easier to apply comparing to other cards. For example, the information related to toughness and elasticity in material card 4, was much easier to apply in a product than the material information related to 100% biodegradable in material card 5. The type of information, whether the given info is related to manufacturing process, sensorial aspects or technical aspects might affect the efficiency of the information use in the process. On the other hand, when one thinks about the reasons behind the least used information card (sample 5), he/she might conclude that if the given sample is a finish product, participants might not need to learn further about the material. In other words, in that case the provided sample talks for itself. When the provided sample/product provides participants with enough inspiration/information itself, they do not seek for additional written information and just use the properties observed in the physical sample. Below figure exemplifies one of these cases where designers use the ‘friction’ of the material in their idea although this property is not given in the information card (Figure 6, left). We expect that the familiarity with a provided sample/product (which is the case of Sample 5) might also affect the use of material information.

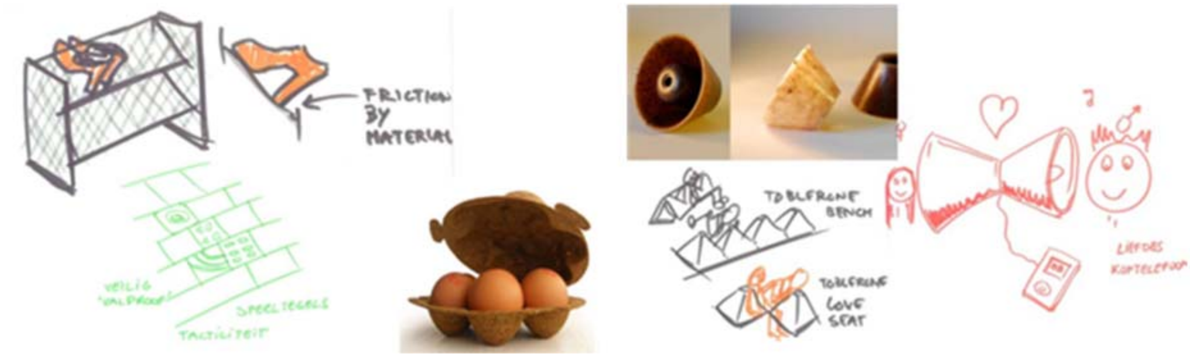

Figure 6. Participants are inspired by a property of a material which is not given in the written text but deducted from the sample (left); Participants inspire by the shape characteristics of the material samples (right)

Inspiration by material samples: shape, production techniques and sensorial properties: Shape of the material samples (geometric, organic, amorphous, etc.) had some obvious effects on the final results. A clear example of this can be seen in the use of sample 10, the injection moulded sample made of PE and coir fibres. The shape of the truncate cone can be found in different ideas (Figure 6, right). Might this be a drawback for a Tool Kit in the sense that a specific shape of a sample overshadows the given material information? We believe not. *Shape* often unveils the possibilities and limitations of the production technique that is used to process materials. In the previous example, the features (angled surfaces) are needed to release the part after injection moulding. Therefore, by adapting the shape characteristics in the design proposals, the participants create something that is producible. Moreover the shape of the sample shows that complex parts with high tolerances are possible to produce. This is for example used in the idea below, where the sharp-edged shape of a sample is used in an idea for a cutting device for children (Figure 7, left).

Figure 7. Participants are inspired by a sharp-edged shape of a material sample (left); Participants are inspired by the sensorial aspects of material samples (right)

Besides the shape characteristics, some participants were also inspired by the sensorial properties of the material samples. The visual properties of sample 10 (e.g. colour, patterns) are compared to chocolate, and used as inspiration to design a *chocolate bar*, and *chocolate love seats* (Figure 7, right). In addition, the translucency of the same material is used for designing a *windshield for camping fires*, and a *ballpoint* where the translucency is used in combination with a LED to lighten the pen. Tactual properties of samples are also used for inspiration. This can be seen in a previously given example (Figure 6, left) of a shoe shelve where the friction is used in the design. In the same figure, another example where participant are inspired by the tactual properties of the same sample in their *play tiles* design is shown.

Use of aspect cards: When we look at the overall results, it can be stated that the aspect cards motivated designers to create various ideas; and most importantly showed them the different possibilities in designing with NFC materials. The variety in the level of use of aspect cards in different rounds can be explained with the easiness/difficulty of the design brief which is determined by how the given aspects are linked to each other. In round 8 the aspect cards (business men, fair, writing, elegant) are mostly applied in created design ideas. All the given aspects are closely related to each other (i.e. business-man and writing, business-man and elegant can be associated) and therefore might be more easily applied in design ideas. On the other hand, in round 4, the aspect cards *backpacker*, *nature*, *cooking* and *high-tech* were not applied in a higher rate. One reason behind this result might be that participants could not associate *nature* with *high-tech* products; or high-tech products with NFC materials. Another reason behind this result might be that the function of the product (i.e. cooking) might be more difficultly associated with NFC materials.
Efficiency based on the rounds: The decrease in the use of provided material information and the aspects cards in round 6 can be explained with the rearrangement of the groups after the fifth round. The participants were not familiar with each other; they introduced themselves, exchanged business cards, etc. This 'getting used to each other' session might take time and participants might feel less confident to share their ideas in a new group. On the other hand, in round 7 we observe a sudden growth in the application of the aspects cards and the provided material information. We observe that participants found some design briefs more interesting than others. For example, in round 7, participants were given the following aspect cards: *couples*, *sitting*, *festivals*, *sexy*. This shows that the interest towards a given design brief might have a major effect on the results of the Tool Kit application.

4. Conclusion

It can be concluded that the NFC Design Tool Kit as an informative tool, which presents a variety of NFC materials in a creative game format, was found enjoyable, inspiring and well structured by designers. They also expressed their wish to learn more about the technical aspects of the materials and the production possibilities. This was parallel to our expectations that the Tool Kit created further curiosity regarding the presented materials. The Tool Kit is aimed to be further developed (in progress) with an extension that can support designers in different phases of the design process by including more specific information regarding the technical properties and production techniques of NFC materials.
It should be remembered that the assessment of the created ideas is based on the subjective evaluation of the facilitators. We looked for clear indications (written words, clear *context of use* indications) and first evaluated individually then compare our own interpretation with each other. Nevertheless we are aware of the fact that the created graphs in Figure 6 might be slightly different when the ideas are evaluated by another expert. Moreover, the results might also be affected by the drawing qualities of the participants. Although the propose evaluation method helped us to create a rough overview on the usefulness of the Tool Kit, in next steps, more detailed assessment, including further interviews with the workshop participants on the created ideas is recommended. After conducting the study with different participants with a more detailed assessment, more significant conclusions can be obtained. It should also be recognised that despite the fact that the Tool Kit has been developed for introducing a particular material type (NFCs) to designers, the principle behind the Tool Kit can be with ease applied to any other type of material for similar motivations in mind (i.e. creating awareness, inform and inspire).

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