Material Considerations in Product Design:

A Survey on Crucial Material Aspects Used by Product Designers

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Abstract

The competitive market rising from the increase in product consumption makes product designers consider more about materials than before. Materials, indeed, have been extensively studied in science and engineering for years. Existing materials selection sources can serve as useful function in giving up to date information on technical (physical, quantifiable) characteristics of materials. However, designers also use some intangible aspects with the aim of expressing their intentions; attributing some meanings to their products through their appropriate choices of material. The main objective of this paper is to evaluate materials selection process in product design in order to find out what kinds of aspects of materials are significant for product designers in their selections. This paper includes an experiment conducted with 20 professional designers. The findings from the experiment were used for establishing a required data table representing the material considerations of designers in materials selection. The crucial role of intangible characteristics of materials in their selections is emphasized.

Keywords: *selection of materials, properties of materials, product design,*

1 Introduction

In the 21st century, one of the hallmarks of modern industrialized society is the rising use of materials. Not only are people consuming materials more rapidly, but also they are using an increasing diversity of materials. Indeed, it has been postulated that assuming current trends in world production and population growth, the materials requirements for the next decade and a half could equal all the materials used throughout the history up to date (Forester, 1988).

People interact with these vast numbers of materials mostly via products. The interaction involves a number of attributes. For instance, material of a product with its technical properties should fulfill the functional requirements for an intended use and with its sensorial properties it should appeal to the senses of its user. Therefore, product designers are responsible for selecting appropriate materials for their products by taking these technical and sensorial characteristics of materials into consideration.

However, the competitive market rising from the increase in product and material consumption have made product designers consider some intangible aspects besides the technical and sensorial ones. For instance, designers have started to make us of materials in order to attribute particular meanings to their products or support the existing meanings. There are plenty of examples that provide sufficient proof for this statement. For instance, metal appears cold and can connote precision, and it seems durable and robust; for this reason, designers can use metal to emphasize the technological superiority and high level engineering (Arabe, 2004).

Materials indeed have been extensively studied in science and engineering for years. Existing materials selection sources can serve a useful function in giving up to date information on the technical (physical, quantifiable) aspects of materials. However, as mentioned in the previous paragraph, product designers use also some intangible aspects, in order to express their intentions through the selected materials. Conversely, even though these intangible aspects in materials selection process are crucial for designers, the existing materials selection sources neither consider them, nor offer a systematic way for involving them into materials selection process. Ashby and Johnson (2002) state that for engineering designers, it is easy to access to information they need- handbook, selection software, advisory services from material suppliers- and to analysis and optimization codes for safe, economical design. However, they add that, at this point product designers are disappointed that they do not have equivalent support. In other words, there is no similar abundance of support for product designers.

This paper aims to find out the aspects of materials, which predominantly shape the materials selection process in product design, in order to emphasize the 'insufficiency' of the existing sources for product designers. The ultimate goal is to provide guidelines for further studies and for the establishment of a new selection source for designers.

In the next section, we explore the effective materials selection criteria, which mostly take place in engineering based sources. The aim for this exploration is to underline the missing, or insufficient points of these sources for product designers. The third section concentrates on the intangible characteristics of materials mentioned in design related sources and current researches. After that, the fourth section addresses a field study conducted with 20 industrial designers in Turkey for identifying their materials considerations and the data they need while selecting materials. Finally we come up with a *required data table*, which, we suppose, provides a valuable guideline for further studies and for the establishment of the new selection sources.

2 Factors effective in materials selection in engineering design

The selection of a material for a specific application is a thorough, lengthy and expensive process. Almost always more than one material is suited to an application, and the final selection is a compromise that brings some advantages as well as disadvantages.

There are many factors or constraints to be considered in selecting materials. There are of course some situations that the certain criteria for a material are defined at the beginning of the design project. Although at such situations the required criteria dominate the selection process, most of the time one material among a range of materials is selected depending on some factors. At different engineered based sources, the factors that affect the materials selection are grouped under various subtitles, which can be followed in **Table 1**. Although most of these sources define the design process as an entire process covering both technical and non-technical issues of design, they mostly concentrate on the technical side; which shape the content of the engineering based sources.

Patton (1968) states that, when a designer selects a material, he must consider fulfilling the three basic requirements: (1) *service requirements*, (2) *fabrication requirements* and (3) *economic requirements*. According to him, the service requirements are supreme. The material must stand up to service demands which commonly include dimensional stability, corrosion resistance, adequate strength, hardness, toughness and heat resistance. The material must be possible to shape and join to other materials. Patton puts those properties of materials under 'fabrication requirements'. Finally, he states that, the objective of a designer is to minimize overall cost of the product and manufacturing. For example, a more expensive free-machining metal may be substituted for a standard metal, since the savings in machining cost may overweigh the increased cost of the more expensive metal.

Table 1 Review of different sources defining the effective material aspects for materials selection process.

Materials (1967)	**Patton (1968)**	**Esin (1980)**	**Ashby (1992)**	**Lindbeck (1995)**	**Budinski (1996)**	**Mangonon (1999)**	**Ashby & Johnson (2002)**	**Ashby (2005)**
- Mechanical properties	- Service requirements	- Production requirements	- General properties	- Mechanical properties	- Chemical properties	- Physical factors	- General attributes	- General properties
- Cost	- Fabrication requirements	- Economic requirements	- Mechanical properties	- Physical properties	- Physical properties	- Mechanical factors	- Technical attributes	- Mechanical properties
	- Economic requirements	- Maintenance	- Thermal properties	- Chemical properties	- Mechanical properties	- Processing and fabricability	- Eco attributes	- Thermal properties
			- Wear	- Thermal properties	- Dimensional properties	- Life of component factors	- Aesthetic attributes	- Electrical properties
			- Corrosion/ oxidation	- Electrical properties	- Business issues	- Cost and availability		- Optical properties
				- Acoustical properties		- Codes, statutory and other		- Eco properties
				- Optical properties		- Property profile		- Environmental resistance
						- Processing profile		
						- Environmental profile		

In another source, the '*mechanical properties of materials'* and the '*cost'* are identified as the two basic requirements in materials selection (Materials, 1967). The authors explain that, the acknowledgment on the basics of the mechanical properties of materials provides the development of material science and encourages designers to explore new use areas for new materials; because mechanical properties of materials define their usage and environment. Strength and rigidity, quality and durability of the surface are listed as the most important mechanical properties.

Similarly, according to Lindbeck (1995), requirements related to the *physical properties* (material's melting point, density, moisture content, porosity, and surface texture); *chemical properties* (resistance to corrosion and dissolution); *thermal properties* (heat conductivity, heat resistance); *electrical properties* (materials' conductivity and resistance to electrical charges); *acoustical properties* (materials' reactions to sound), and *optical properties* (materials reactions to light), must be fulfilled through appropriate materials selection. He adds that, *mechanical properties* are especially important because they are indicators of strength, producability, and durability. Knowledge of such forces and the ways in which materials react to them are valuable in determining which material to use in a specific application.

Budinski (1996) divides the factors to be considered in materials selection into four major categories: (1) *chemical properties,* (2) *physical properties,* (3) *mechanical properties* and (4) *dimensional properties.* As being different from other sources, he uses 'dimensional properties' as an individual title. To him, this category is not listed in property handbooks, and it is not even a legitimate category by most standards. However, he emphasizes that, the available size, shape, finish, and tolerances on materials are often the most important selection factors.

Another unique term used by Budinski (1996) is 'business issues'. In the U.S. and some European countries, environmental and regulatory issues, which he calls the business issues because business must deal with them, can be of equal importance with, or even of more importance than, economic factors. Because, it may not be possible to use a particular material (no matter how appropriate it is) unless it is on 'the approved list' of some regulatory agencies. For example, in the U.S., the Food and Drug Administration regulates the materials of construction that can be used for medical instruments.

Budinski also stresses the significance of the 'availability' factor. According to him, one of the first things that many designers ask initially while considering the use of a specific material is whether the material is on hand. A "no" answer will provoke a second question: Can we get it in one week? Two weeks? And so on. If this answer is acceptable, the next question is, do we have to order a minimum quantity? He adds that, there are more than 15,000 plastics that are commercially available, but only a dozen or so are available in standard shapes from warehouses. Since it is the designer's responsibility to establish a time line for procurement of materials, and if a desired material cannot be obtained within the constraints of this schedule, another material will have to be substituted or he recommends selecting materials that are known to be readily available.

Esin (1980) groups the factors considered in materials selection under 3 categories: (1) *production requirements*, (2) e*conomic requirements*, and (3) *maintenance requirements*. Esin explains that, a material, which has been selected on the basis of its functional merits, must also be capably embodied. The designer, therefore, take into consideration of a much wider range of properties such as the ability of the material to be machined, shaped, formed, cast, welded, hardened etc. For most situations, the designer has to make some sort of comparative assessment to select the most favourable material. Like Patton, he believes that the greatest limitation to any material is the final *cost of the product* manufactured from it. Finally, Esin states that, the designer must also consider the *maintenance requirements*; whether replacement or repair is envisaged will depend upon the size of the part, extent of possible damage, maintenance and repair faci1ities of the potential costumers and the acceptable level of replacement or repair costs.

Mangonon (1999), a well-known design engineer, defines five factors having influence on materials selection: (1) *physical factors*, (2) *mechanical factors,* (3) *processing and fabricability,* (4) *life of component factors,* (5) *cost and availability and* (6) *codes, statutory, and others.* Named differently, *life of component factors* herein relate to the length of time the materials perform their intended function in the environment to which they are exposed. The properties in this group are the corrosion, oxidation, and wear resistance, creep, and the fatigue or corrosion fatigue life properties in dynamic loading. As it is seen, he combines '*cost'* and *'availability'* criteria, and explains that, in a market-driven economy, these two factors are inseparable. For the last category- *codes, statutory, and other factors* which had been called as 'business issues' by Budinski (1996)- Mangonon states that, *Codes* are sets of technical requirements that are imposed on the material or the component. These are usually set by the customer, or are based from those of technical organizations such as the ASTM (American Society of Testing Material, 1958). *Statutory* factors relate to local, state, and federal regulations about materials and processes used or the disposal of the material. These are regarding to health, safety, and environmental requirements.

Interestingly, at most of the sources, the environmental issues are placed at the bottom of the listed requirements for design engineers. On the other hand, Mangonon (1999) makes another classification for the current design engineers, and organizes the factors under three topics: (1) *property profile*, (2) *processing profile*, and (3) *environmental profile*. As indicated by him, selection based on the environmental profile covers the impact of the material, its manufacture, its use and reuse, and its disposal on the environment topics. He adds that designers and companies feel that if the costs of incorporating them in design are prohibitive, the environmental aspects are usually laid aside, unless law mandates it. However, Mangonon says that in spite of the added cost, designing for the environment is a good strategy because it can be a good marketing tool for environment-conscious consumers.

Ashby (1992) puts the emphasis on (1) *general properties*, (2) *mechanical properties*, (3) *thermal properties*, (4) *wear* and *corrosion/ oxidation properties* of materials. In the more recent edition of his book, Ashby (2005) defines the basic design limiting properties of materials as: (1) *general properties* of materials (density and price), (2) *mechanical properties*, (3) *thermal properties*, (4) *electrical properties*, (5) *optical properties*, (6) *eco- properties* and (7) *environmental resistance properties* of materials.

Ashby and Johnson (2002), besides the (1) *general*, (2) *technical* and (3) *eco- attributes*, add the (4) *aesthetic attributes* of materials (which are the sensorial properties of materials, like warmth, softness, etc.) into their material properties list for designers. Ashby and Johnson were the first authors we come by, who were mentioning the significance of the aesthetic attributes of materials for a proper materials selection in product design. In addition to the aesthetic attributes of materials, they define the materials' two overlapping roles as: providing technical functionality and creating product personality. Accordingly, they redefine their list of requirements adding some intangible issues: (1) *technical*, (2) *economic*, (3) *sustainability* (related with environmental issues), (4) *aesthetic*, (5) *perceptions* and (6) *intentions*.

Likewise, a few sources slightly touch upon similar kinds of intangible characteristics of materials; but they do not propose to integrate these characteristics into their material requirements list. Lindbeck (1995) names these characteristics of materials '*indefinable characteristics of materials'*, which are the appearance, odour, feel, and general impression that result from special uses and combinations of materials for aesthetic purposes. He emphasize that these characteristics are directly related to the emotional approaches of the consumers and can easily be affected by the marketing strategies. Patton (1968) also mentions this issue and says that:

> Interesting to note the high value at which the market rates some properties and the low value applied to others. Relatively little economic value is attached to a high modulus of elasticity, for example…the attractive appearance of the plastics vastly overweighs their poor dimensional stability.

Consequently, if the concise evaluation of this section is done, it becomes apparent that: the existing engineering design based sources put more emphasis on the technical properties of materials. In more recent sources, like Ashby and Johnson (2002), the significance of sensorial properties and the intangible issues like perceptions, associations and emotions are underlined. Nowadays, some researchers in design and materials field explore this topic intensively and define the major design limiting materials characteristics based on product designers' needs and expectations. In the next section, some of these studies will be examined for the aim of finding out what these characteristics are.

3 Intangible characteristics of materials (ICM)

Product designers may have several questions regarding to intangible characteristics of materials (ICM) come along with the materials selection process, like "Does the selected material support the indented meaning of the product?", "Does it convenient for the aimed target group?", or "what kinds of associations can it evoke?".

In existing literature on materials and design, the collective approach is the emphasis on the significance of the ICM. They mention these characteristics in various ways; such as, the second and third order materials characteristics (Hodgson and Harper, 2004), emotive- stage materials characteristics and softer criteria of materials' considerations, invisible characteristics (Lefteri, 2005), less tangible issues of materials (Conran, 2005), qualitative properties (Jee and Kang, 2001; Edwards, 2002), non-active or passive functions of materials (Deng and Edwards, 2005), non- technical issues of materials (Ferrante et al, 2000), material image, metaphysical aspects of materials, non- physical properties of materials (Ljungberg and Edwards, 2003), material personality, personal dimensions of materials (Ashby and Johnson, 2002, 2003), intrinsic cultural meanings of materials (Manzini, 1986), subjective dimensions, essential and indicative character of materials (Rognoli and Levi, 2004), perceived characteristics of materials (Zuo, 2005), and perceived values of materials (Karana, 2004a, 2004b). Although, most of the authors try to highlight the similar kinds of materials characteristics with the terms above, there is not an exact, or conjunctive, definition used by all of them. On the other hand, the one of the most important common points lying under the given terms is that they are all expressing some *intangible* characteristics.

The dictionary definition of *intangible* is: (1) not having a physical substance or intrinsic productive value (of especially business assets: intangible assets such as good will), (2) incapable of being perceived by senses especially the sense of touch, (3) hard to pin down or identify, (4) lacking substance or reality; incapable of being touched or seen (Word Net*, 2005). When it is adapted to the materials domain, the *intangible characteristics of materials* are the attributed meanings and the evoked emotions, which cannot be identified with the numerical values and cannot be perceived by senses (Karana, 2006).

Although in literature, as it was affirmed in previous paragraphs, the significance of benefiting from the ICM is emphasized, only few authors (Hodgson and Harper, 2004; Ferrante et al, 2000; Ljungberg and Edwards, 2003; Karana, 2004b; Zuo, 2005) conducted experiment on this subject and proposed a way for linking them to materials selection process for designers. Explicitly, there is not a materials selection source, which integrates the ICM with the tangible selection activity in design process. The existing sources are inadequate for product designers (Karana, 2004a; Deng and Edwards, 2005; Hodgson and Harper, 2004; Lovatt and Shercliff, 1995; Zuo, 2005; Lefteri, 2005; Conran, 2005; Sapuan, 2001; Ljungberg and Edwards, 2003).

4 Design and conduct of field study

In order to provide some critical guidelines upon not only the content of required data for a materials selection source, but also how the most comprehensive ways can be to present this data to product designers, we conducted a field study with 20 professional designers. In this paper, since we concentrate on the 'content' part, we merely present the results of the content related questions.

4.1 Participants and Procedure

The study was conducted with 20 professional designers in Turkey. One of crucial criteria for selecting the participants was whether the designer works as an in-house designer in a manufacturing firm or as a consultant designer for various different firms. Since we assumed that this would affect the defined materials' requirements for a particular project, the sample group was including both in-house and consultant industrial designers in equal numbers. The in-house designers of the sample group were selected from the firms that involve the R&D (Research and Development) departments and the production facilities. These were ASELSAN, VESTEL Electronic, KAREL, ARÇELİK, NURUS and MAN Türkiye.

The consultant designers of the sample group were working for the firms that serve design and consultation and do not involve the production facilities, such as Tasarım Üssü, Nesne Design, Centipede Design (kırkayak design), and Kilittaşı, Unique Projects Factory, Özden Design Ltd. Apart from those firms; the experiment was also implemented to two designers who give courses in design faculties and occasionally design products for specific projects.

Two techniques were used to analyze the group: interviews and questionnaires. Attention was paid to conduct the experiment in the original working environments of the participants, in case they would like to give exact names for the sources they use for materials selection in their offices. The experiment took approximately 40 minutes per each participant.

The participants were first asked to explain what kind of material aspects is significant for their materials selection processes. Then, they were requested give some example sources which they frequently use while selecting materials. And finally, they explained their expectations from a materials selection source.

After the interviews, the participants were requested to fill in three-question questionnaire. In first question they were asked to rank some aspects of materials leading their selection activity (**Table 2**). The open- ended version of this question had already asked in interviews. With this question, we aimed to gather some quantifiable data on the same topic and to remind participants some possible aspects they would have forgotten to mention previously. In order to create the material aspects list, we summarized the findings from the literature survey presented in the second and third sections. The order of the aspects was changed randomly for each participant.

Table 2: The first question of the questionnaire: *Please rank the given materials' aspects (from 1 to 6) according to their importance in your materials selection process.*

- □ technical properties of materials (density, conductivity, strength…)
- □ manufacturing of materials (easy to manufacture with existing manufacturing facilities…)
- □ economic properties of materials (cost for material and production, availability…)
- □ ecological properties of materials (recycleability, sustainability…)
- □ sensorial properties of materials (color, texture, smell…)
- □ intangible properties of materials (emotions, meanings, effects of cultural differences, trends…)
- □ others

The second and third questions of the questionnaire were focusing on the sources known and used by designers. In the third questions, they were asked to mark the source type they mostly use/prefer while selecting materials (**Table 3**). The source types list was prepared based on the literature survey on existing materials selection sources (Karana, 2002).

Table 3: The second question of the questionnaire: *Please mark the sources which you use during your materials selection process (you can mark more than one sources)*

- □ books
- □ magazines
- □ materials suppliers/ catalogues
- □ fairs/ seminars
- □ CD/ DVD/ VCD (materials selection databases)
- □ internet
- □ advisors
- □ others

Then, the participants were presented with six well-known sources regarding materials, materials selection and materials in design issues (**Table 4**). These names, similarly, were identified with the findings from the literature survey.

Table 4: The third question of the questionnaire: Please mark the ones which you are familiar with *(you can mark more than one options)*.

□ Cambridge Engineering Selector (CES)
□ Materials ConneXion
□ Designin Site
□ ASM Material Handbook
□ www.matweb.com
□ Mike Ashby

The interviews and the questionnaires were focusing on the issues of materials selection processes, materials selection sources, and the significant material aspects in product design. Taking these priorities into consideration, we analyzed the results from interview and questionnaires and came up with some critical results.

4.2 Results and Discussions

The answers of the second and the third questions of the questionnaire, as they appeared to be easily categorized quantitative data, were converted into the charts presented below (Figure 1 and Figure 2).

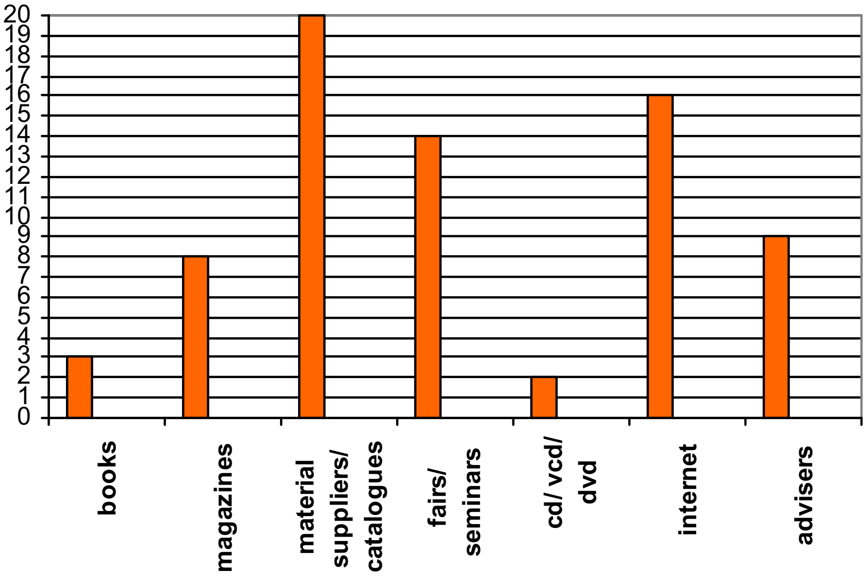

Figure 1 Materials selection sources used by product designers

Figure 1 addresses what kind of sources product designers use while selecting materials in design process. All of the interviewed designers defined 'materials suppliers and their catalogues' and 14 designers mentioned 'fairs and conferences' as the most important sources for their materials selection processes. Obviously, the interviewees are inspired from the existing products and various application fields of the materials. Consequently, we reached two important findings herein: (1) product designers mostly look for materials with required properties matching with those of another existing material; that is 'selection by similarity' (Ashby and Johnson, 2002); or (2) they visit fairs, exhibitions and stores, observing the products and materials for seeking ideas randomly until finding one or more appropriate for the project, which is called 'selection by inspiration' (Ashby and Johnson, 2002).

Most of the designers (16/ 20) are also seemed using Internet source in their material searches. Two major motives explaining why they prefer Internet sources are (1) updated information can be found especially on new production technologies and material innovations, and (2) accessibility of the source is easy and it does not take too much time (as expected, all of the designers have computers and Internet connections).

In the third question of the questionnaire, the interviewees had been asked if they had heard about given six names. These six names, distinguished from the literature survey on related topic, had been selected by depending on their privilege in materials' selection issue. As it is followed in chart (**Figure 2**), 5 out of 20 the designers know about 'Designin Site'[1] and 4 out of 20, heard about 'Material ConneXion'[2].

[1] Design inSite is a Danish website, founded in 1997, aiming to be a guide for manufacturing for especially industrial designers. Various manufacturing processes and materials are described as well as the products where they are used. They define their purpose as to inspire designers in their design work to consider materials and processes, which are new or unknown to them. The web site includes descriptions of about 190 products, 120 materials and 100 processes.

[2] Material ConneXion holds one of the most famous worldwide materials' exhibitions, which was named as '**materials without boundaries**'. Founded in 1997*, Material ConneXion*, is the largest global resource of new materials. The significance of the firm is that, it has the biggest material samples library which houses over 1,400 new and innovative materials representing eight categories: polymers, glass, ceramics, carbon-based materials, cement-based materials, metals, natural materials and natural material derivatives. The complete library information of the organization is accessible via the Internet, using Material ConneXion's database.

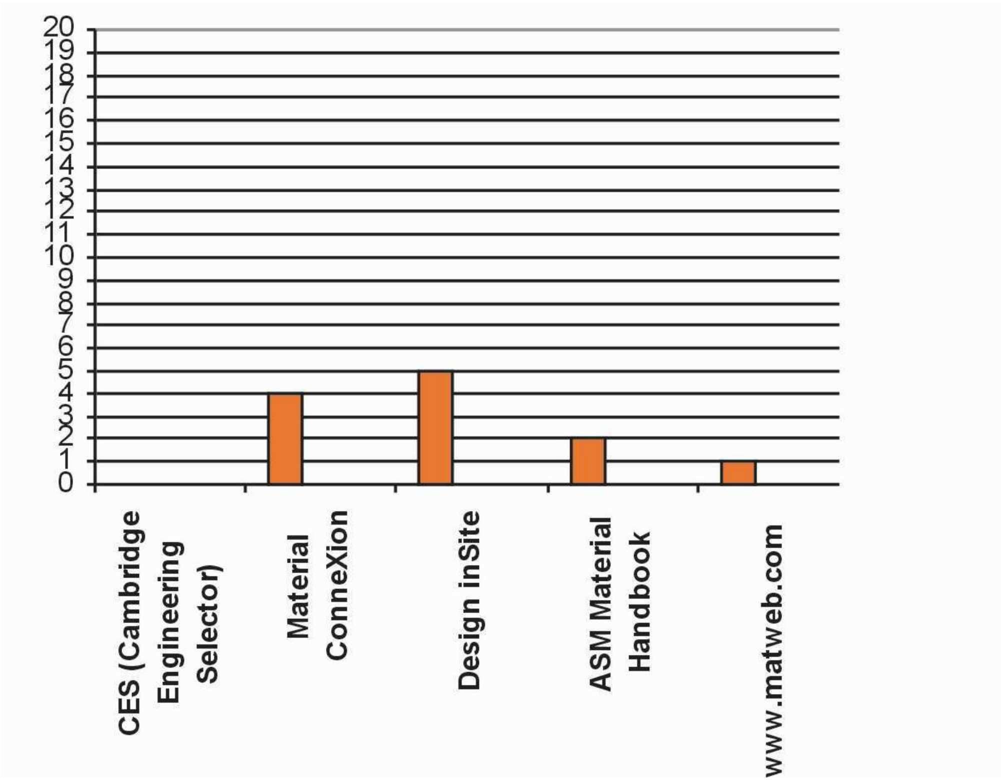

Figure 2 Do the Turkish designers know about the common sources?

Cambridge Engineering Selector (CES)[3] by Mike Ashby is not known by interviewed designers. The results of this question again confirmed that Turkish product designers make their preliminary selection mostly by inspiration and similarity; that explains why they know Designin Site and Material ConneXion, but not the CES. They ones again emphasized that, they do not use any materials selection database for their preliminary design process.

As materials selection process involves lots of considerations, most of the participants stated that they didn't want to get the whole responsibility on this subject. Therefore, for almost all of them, a designer cannot carry out a materials selection process by himself/herself without getting consultancy from colleagues, engineers, friends or a specialist on a material. Regarding to this

[3] One of the most important software databases is CES: Cambridge Engineering Selector (1992) developed by Cambridge University Engineering Department in the U.K. It is a remarkable tool centered on methods developed by Mike Ashby and colleagues at Cambridge University and Granta Design. It combines three principal functions: (1) straightforward search for information, material properties, process methods, suppliers, and so on; (2) a systematic approach for analysis of material and process information and optimal selection; and (3) modeling of complex properties such as creep or fatigue, or of process cost. The CMS consist of all materials types.

issue, when the answers of the first interview question were analyzed (what kinds of aspects of materials are significant for you materials selection process?), it was seen that most of the participants (17 out of 20) were easily accessing the technical data on materials. 10 out of 17 were in-house designers (all in-house designers who participated to the experiment) especially stressed how easy to obtain the technical data in a big manufacturing company; as they work in a multi-disciplinary environment including materials scientist, manufacturing specialist and engineers.

However for pre- selection process, in which they make their preliminary decisions about the materials of their products, they do not use only technical data. The assessment of the first interview question was combined with the results of the first question of the questionnaire; and a *content of data* table, representing the fundamental requirements of designers in their materials selection process in a sequential way, was established (**Table 5)**.

All participants emphasized that, the cultural backgrounds and the past experiences of people are effective in their product and material preferences. In other words, people can perceive a material as more valuable than the other, and can make some associations based on their cultural backgrounds and past experiences. Therefore, among various alternative products with different materials of nearly equal technical qualities, people can prefer one product to another with the influence of these issues, which were defined as *intangible characteristics of materials* previously.

As it is seen in Table 5, the product designers initially look for the data on *sensorial properties of materials* in materials selection process. They believe that the ICM are certainly important issues in their selections and the sensorial properties of materials are one of the most vital aspects for creating the ICM. For instance, in order to attribute the meaning of 'modern' (which is an item expressing an intangible characteristic) to a material, they prefer to select a material providing a grey, shiny and smooth surface (which are three features representing the sensorial properties of materials). That explains why sensorial properties of materials come first in 'content of needed data' list in Table 5.

Table 5 The order of the required data of a materials selection source for industrial designers

CONTENT OF DATA

for a materials selection source for industrial designers

1 Sensorial Properties

- vision, touch, sound, smell, taste

2 Intangible Characteristics

- perceived values
- associations
- emotions
- cultural meanings, design movements and trends

3 Technical Properties

- manufacturing processes
- volume of production
- appropriateness to the existing manufacturing techniques
- durability
- cost of production

4 Design Notes

- recommended usage environment
- design limitations
    * limitations for form creation
    * limitations for combined materials (like joining)
    * limitations for health and safety regulations
- environmental notes
- similar materials
- industrial designers' notes

Availability

- suppliers (cost of materials)
- consultancy

Moreover, according to interviewees, most of the Turkish product designers, unless the particular criteria for a material are defined at the beginning of the design project, make their preliminary selections depending on *the appearance of the material*, that is texture, final surface finish, color and all properties appealing to the sensorial evaluations.

In the concept creation period (pre- selection process), the interviewees consider the technical properties and manufacturing techniques of materials, but not in detail. They believe that it is hard to separate these two aspects from each other. In other words, manufacturing process, since directly related to the technical properties of materials, is considered reciprocally with the technical properties. Subsequently, manufacturing process is presented under the technical properties of the materials in Table 5. On the other hand, most of the participants (16/ 20) stated that, when they finish the conceptual period and proceed to the 'embodiment' and 'detailed design' periods, they begin to concentrate on these two aspects more intensively. They search for various kind of technical properties of the material, appropriateness of the material for the existing manufacturing techniques and the cost of overall production.

Table 5 also consists of some noteworthy keywords like *durability* defined by designers as the most effective technical criteria in materials selection process. As it is seen in table, the *availability* factor- the easy access to the selected materials- was written vertically, because *availability* factor is evaluated by designers in any time through the whole selection process. In fact, this is the most important factor for them and designers start considering it from the beginning of the process.

Another factor that does not have a defined time in the selection process is the *consultancy*. Throughout the interview we realized that product designers tend to talk with their colleagues and benefit from their experiences on candidate materials. The interviewees stated that they need advice about materials at every stage of design activity. Therefore, if the contact data of any consultancy service on candidate materials can be offered, it would be very valuable for them.

Finally, there seems d*esign note* title in the table. This title includes special design limitations related to the requirements about the form creation, combined materials and health & safety regulations, recommended using environment, similar materials which can be used instead of the selected material, environmental notes like sustainability or recyclability of the material, and some specific design notes from the experienced designers.

5 Conclusion

In brief, the guidelines are required in all of the stages of design process, but predominantly in the detail design stage, in which the specific information is needed and details are clarified about technical properties of materials and manufacturing. However, in the conceptual design stage, designers are more interested in sensorial aspects of materials and additionally consider some intangible characteristics of materials. Intangible characteristics of materials (ICM) - involving the perceived values and cultural meanings, trend issues, associations and emotions evoked by materials- are used by product designers in order to create the intended meanings with the appropriate selections.

Although the significance of the intangible characteristics of materials is emphasized in number of sources and by interviewed product designers, the existing materials selection sources do not include these characteristics of materials. Consequently, researches with more emphasis on ICM and the integration of these aspects of materials into materials selection sources can provide a considerable advantage for product design domain.

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