Material and process selection using product examples

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Abstract:
The objective of the paper is to suggest a different procedure for selecting materials and processes within the product development work. The procedure includes using product examples in order to increase the number of alternative materials and processes that is considered. Product examples can communicate information about materials and processes in a very concentrated and effective way. The product examples represent desired material properties but also includes information that can not be associated directly to the material, e.g. functional or perceived attributes.

Previous studies suggest that designers often limit their selection of materials and processes to a few well-known ones. Designers need to expand the solution space by considering more materials and processes. But they have to be convinced that the materials and processes are likely candidates that are worth investing time in exploring.

A database that support the selection procedure has been compiled. It contains uniform descriptions of a wide range of materials and processes. For each of those, good product examples have been identified, described and associated with keywords. Product examples matching the requirements can be found using a search engine, and through hyperlinks can relevant materials and processes be explored. Realising that designers are very sensitive to user interfaces do all descriptions of materials, processes and products include graphical descriptions, i.e. pictures or computer graphics.

Keywords: Material and process selection, Design for Manufacture, Industrial Design, Hypermedia and multimedia

Background

New and improved materials keep emerging and there is a rapid development within manufacturing processes. For example is plastic today used in quality products as well as complicated high tech products. Earlier it was considered as a discount material. Advanced carbon fibre composites makes significant weight reductions possible and is today used in many sport products and in transport equipment. With sintering techniques metal parts are produced without material waste and with drastically reduced energy consumption. Surface technology offer many possibilities for changing the surface of the materials and add new properties to them.

This rapid development can be difficult to follow and it is not always clear to industrial and engineering designers, how they can be exploited. It is important that the materials and the manufacturing are considered as part of the product already early in the design stage. Many costly changes can be avoided if the right choices are made. New products can even be directly inspired by the new technological possibilities.

The objective of the present paper is to suggest ways of communicating information about materials and manufacturing processes in a more efficient way. Previous studies suggest that designers often limit their selection of materials and processes to a few well-known ones (1). This is unfortunate when new and innovative products are desired. A reason could be that the designer avoids risks. Another simple and very important reason is that the existence of the material or manufacturing process is not known or that it is wrongly believed not to be suitable. Only little help is found in existing literature to help this problem (2). The structure of common sources requires that the material or the process sought after have to be known in the first place. This is the case for most of the existing literature on manufacturing processes and materials. The problem for the designer is to set up a list of alternative materials and/or processes that could be worth while exploring. They have questions like: How good is the material? What has it been used for? Was it a success? Is it worth while spending further time on investigating it?

Product development involves several competences. Engineering and industrial design activities are both concerned with material and process selection, but the level of detail and the focus within the designwork are different. Industrial designers are often involved in more comprehensive redesign of products or completely new designs. They will therefore often be more willingly to consider new materials, since their dependency of previous solutions is less distinct.

Industrial design is often associated with the term styling, which means an aesthetically pleasing shaping of the external shell of a product. But industrial design includes more than the mere styling. A good industrial designer will plan the identity of the product and shape it in accordance with it. To build identity into the product is very important. Many products are today sold based on the image it adds to the consumer. There are numerous examples in cars, clothes or leisure equipment. But the identity is also important for the user’s comprehension of the product and the choice of material can have significant impact on whether the product is seen as a quality or a discount product.

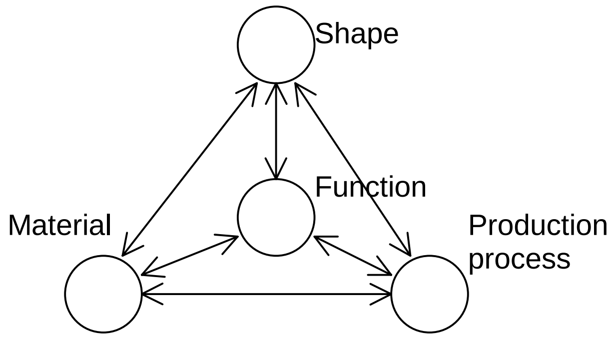
The designer will consider the user interface and try to understand how the user sees the product. They are furthermore well trained in visualising product concepts using both hand sketching, computer drawing and physical modelling. An industrial designer is an important participant in the whole product development, and can have the determining influence on the materials and processes that are selected. Product examples are often used (for example by material vendors) to convince the designers that the material and production process successfully have been used before and consequently reduce the feeling of taking a risk.

Without the materials and the production facility there is no product. The fact that there are many different materials and that they can be manufactured in many different ways gives the practical possibilities for the design of the product. They are in other words the degrees of freedom available to the designer. And they can be a valuable inspiration source for re-creation of products. In order to get a good product the designer should not only select a suitable material but also think about the special properties of the material and of the possibilities that the manufacturing of it gives. The first products in plastic were not very successful and part of the reason was that they were designed as metal look-a-likes instead of utilising the benefits of the material.

Approaches to material and process selection

Jakobsen (3) describes how the selection of product function (F), materials (M), production processes (P) and shape (S) is very closely interrelated (figure 2) and that different sequences or strategies for the selection of the 4 aspects can be followed. The sequence FSMP for example means that first is the product function considered followed by determination of the shape of the part. Then a material is selected and finally the manufacturing process is found.

This can be illustrated using a frame for a bicycle as an example. All the examples assume the same functionality, i.e. physical connections between front and back wheel, pedals and saddle. Using the FSMP sequence a traditional double diamond frame using tubes determines the shape. Aluminium can then be selected as material and finally manufacturing processes can be tube drawing and welding. A FSPM is similar but following the choice of shape the selection of tube drawing and soldering result in another material selection, namely steel. FMPS is followed if it is decided to use carbon reinforced epoxy for the frame. The shape can first be determined after the selection of manufacturing process, for example hand lay-up. If a pre-preg technology or a pultrusion process is selected the possible geometries are quite different. Using FPMS a super plastic material pressing can be selected followed by possible materials, e.g. a specific type of aluminium. Finally a plate frame is sketched as a non-symmetrical S-shape.



F → S → M → P
F → S → P → M
F → M → S → P
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Figure 1. Product function (F), materials (M), production processes (P) and shape (S) is very closely interrelated (3)

A very commonly used approach to material and process selection is the one that many material databases support, e.g. Matweb (4), Campus (5) or CES (6). It can be called a property based search, since the function and the overall shape of the part/product should be determined first and then possible materials and processes can be searched, most often based on desired properties. This can be expressed as FSMP or FSPM.

Other work has proposed to use a morphology (7) in order to expand the solution space regarding manufacturing processes. The morphology describes patterns of motion, energy transfer, materials states before and after transformation etc. The morphology supports a selection sequence expressed as FSMP.

Some designers are trained in a craft profession like ceramics, glass, textiles or wooden furniture. Their approach to material and process selection is often to explore a given material by experimenting with different ways of processing and treating it. Through the experiments shapes or surface textures that was not foreseen emerges. This approach is FMPS.

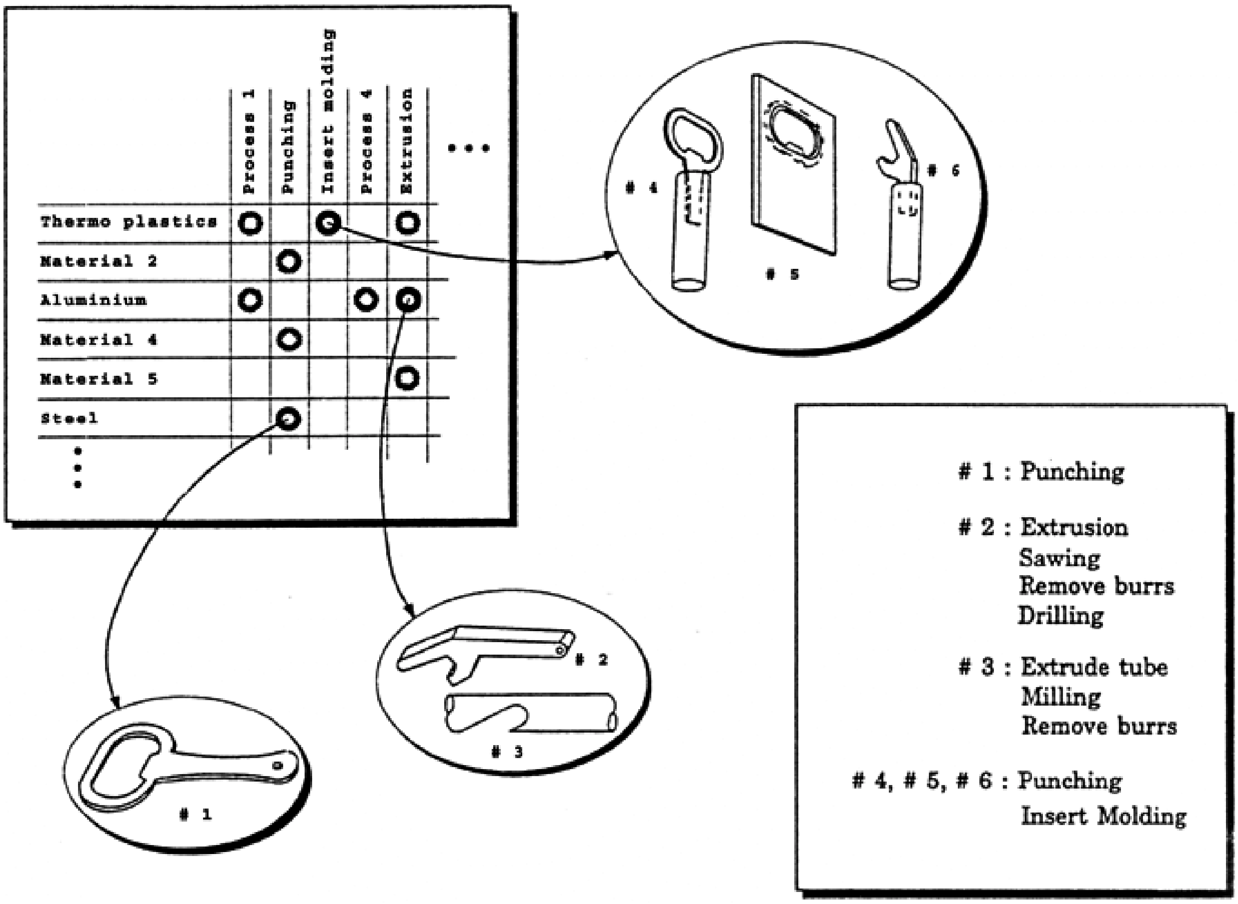

Figure 2. Using material/process combination for generating different shapes for a bottle opener (8).

Haudrum (8) suggests that the designer, on the basis of the given functions of the component, sketches a number of solutions consisting of material, production process and shape. With each of the relevant material/production process combinations in mind a number of shapes are sketched as illustrated in figure 2. In this way very different shapes can be generated. Furthermore is it more likely that the sketched solutions are actually produceable by the given production methods. This is either a FPMS or an FMPS approach. The number of combinations can however become very large and there is therefore a need for limiting the number of alternatives i.e. the solution space.

The product-based approach presented in this paper uses the approaches FPMS or FMPS.

The product-based approach
A basic assumption of the work presented here is that a more limited expansion of the solution space can be made by introducing the designers to good product examples that utilise a specific material or process.

The approach can be described as
a) formulate requirements to the product
b) search for products satisfying these requirements
c) display the found products with emphasis on the graphical presentation for more effective communication
d) link to relevant materials and manufacturing processes and to other products
e) select relevant candidate materials and manufacturing processes
f) sketch product solutions for each material/ manufacturing process combination
g) evaluate and select based on the product solutions

A database has been compiled that support the approach (9). It contains uniform descriptions of a wide range of materials and processes (about 150). For each of those, good product examples have been identified, described and associated with keywords. The typical products are selected for the database in order to illustrate special characteristics or features for each material or process. These features are described in the attached textual description, and the graphical illustration is made so it highlights these arguments. Using good product examples makes it possible to communicate central information about materials and manufacturing processes in a very concentrated way. In this way designers may be convinced to consider more materials and production processes.

A list of keywords describing typical requirements have been compiled based on an analysis of the major arguments for material/ manufacturing process selection for the products. In order to use the keywords for search purposes they are formulated as short as possible, e.g. instead of low weight only the word weight is used. The keywords describe as different product properties as strength, stiffness, container, ageing, wear and environment.

The search engine will find all products that include the search words in their description. In the design process there may be a need to find out how a certain property can be obtained, e.g. wear resistance, low weight, a certain function or special aesthetic properties. A search will then find product examples that illustrate how these problems have previously been solved. From each product there is a link to the materials and processes used. The idea is that seeing examples of successful applications may motivate the designer to invest more time in exploring materials and processes that they either did not know about or did not think of as a solution.

Figure 3. A paper puncher made by extrusion of aluminium (9).

Based on the found products and associated materials and manufacturing processes, the designer can make a list of candidate materials and production processes. For each combination of those the designer should sketch a product, e.g. sketch how a paper puncher can be made from aluminium using extrusion or from injection moulded plastic. The material and process selection is then determined by which product solution that is most promising.

Product examples in material selection

Using product examples in material and process selection can be illustrated with a few examples.

Reduced weight is desirable in many cases like transport equipment, furniture and movable products. A search could result in the following very different products: Plywood chair, gear box, canoe and pedestrian bridge. The chair shows that plywood can be used for very light weight products given a well designed structure. The gear box made from diecasted magnesium convinces that the material can be used in outdoor applications without special protection. This hopefully shakes the scepticism to magnesium that is often thought of as expensive, inflammable and highly vulnerable to corrosion. The canoe being 5 meters long only weighing about 5 kg illustrates the powerful properties of advanced composite materials including carbon fibres and epoxy. The pedestrian bridge made from glass fibre reinforced polyester proves that it is feasible and advantageous to use the material for products that are heavily dominated by traditional materials like steel and concrete. The bridge shows that not only is a weight reduction of up to 70% possible. Life times on about 30 years without maintenance is impressive for a material group (polymers) generally known to have poor outdoor performance. The examples show that light weight products can be made from light weight materials as well as more heavy materials used in the right structure.

Figure 4. Products characterised by the keyword “weight”: Plywood chair, composite canoe, pedestrian bridge (9).

Reduced wear is often associated with harder materials but a search can only partly confirm this. A wear resistant harrow pin can be made from a mixture of steel and ceramic material using powder compaction. The mixture gives the best from both materials: The wear resistancy from the ceramics and the ductility from the steel. A ceramic blade razor shows that cutting edges will remain sharp much longer when zirconium oxide ceramics are used. But that a self-lubricating bronze bearing exhibits good wear properties is not due its hardness property but rather to the lubrication mechanism. And that a significant improved wear resistance can be found in a soft elastomer horse shoe is a surprise to many.

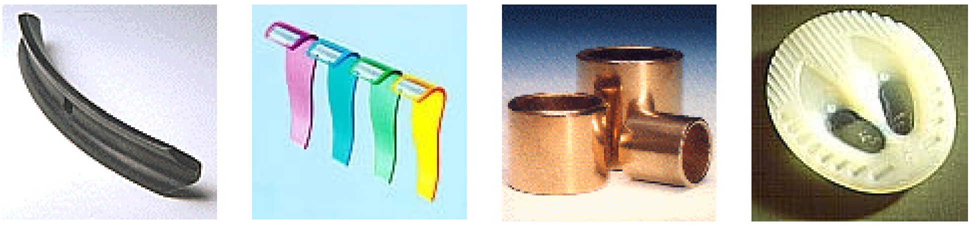

Figure 5. Products characterised by the keyword “wear”: Harrow pin, razor, bearing, horse shoe (9).

A search for transparent products will confirm that many polymer materials can be used but it will also bring surprises. A tail light glass for a car is made in acrylic polymer, and the product example shows how different colours can be integrated using a multicolour injection moulding process. The tail light glass also illustrates that PMMA are used in a product which is exposed to extreme weather conditions. By using the link to the PMMA material description it can be confirmed that the material has good weather resistance, one can se that it not suited for harsh chemicals and that is also used for sanitary products. A recyclable bottle for mineral water shows not only that a transparent pressure container can be made. It also illustrates that the material can withstand the hot water and harsh chemicals used when cleaning the bottle and still be suitable for food packaging. A transparent CO_2 container made from glass fibre reinforced epoxy shows not only that transparent materials can be made that holds high pressures. It also shows that a composite material can be made transparent. An ice-cube plastic bag shows that the very inexpensive and low-grade plastic used here can withstand severe cold temperatures. A surprise is that metal films become transparent when they are thin enough. A certain type of insulating window is coated with a thin layer of aluminium to reflect the infrared heating waves back into the building. Another window is coated with a thin electricity-powered metal film that works as a built-in heater in order to avoid the cold areas at the bottom of the window.

Figure 6. Products characterised by the keyword “transparent”: Tail light glass, mineral water bottle, ice cube bag, CO2 container (9).

The importance of graphics

Realising that designers are very sensitive to user interfaces, the development group for the database included both graphical/communication designers as well as industrial designers. In the database do all descriptions of materials, processes and products include graphical descriptions, i.e. pictures or computer graphics. Graphics are also unique for communicating large amount of information on little space. A picture of a material tells about possible surface quality, colours, reflections etc. A product picture gives both direct information about the appearance of the product but also indirect information about strength, stiffness, wear properties, corrosion, human compatibility, and many other properties.

Since the visual appearance of the materials is very important to industrial designers, it is important that product examples as well as material descriptions include good illustrations of the visual properties. The illustrations furthermore have the advantage that they can include quite a lot of information in very little space. The ABS plastic illustration for example shows the glossy surface that can be obtained and the toy building blocks gives an impression of impact strength, stiffness and production tolerances. The PA illustration shows a typical PA surface and tell about strength properties (as well as ageing and laundry properties) through the picture of the suitcase. The PMMA spoons tells that a highly glossy material can be used together with food. The picture of the PVC-boat fender made by rotation moulding tells a story about strength and corrosion resistance (sun light and see water).

Figure 7. Graphical description of materials: ABS, PA, PMMA and PVC (9).

Conclusion

The paper argues for importance of informing designers about materials and manufacturing processes. They often have a major influence on material and process selection. Different strategies can be followed when selecting and the product based approach presented here follows a FMPS or FPMS strategy (Function, Material, Process, Shape). The approach involves a formulation of product requirements, search for other products, display of the found products, link to relevant materials and manufacturing processes and to other products, selection of candidate materials and production processes, sketch of product solutions and evaluation. The approach should stimulate designers to consider more alternative materials and processes. In describing products as well as materials and processes emphasis has been on the graphical presentation. The grahics makes more effective communication possible.

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