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Abstract:

Research and development of new materials and technologies has traditionally been dominated by scientific and engineering disciplines. However, methods are emerging that integrate design into the process to accelerate timeframes, lower risk and improve market uptake.

Within an Australian context, the Collaborative Research Centre for Wood Innovations integrated design with engineering and science in the initial stages of new materials development for Microwave Modified Timber.

This paper will explore how different modes of operation for industrial design were necessary to successfully engage in this cross disciplinary research environment. The research strategies developed, non-traditional activities employed and alternative application of industrial design processes will be discussed using a case study of outdoor café furniture.

The research shows new ways of working for industrial design were effective, allowing design to drive research and align material properties with real world product need. It also suggests the strategies are transferable to other kinds of new technology development.

Keywords:

New materials and technology development, collaboration, industrial design, design research methods, Microwave Modified Timber technology

1. Introduction

The following paper explores how contemporary new materials and technology development has shaped new ways of practice for industrial design. It is positioned in the context of an Australian research environment where design, science and engineering collaborate. This discussion is facilitated by PhD research for new Microwave Modified Timber (MMT) materials provided by the Cooperative Research Centre (CRC) for Wood Innovations.

Firstly background information will be presented on new materials and technologies development, considering general trends and methods for integrating design. An explanation of CRC Wood Innovations and MMT will also be offered before discussing specific details of the research pertinent to new ways of practice for industrial design. Strategies developed for integrating design within the
given context are detailed before introducing a case study of outdoor café furniture which provides a platform for exploring the roles of non-traditional design activities, alternative applications of industrial design processes and design thinking. The conclusion will then summarise the effectiveness of new industrial design practices within the given context, suggest that the strategies developed would be useful for other new materials or technologies development.

2. New materials and technology development and the integration of design

2.1 Trends in new materials development

Today the world is flooded with a vast choice of different materials with new options being developed everyday. In order to be successful on the market, it is becoming necessary to offer a variety of beneficial properties. This evolution is evident in elite new materials development. Polymer composite development has always been driven by aircraft needs for lighter, stronger and stiffer materials, however material performance is no longer the sole motivating factor. Affordability has now become important (Wessel, 2004). The development of composite materials based on natural, fibrous resources also demonstrates this trend. Maderon was created to use waste almond shells, so by origin, it’s primary purpose is to offer a sustainable material choice. The successful uptake of Maderon was also a result of a range of other useful properties including low cost, ability to be injection moulded like plastic, ranging densities and the ability to be heatproof treated (Antonelli, 1995).

Knowing what materials and technologies exist and are best suited to product design applications can be difficult with the almost limitless options available. This issue is acknowledged by the rise of materials libraries around the globe in the last decade. Material libraries such as Material ConneXion, Innovatheque and Materio (Innovatheque, 2005; Material Connexion, 2005; Materio, c.2006), are organisations that exist purely to disseminate information about new materials or technologies through physical, see Figure 1, and online collections. The growing need to link new materials or technologies with real products is also evident in materials that exist but have no application, such as Ligafill (Stattmann, 2003). This ceramic sheet material has an aerated core providing lightness in weight, heat resistance and excellent stiffness, but when published in UltraLight, Superstrong: A New Generation of Design Materials, it had no current applications (Stattmann, 2003).
2.2 Integration of design into processes for new materials and technology development

In the last decade there has been an emergence of methods for developing new materials and technologies that integrate design. While the origin of these methods is varied, they all use design with for the same purpose: to increase the probability of commercial success.

Philips developed a “Strategic Futures” methodology that generates product concepts in response to forecast socio-cultural trends and technologies. The idea behind this method is to appropriately focus product innovation and therefore sustain Philips competitive position in the market place. Another advantage of the method is helping to determine the validity in investing to develop the projected technologies (Phillips Design, 1998).

Research and development at Motorola have also use similar methods to Philips. The New Life Forms project proposes concepts for telecommunication devices based on predictions for future lifestyles and technologies. Motorola found this process to provide lower risk in developing products and technologies than through use of traditional product development (Susani, 2002).

For both Motorola and Philips, display of prototypes and consumer feedback were integral, multi-disciplinary teams featured and traditional product development sequences were not adhered to (Phillips 1998, Susani 2002).

In the area of composite materials development, the Defence Advanced Research Projects Agency, a subsidiary of the US Department of Defence, has developed an Accelerated Insertion of Materials (AIM) methodology. The purpose of this method is to use resources more efficiently by using design to establish required material properties in the initial stages of materials development. Other important features of the method are the use of predictive modelling and simultaneous property development. This reduces risk, time and therefore cost (National Research Council U.S. 2004). AIM methodology
is particularly strong in reducing timeframes, producing up to 50% reduction in cycle time according to research partners GE (AIM methodology, 2005).

Accelerating materials development timeframes can also be achieved by linking new materials and product applications. Musso suggests that the strategic market positioning of new materials in product application can reduce commercialisation timeframes (Musso, 2004).

3. CRC for Wood Innovations and MMT technology

3.1 The collaborative research environment provided by CRC Wood Innovations

Cooperative Research Centre’s are an Australian initiative where research partnerships between academia, industry and government are formed over 7-14 yr periods.

CRC Wood Innovations was formed to address an increasing trade deficit experienced by Australia’s forestry and furniture industries. Based around the technology of MMT, the purpose of CRC Wood Innovations is to develop new and improved options in timber materials and manufacturing processes. The collaboration involves science, engineering and design research from a number of institutions and organisations around Australia. Some of the main partners include the University of Melbourne, Swinburne University, Commonwealth Scientific and Industrial Research Organisation, Queensland Department of Primary Industries, Western Australia Forest Products Commission, Carter Holt Harvey, Furniture Industry Association of Australia and Furntech.

3.2 MMT technology and derivative new materials

Microwaving timber alters the properties by creating a series of voids throughout the material. CRC Wood Innovation provides a technology that can control this process. By varying the intensity of the microwaves, the size of the voids can be controlled. Increasing the intensity creates relative increases in void size, which may vary up to approximately 5mm in size.

Figure 2. Cross sections of MMT samples showing barely visible and large voids
Properties of MMT include increased porosity, lightweight, reduced strength and possible acoustic and thermal characteristics. The increased porosity means that MMT can be turned into a composite material by filling the voids with another material. New materials development for MMT looked at impregnating resin to create a new material, see Figure 3, where the properties could be tailored according to resin type and timber species. Selection of timber species is particularly important as it’s base structure is still inherent. This type of material was named Vintorg and is the material the PhD research is concerned with. Vintorg has a number of generic characteristics such as increased strength, density and dimensional stability. Many other properties could be tailored, including durability, appearance and surface hardness. With such variation in material properties possible, Vintorg development needed focus.

![Figure 3. Vintorg sample showing dark flecks of resin that have filled voids](image)

4. New ways of practice for industrial design

4.1 Strategies developed for integrating design, science and engineering research in CRC Wood Innovations

A Pre-commercial Technology-Push Design Strategy was developed in order to facilitate collaboration between science, engineering and design to develop new materials in CRC Wood Innovations. Taking into consideration approaches of existing methods, the framework for the strategy was formed in response to the current stage of progress in materials development for MMT (Anderson, et al, 2004).

The Strategy has three stages. The first two are embedded in the initial stages of development, see Figure 4, and the third deals with product adoption and final stages of commercialisation. Due to the progress of Vintorg development, the PhD research did not have the opportunity to proceed to the third stage so it will not be discussed in this paper.

The first stage, Contextual Parameters, uses industrial design thinking to choose an appropriate case study that will give real world focus to the type of Vintorg to be developed. Case study selection is based on current material knowledge and the product/applications capability to generate knowledge of material characteristics for other types of Vintorg. Aligned with the product requirements of the case study, performance criteria for property development are specified as a goal for science and engineering research.
The second stage, *Iterative Research*, provides framework for collaborations between research conducted by design, science and engineering. Research in the different areas occurs simultaneously, informing and responding to one another in iterations. The different design activities that stem from and feed into design research can be seen in Figure 4.

Figure 4. Diagram explaining the first two stages of the Pre-Commercial Technology-Push Design Strategy
4.2 Outdoor café furniture case study

A case study to design outdoor café furniture was selected to develop a specific type of Vintorg, Café Vintorg. This was appropriate as outdoor café furniture would exploit many of the potential properties of this new material and push them to their limits because of the extreme conditions it must endure. This detail is important as Café Vintorg would therefore generate property knowledge for other types of Vintorg and determine types that are in fact appropriate.

The case study resulted in the design outcome of the Matchstiks chair, show in Figure 5. It addresses real product requirements of outdoor café furniture by featuring the ability to space save through stacking, portability through lightweight, durability, contemporary aesthetic, appropriate ergonomics, modularity and variation in finish. The validity of the design to successfully meet these needs was confirmed by feedback through display of aesthetic models at trade shows and virtual testing through Finite Element Analysis (FEA).

The Matchstiks design embodies the contributions of design research, as it is a culmination of the different modes of practice industrial design employed that will be discussed in the following sections.

Figure 5. Aesthetic prototype of the Matchstiks chair showing different options for the seat.
4.3 Alternative application of industrial design activities

The nature of design research in the Pre-Commercial Technology-Push Design Strategy itself shows an alternative application of industrial design activities as it is working towards developing new materials instead of new products. Through implementing the first stage of the design strategy, industrial design thinking is used to determine the parameters of the case study and drive research direction.

Industrial design processes were also used to determine different types of scientific and engineering experiments. Through concept generation, questions were raised about the possibility of various characteristics that would be of value to the case study product. For example, in the design of the Matchstiks chair, concept generation explored the possibility of coloured appearance as outdoor café furniture typically offers options in appearance through varying material and finish. Concept work also proposed what the coloured appearance of Vintorg may look like, see Figure 6. In response to this, scientific experiments were undertaken to investigate the effects of adding unnatural coloured pigments and dyes to the resin used in Vintorg production. Results of these experiments confirmed that a flecked appearance was created, see Figure 7, and therefore greater knowledge on appearance options achievable in Vintorg was generated.

Figure 6. Sketches proposing coloured Vintorg

Figure 7. Samples from coloured resin experiments showing a flecked appearance
Through concept generation, refinement and detail design, guidelines for how to design with Vintorg would also be generated. Through following these design activities for the *Matchstiks* chair, further understanding of joints that are appropriate in Vintorg were generated based on a strong understanding of material characteristics. Increased strength is achieved through a higher density at the material surface of Vintorg. As a result, to design with Vintorg you must utilise standard section sizes and detail joints that do not interfere with surface properties. The open mortise and tenon joint with loose tenons, shown in Figure 8, are ideal as machining of the surface is uniform. This also shows another element of Vintorg development that design activities informed: standard sizes and cross section profiles that are best suited to product application.

![Figure 8. Sketch explaining open mortise and tenon joint that features uniform machining and pressed to size Vintorg sections.](image)

Sequencing and timeframes of different industrial design activities also varied from those generally observed in product development processes. Time taken to progress from initial concept generation to detail design was much longer due to the lengthy periods required to properly carry out scientific experimentation and engineered testing for Vintorg. Integrating findings from science and engineering also meant that concept generation was often revisited or not progressed beyond according to property
testing. For example, concepts proposing a Vintorg sheet material in seating and table top surfaces were refined to the stage of mock-ups, but were abandoned after material experiments determined a sheet format for Vintorg as unviable, so concept generation continued.

4.4 Engaging in non-traditional industrial design activities

Design research in the PhD not only helped to define scientific experiments and engineer testing as discussed in the previous section, it also actively engaged in these processes. Industrial design research participated in a range of different activities contributing towards experiments and testing of Vintorg, including the design of experiments, conduction of experiments and assistance with Vintorg sample production. The participation in these science and engineering based practices gave a deeper understanding and insight of Vintorg characteristics, enriching design research’s ability to respond to material findings. For example, participating in the experimentation for coloured Vintorg, see Figure 9, gave insight to the way resin impacts surface properties of the material. Without participation, this understanding would not have occurred. Without this understanding, propositions for appropriate jointing techniques for Vintorg, described in Figure 8, would not have been possible.

Figure 9. Experiments for coloured Vintorg in progress: treating samples with resins

5. Conclusion

Different modes of operation allowed for industrial design research to effectively contribute towards new MMT materials development. Alternative uses of industrial design processes allowed for design research to respond appropriately to material findings in science and engineering. It also allowed design to drive research directions that would ensure material properties remained focused on addressing real world product need. Participation in science and engineering based activities provided a deeper understanding of material knowledge. This enriched design activities, maximising their contribution to materials development. Developing a Pre-Commercial Technology-Push Design strategy was integral in keeping all the various research activities cohesive. The research suggests that this framework would be transferable to other new materials or technology development that have many variables and is in the initial stages of development.
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