Model or prototype which, when and why?

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Abstract

The translation of design ideas from the drawing board to a three dimensional representation marks a key stage in the development of a product. This translation may occur at any time during the design activity, involving resources appropriate to the required outcome.

Techniques adopted to generate three dimensional models or prototypes vary according to the nature of the evaluation required, ranging from card and foam 'sketch models' to precision engineered components.

This paper will discuss techniques adopted in the representation of three dimensional designs that lead to the effective evaluation of product attributes. The terms 'model' and 'prototype' will be defined in the context of New Product Development (NPD); techniques of modelling and prototyping will be addressed; and indications will be given of the reasons for the adoption of particular techniques.

Introduction

During a programme of New Product Development (NPD) a wide variety of techniques are adopted to facilitate the generation, manipulation and communication of design ideas. Two dimensional techniques involve sketching, rendering and engineering drawings. Three dimensional techniques, however, are not so readily defined, yet require by far the greater input of resources.

This paper is the result of NPD experience in both professional and educational environments where three dimensional design techniques are used extensively. Its aim is to afford a greater understanding of what is understood by the three dimensional terms of 'model' and 'prototype', and to identify which is most appropriate at particular stages of NPD.

Although such principles may have applications in the field of architecture, mechanical/electrical engineering, and interior design, the core of this paper will be based around the practice of industrial design and the development of products for high volume injection moulding.

Definition

Model

At its most fundamental a model has been defined as "a way of making a trial that minimises the penalties for error"[1]. For a product that may require the investment of large amounts of capital it is clear that design and production errors must be corrected at the earliest possible opportunity. Indeed the penalty for such errors could result in a product recall, or at its most extreme the injury or even death of a user.

Given that a manufacturer wishes to generate profit, a model has an economic function by ensuring that whatever is produced will not result in a financial loss.

During the early stages of NPD there is a requirement to translate ideas into a three dimensional form as quickly as possible. Under such circumstances it is not possible to model all aspects of a product, but ensure that it "contains only those elements of reality that are needed to solve the problem"[1]. This notion of the model as a focused simplification of a system is reiterated by Brown[2] when he states that, "no model is ever a perfect representation of the real thing. If it were it would be a replica".

Scaling may be considered an essential aspect of a model where the size of a product or system makes a full size representation uneconomic or impossible [3,4]. Under such conditions not only linear dimensions may be scaled up or down but all other important quantities such as time, force, density, and viscosity.

Although the notion of scaling may be important to engineering designers working, for example, on an aircraft fuselage, it is not necessarily an important factor for the industrial designer whose primary concerns are with the visual and ergonomic aspects of products. Indeed it is preferred not to scale models but produce them full size whenever feasible to ensure an accurate assessment.

Few publications make reference to those models produced by industrial designers: studies have largely focused on engineering design. However, Emori[3] has identified the 'subjective model' and 'qualitative model' which do have direct relationships with the practice of industrial design. The subjective model represents a total concept that may have little or no feasibility as a production item. An example of such may be a solar powered lawn mower where the principal objectives are to identify form and use.

Although industrial designers may be commissioned to produce subjective models of their designs, the costs involved in the modelling process means that the majority of models are based around products that are intended for production. These are represented by the qualitative model which has the external appearance of a proposed product but lacks proper functioning. Such subjective models are referred to by industrial designers as a 'block model' as they are generally produced from blocks of solid material with the hardwood Jelutong being most preferred.

The two other types of model defined by Emori are 'analog models' such as contour maps; and 'mathematical models' such as formulae. He apparently fails to recognise the value of the 'sketch model' that is often made by the industrial or engineering designer in foam or card. As the first translation of an idea into three dimensions these mark an important stage in the progression towards a final proposal.

Prototype

With so many derivations possible of the term 'model' it may be considered unnecessary to include the notion of a prototype. However, the word prototype is still used extensively to identify a particular form of three dimensional representation as opposed to a model.

From the definitions of models already discussed [2,3,4] one could argue that a prototype is in fact a type of model when seen in economic terms as 'a way to make mistakes safely and relatively cheaply'.[1] Nevertheless, prototypes are generally regarded as being distinct from models in that they are always the same size as the system that they represent. This is recognised by Luzadder[5] who defines a prototype as "a full-size working model of a physical system".

The extent to which a prototype resembles the final product is difficult to define for reasons that will be discussed in greater detail under 'Tooling Prototypes', but as a working system it must be considered advantageous to reproduce as much detail as is economically viable. This is succinctly acknowledged by Mayall[6] who believes that it is a wise designer who tries to get his prototype version as close to the production model as possible.

It is often the case that not one but many prototypes are produced. This can be an extremely expensive exercise as witnesed by the 63 prototypes built to evaluate the construction and production of the Ford Sierra at a cost of half a million dollars each[7]. A single prototype rarely exists as there are more likely to be a series of prototypes, each representing a differing degree of conformity with the production item.

Having determined a working definition for the terms 'model' and 'prototype' the approximate sequence and nature of three dimensional design development will now be defined. It must be acknowledged that deviation from this scheme is inevitable as no two design programmes are ever identical. At the end of the day it is up to the designer and client to decide which is most appropriate and when.

Sketch Model

Whilst undertaking design activity it is often necessary to translate drawings into a more representative format. This enables the designer to understand more fully the complex relationships between components, cavities, interfaces and form.

This may take place at any stage in the design development process but often occurs during the generation of two dimensional sketches. The early evaluation of relationships between surfaces and ergonomic elements is most effectively undertaken in three dimensions by the manipulation of foam and card. Only basic equipment such as scissors, knife, glue and tape are required but the results often have a profound effect on the development of a product. Being able to hold, move, and look inside a product concept can reveal discrepancies and possibilities not apparent whilst sketching in two dimensions.

Industrial designers make extensive use of sketch models but largely at the personal or design team level. It is rare that such models would be presented to a client unless specifically requested.

Foam Model

In a typical design project a consultancy may present three concepts to a client. One of these would then be selected for further development. This may involve another rendering with modifications as required by the client. On accepting this second rendering the next stage requires a relatively accurate three dimensional representation at moderate cost.

The properties of styrofoam make it an ideal media for the creation of accurate three dimensional forms in a relatively short timescale, being easy to work and having good surface definition. Basic equipment such as abrasive paper, craft knife, and hand saw are sufficient to undertake this level of modelling, but a band saw and sanding disc improve both speed and accuracy.

Inert paints can be used to add colour and realism though the open pores of the foam make a gloss finish impossible. With a little extra work additional features can be added such as moveable handles and rolling wheels (for ergonomic assessment).

The main disadvantage of foam is its lack of durability. Only moderate abrasion to the surface causes deformation or the removal of paint. Customised containers are therefore useful when transit or storage is involved.

Principle Model

Technological innovation requiring a dramatic departure from current practice is often first realised using techniques bearing no visual resemblance to the final proposal but immediately illustrates the relevant principles. Kits allied to Meccano are available for such development work and incorporate linkages, gears, motors and transmission systems.

At a more fundamental level the innovator often makes use of materials more readily available. Hence Christopher Cockerell utilised a biscuit tin and vacuum cleaner to illustrate the principle of the hovercraft. This could have been represented in a two dimensional form or more thoroughly engineered representation, but during the early stages of concept development it is often more appropriate to create something that actually works.

Block Model

Block models are produced towards the end of the industrial design phase of NPD. Such models are highly finished with accurate surface treatment in gloss or matt along with appropriate badging. Materials used include plastics (sheet, extruded sections), wood (Jelutong, Medium Density Fibreboard), and cellulose paints. Metals are generally used for the more structural components. The result is a visual impression of the final proposal, accurate in form and finish but not materials usage.

It makes greater economic sense to produce a hand made component to assess visual acceptability than to commission an injection moulding that is extremely difficult if not impossible to modify.

Block models rarely have any functional components as only the essential features for an ergonomic and visual assessment are possible. This is due partly to the difficulty of creating moving surfaces with sufficient structural integrity to perform as required of the production item.

Once the design is accepted using the block model the production tooling may take many months to complete. In situations where the product launch date is critical models frequently have a second role in the promotion of the product (that does not yet exist!). Hence many products featured on packaging are in fact photographs of the block model as artwork would have been produced in parallel with tooling for the actual product.

System Prototype

Testing is an inevitability during the development of any product. Before tooling is commissioned it is essential that the manufacturer be satisfied that no injury or loss will result from use (and moderate misuse), and that the required performance can be achieved.

Various prototypes are thus required to assess and develop the many functional attributes of products. For a vacuum cleaner the proposed motor and collection system would be produced in a laboratory to ensure its ability to collect as required. This may not look anything like the finished product but would be invaluable in the development of the engineering solution. Equally the heating elements of a toaster would be housed in a cavity to ensure it was capable of browning toast in an acceptable time without overheating.

Generally the system prototype would utilise many components that were specified for the final product. More complicated products may utilise several system prototypes to assess and test various aspects. These may then lead to a more complete system prototype that is more representative of the final product.

Tooling Prototype

Tooling usually represents the greatest single investment in a product’s development. For example, an injection moulding tool for something of the size and detail of a washing up bowl could cost approximately twenty thousand pounds. Once commissioned such tools for injection moulding, steel pressings or die castings are difficult or impossible to modify. It is therefore important to get it right first time.

Following the industrial design and system prototype it is possible to combine the two into a visually representative product that actually works. This not only allows the creation of a working product but also enables any potential tooling problems to be intercepted as the fabricator would be using the engineering drawings eventually destined for the

toolmaker. Any discrepancies of form or fit should appear at this stage.
Components produced using techniques such as injection moulding can only be accurately assessed as production items. If a hairdryer body is fabricated using a combination of vacuum forming and bonded components it will not have the inherent structural characteristics of the actual injection moulding. Hence it would not be representative to undertake a drop test with the tooling model and expect the injection moulding to respond in the same way. Even components machined from block ABS do not have the same mechanical properties as an injection moulded item in the same material.

Occasionally sufficient strength cannot be attained by fabrication techniques. In these instances it is often necessary to supplement bonding with mechanical fixings such as nuts and bolts. This is one of the necessary visual compromises of the tooling model that is often used for functional tests. However, the presence of nuts and bolts should not be misinterpreted, as the final appearance would have been assessed independently via the block model.

A more recent technique involves the production of silicon moulds using fabricated patterns. These moulds are then filled with resin which when cured gives an accurate component in a uniform material. These resins are currently being formulated to perform as the proposed injection moulding materials such as ABS and polypropylene.

Off-Tool Prototype

'Off-tool' samples refer to those components produced using the tooling and materials intended for the production item. This may be an injection moulding, steel pressing, or die casting.

When off-tool samples are brought together to create a product, it is likely that some components may not fit together due to material contraction, screw bosses may need strengthening, or ribs may have to be added to prevent flexing. Even more cosmetic factors such as an unacceptable surface finish may have to be rectified. As further development work would normally be required these assemblies are known as off-tool prototypes.

Once available the off tool samples can be subjected to rigorous tests to ensure compliance to international standards and corporate values. These components would respond to such assessments in a similar fashion as when used on the production item.

When assembled, the off tool prototypes would be hand built by technicians or, in some organisations, by the designers themselves. In assembly terms they would therefore fall short of the production item as they were not assembled by shop floor personnel. Only the pre-production prototype has the attributes of production components combined with the assembly techniques and personnel of the final product.

Pre-Production Prototype

By this stage any necessary tooling modifications should have been undertaken and the production line would have been prepared. A relatively low volume production run would then be undertaken to ensure both speed and quality of manufacture.

Inspection of these products will determine that the required fit and finish is being achieved. Over, or under-tightening of screws can be identified. Careless handling may scuff surfaces requiring some form of transit packaging. The chances are that it is not the product itself that requires modification at this stage but the assembly process.

Production Item

Hopefully by this stage the product is no longer a prototype as it should now appear at the point of sale. However, what if an undetected fault in production or design gets through the system? A product recall must surely mean that the item is still unsuitable for sale. If it did go on sale before the fault was recognised then it could have been deemed to have been a prototype as deficiencies existed that made the item unsuitable for sale.

Fortunately in practice product recalls rarely take place as the rigorous modelling and prototyping procedures undertaken during the product's development ensure that the product is of 'merchandisable quality'.

Conclusion

To undertake the design, development and production of a high volume product requires many discrete models and prototypes, each devised to allow the necessary evaluation. This rigorous process is intended to ensure that problems are identified as soon as possible, with the aim of avoiding expensive modifications, recalls, or liability damages.

Whether a model or prototype is selected depends on the particular features being assessed or developed. Unfortunately the uninitiated or misinformed may consider either of these as being deficient. Hence one may be impressed by a block model as it would appear as a complete and desirable product. Only by attempting to use it would functional deficiencies be realised. Equally a system prototype may be dismissed as being ugly, difficult to use and dangerous, despite the fact that it may perform its intended function. It is therefore essential to understand whether a model or prototype has been produced, when it was produced, but, more importantly, why it was produced.

References

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