DESIGN INTERPRETATION: A METHODOLOGY FOR ADAPTIVE DESIGN

by

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Abstract

Adapting designs of products to suit local requirements is crucial for the development of countries like Sri-Lanka. This often involves identifying the functions performed by the product and eliminating the facilitating functions which use high technology and which can be avoided to suit the local requirements. Design Interpretation is a methodology to analyse the designs of current products and extract the design information at different levels of abstraction. These are then used to develop the product and solution concepts of the next generation product or the adapted product. Illustrative examples are given to explain the use of the methodology. Finally a case study on the development of a balancing machine is also given.

1 Introduction

The past few decades have witnessed an unprecedented rate of technological advancement. Because of these reasons and the ever-increasing demand from the customer for product sophistication at lower costs, companies in the developed countries look for the development of 'Next Generation' products. These products perform the functions performed by the current generation products with extra sophistication resulting from the employment of better technologies at conceptual, embodiment and detailed design levels. While these changes are desired in the developed countries, developing countries do not want the facilitating functions provided by the expensive high technology subsystems. They want the next generation products to be simple providing the required essential functions. In order to make the development of these Next Generation Products in an efficient and transparent manner, a systematic methodology is needed. This paper describes such a methodology, which employs Design Interpretation to analyse the existing product, which forms the basis for the development of the Next Generation Product.

2 Design Process and the Generation of Information

The design and development of a product starts with the identification of a need in the society, which may be expressed as a set of requirements. The design team transforms these requirements into a set of functions, which the proposed product has to perform so that the requirements arising from the societal need are satisfied. These functions are expressed as a list of prioritised functions, expressed in a verb noun phrase format, in a solution neutral form. Conceptual design is the definition of subsystems that perform a subset of the functions in the product concept individually and perform all the functions in a harmonious fashion collectively. This function - subsystem relationship can be expressed as a tree diagram called Function Tree diagrams. The conceptual designs are further developed to form the Embodiment Designs, which essentially defines the constituent parts of each subsystem. Parts Trees best describe them. The next step in the design process is the detailed design of parts. Thus the Design Process generates five types of information about a design at different levels of abstraction. This is schematically shown in Figure 1.

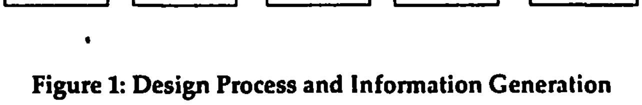

Figure 1: Design Process and Information Generation

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3 Adapting Designs to Develop Next Generation Products.

Next Generation Products can be developed based on one or several of the following approaches:

a) Addition of extra requirements to make the product to be more efficient, effective and useful to the customer.

b) Enhancing the 'Product Concept' with extra functions which are made possible due to economic and other reasons

c) Replacing the conceptual design of one or more of the subsystems with technologically better ones resulting from latest technological developments.

d) Changing the Embodiment Design by the combination of some of the existing parts or by replacing few parts with a single better part.

e) Changing the detailed design of one or several parts.

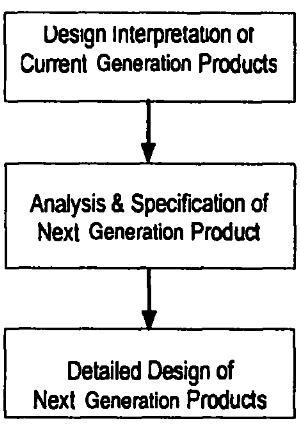

Figure 2:Model for the Development of Next Generation Product

Systematic approach to the development of Next Generation Products involves three steps as shown in Figure 2. In the first step the existing design is analysed to generate information about the current generation product in the categories shown in Figure 1. This process is called 'Design Interpretation' and is described in Section 4. In the next step the generated information in step 1 is analysed and the product is redefined in terms of (a) Requirements (b) Product Concept (c) Solution Concept (d) Embodiment Design and (e) Detailed Design. Once the enhancements are finalised the detailed designs of the Next Generation Product can be developed.

4 Design Interpretation - Method and Illustration

Design Interpretation starts from the end of the design process i.e. the detailed design and works backward to establish the Embodiment Design, Solution Concept and Product Concept. The objectives are

a) To establish the Embodiment Design in the form of a Parts Tree

b) To establish the Solution Concept and Product Concept in the form of a Function Tree

The following sequence of steps is recommended in the Design Interpretation process.

a) Describe the process or the action of the product with the intention of identifying the underlying working principle.

b) From the description establish the various subassemblies which form part of the Embodiment Design

c) From the Embodiment Design establish the functions performed by the various subsystems (group of functions) which forms the combined product and solution concept.

4.1 An Illustrative Example - A Screw Driver

Process Description of a Screwdriver - A screwdriver receives a torque and positioning effort from the human hand, transmits it to the tip or application unit and applies it on the screw. This torque may be used to drive in or draw out screws.

Establishment of the subsystems - From the process description three subsystems can be established. They are

1. Receiver - the system which receives the effort (Part: Handle)
2. Transmitter - the system which transmits the torque (Part: Shank)
3. Application Unit - the system that applies the effort on the screw (Part: Tip).

Thus, the derived Embodiment Design can be schematically described by the tree shown in Figure 3.

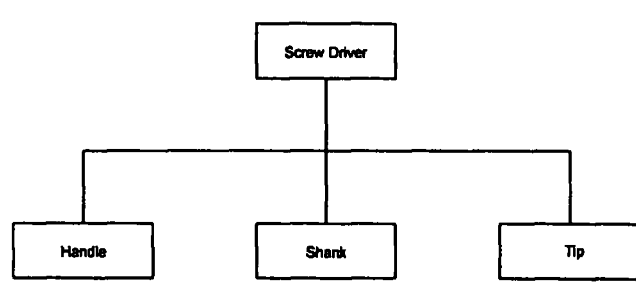

Figure 3: Embodiment Design of a Screw Driver

Establishment of the Function Tree - Once the subsystems are identified it is easy to establish the functions performed by each of them in a solution neutral form.

This and the embodiment design in a combined form establish the Function Tree, which show the various subsystems and their functions. Figure 4 shows the Function Tree for the screwdriver.

4.2 Establishing the Customers' Requirements

Quality Function Deployment [1] is a method for establishing the customers' requirements. For an existing product this can be combined with Benchmarking to establish the current prioritised customer requirements. King and Sivaloganathan [2] recommend the following steps in these circumstances:

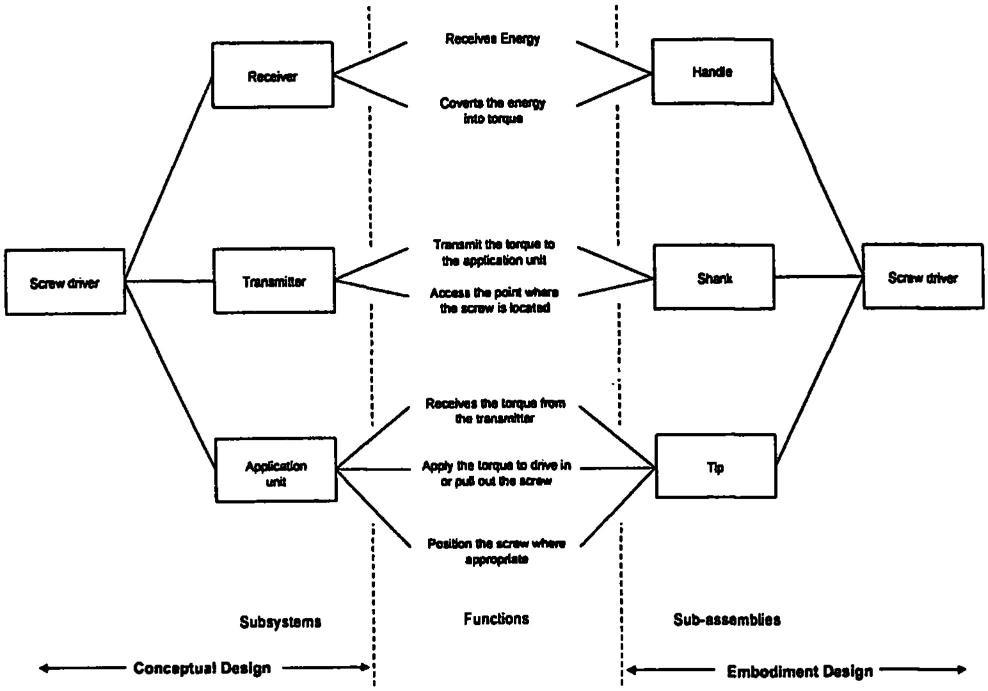

Figure 4: Design Interpretation of the Screw Driver

As mentioned earlier the benefits of this kind of analysis are that the subsystems can be changed when their performance is not up to the mark or when better solutions emerge due to technological development. Also it can be used to eliminate expensive high tech facilitating functions. In the case of the screwdriver the receiver can be replaced with an electric motor if the demand for its use is heavy. Some variations resulting from varied requirements and solution concepts are shown in Figure 5.

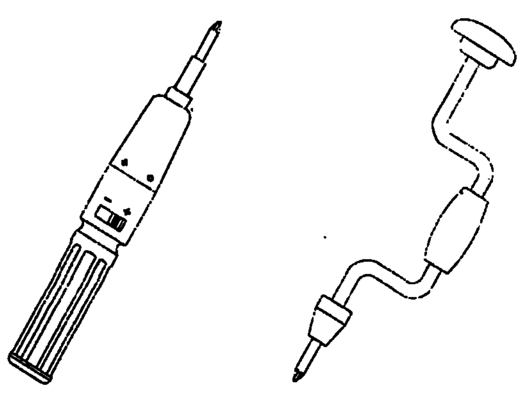

Figure 5: Different Generations of screwdrivers

a. Develop the Market Insight
b. Undertake a Pilot Study for a Questionnaire
c. Use the Questionnaire to hear the "voice of the customer"
d. Integrate the customers as Partners in the team
e. Incorporate the "voice of the company"
f. Set out the complete list of requirements
g. Set out the Function structure
h. Establish the Specifications & Constraints

5 Case Study

In this section a case study to illustrate the power of the Design Interpretation method is presented. This is the result of a project carried out at the Kankesan Cement Works during the 80's. The aim was to develop a Balancing Rig to perform dynamic balancing on the impeller of the preheater fan. The fan is of the centrifugal type with a diameter of the impeller being 1.2 metres. The layout of the impeller is shown below in Figure 6.

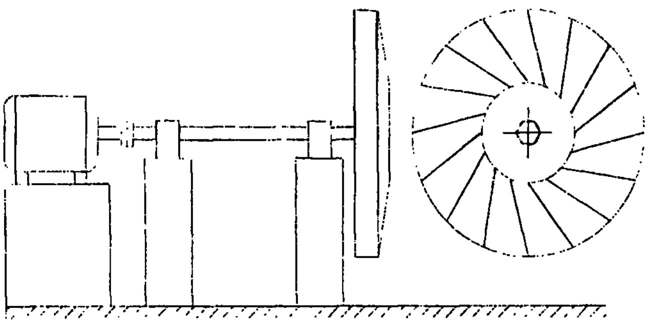

Figure 6: The Layout of the Impeller

Initially, various Balancing Machines in the market were surveyed. A balancing machine supplied by Hofman Company from Germany was identified as the candidate for design interpretation. Figure 7 shows Hofman's balancing machine as given in a leaflet [3]. It also contained the description of the labelled parts as shown below:

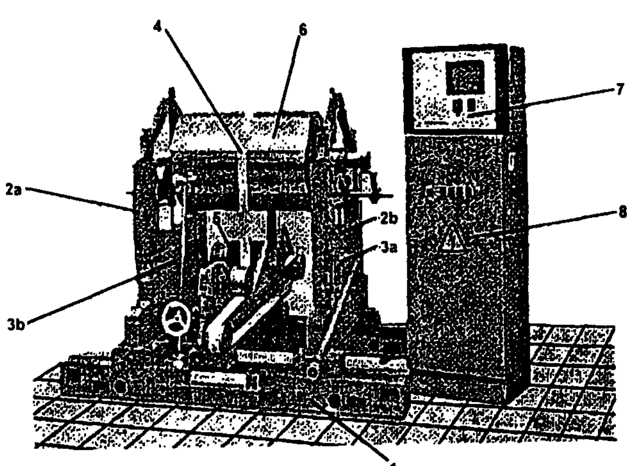

Figure 7: Hofman's Balancing Machine

1 Solid machine base
2a bearing pedestals for accommodation of rotor,
2b detection of measured data, and dynamic support of motor weight
3a Force transducer for generation of signals
3b representatives of the centrifugal forces caused by the unbalance
4 Drive (belt Driven Illustrated): Two types are usually given preference
   a) Belt drive - Medium to small weight range
   b End Drive - Heavy rotors with large diameters and inertia
5 Drive motor - Varies from frequency controlled 3 phase motors or DC motors
6 Rotor
7 Control cabinet with drive control
8 Measurement and computation unit

Description of the process: - The rotor is marked at one point of the circumference and loaded into the machine. The rotor is then rotated by the belt drive. The unbalance forces are transmitted through rigid bearings to piezo-electric transducer. The photocell produces signal each time the mark in the rotor passes it i.e. once per rotation. The amplitude of signal from transducer plotted with respect to the position of the mark. The rotor is finally removed from the machine and balancing masses are attached to it.

Identification of the Sub-systems - Analysing the process description, six subsystems were identified. They are shown in the subsystems diagram shown in Figure 8.

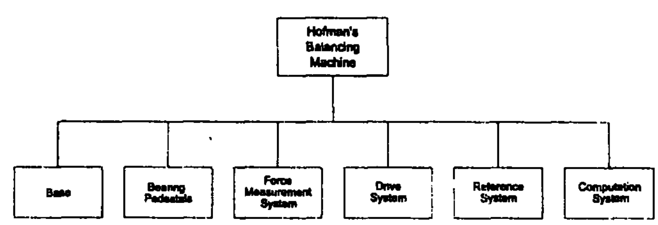

Figure 8: Subsystems of Hofman's Balancing Machine

Function Tree for Hofman's balancing machine can be established from the subsystem diagram. The Function Tree is shown in Figure 9.

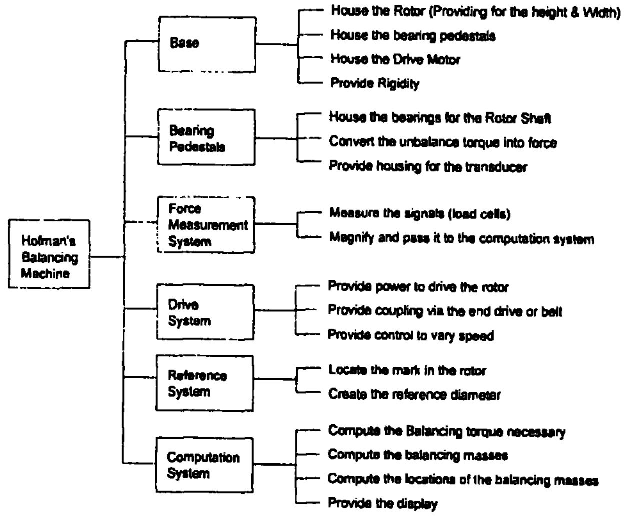

Figure 9: Function Tree of Hofman's Balancing Machine

5.1 Proposed Solution

The proposed machine for balancing of a Rotor as given in the problem was needed for a single specific application and therefore should incur the minimal cost. Therefore a close analysis of the Hofman's Subsystems and Function Tree was performed to identify the unimportant subsystems and eliminate them from the design and to identify the essential subsystems and to incorporate them in the design. The unimportant systems were identified as (a) Separate bearing pedestals and (b) Computation system. A close analysis revealed that the force measurement system and the reference system can be combined into one single system. The essential systems were identified as (a) the base (b) drive system and (c) combined reference and measurement system. The Function Tree for the proposed system is given in Figure 10 and the structure is shown in Figure 11.

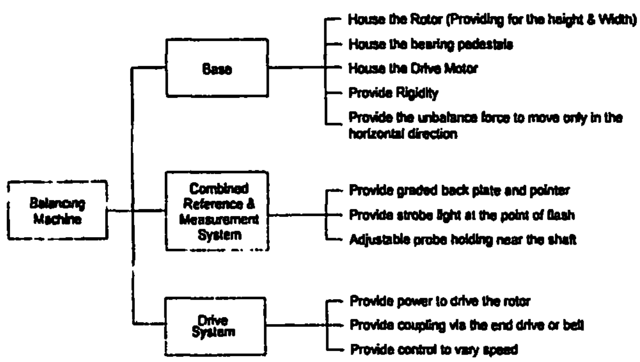

Figure 10: Function Tree for the Proposed Machine

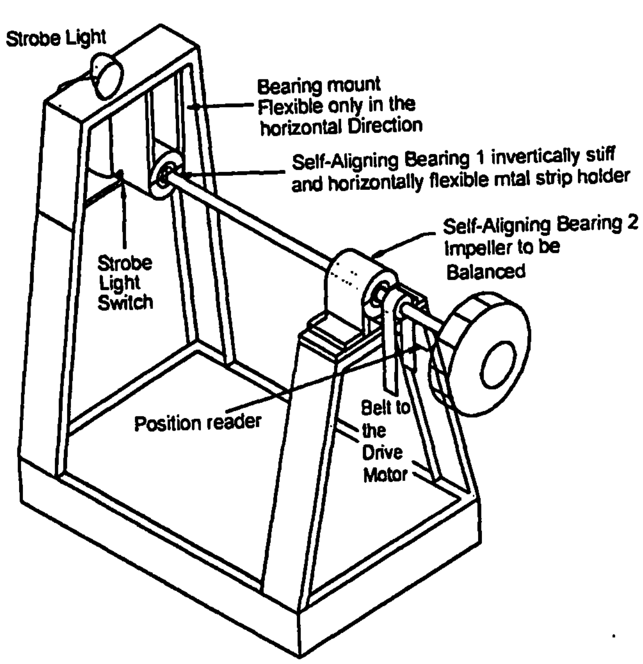

Figure 11: The Structure of the Balancing Machine

The base was constructed to house the fan with the actual bearings and bearing housing (bearing 2 in Figure 11) close to the fan. Bearing 1 was housed between two strips of steel, in a vertically rigid and horizontally flexible fashion. This permitted the shaft to move only horizontally due to the unbalance torque. All other degrees of freedom were curbed. The drive system consisted of a motor, which was housed directly under the shaft, and a flat belt running over the shaft and the pulley attached to the motor shaft. The motor is switched on and off to get the required speed which was measured by the use of a tachometer. The motor did not have enough power to drive the fan in open conditions and therefore a cover plate was used to seal the inlet of the fan. This made the power requirement to be lowered considerably. The probe of the stroboscope was positioned adjacent to a horizontal diameter of the shaft so that the circuit is closed when the shaft moves horizontally and makes contact with the probe. The base plate of the impeller was divided into 72 segments with chalk marks and a horizontal needle was placed in front of the impeller to assist reading. Sticky material (clay) was used to create the counterbalance torque and the process was repeated until the horizontal displacement was negligible. The clay was then replaced with pieces of steel, which were welded onto the impeller.

The case study proved that the development of the product using the strategies, Design Interpretation and Next Generation Product Development, is very efficient. The Design interpretation provided a better insight of the current generation product and the Next Generation Product Development methodology provided the opportunity to redefine the product and solution concepts easily. This provides a new avenue with lot of new opportunities for developing countries like Sri-Lanka.

6 Conclusions

1. Adapting existing designs and Developing next Generation products is seen as a critical factor for success of small countries like Sri-lanka.

2. A three stepped methodology for Next Generation Product development involving (a) design interpretation (b) analysis and specification, and (c) detailed design has been established.

3. Design Interpretation, a three stepped methodology is seen as a valuable method for extracting design information from existing designs.

4. A case study showing the use of the methodology is presented.

7 References

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The authors wish to thank the Management and Technology Support Division of the Commonwealth Secretariat for the support of the first author to visit the Engineering Design Conference 98 at Brunel University which was instrumental for this work.