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MODULARISATION AS A MEANS OF PRODUCT AND PROCESS INTEGRATION.

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Investigative work carried out to determine a strategy to address modularity as a facilitator for integration of design with manufacture. Modularisation is considered in conjunction with a large car manufacturer, a company that produce geophysical measuring systems for down hole drilling, and a company that produce electronic scanners for the pre press printing industry. Generic factors are being determined. These factors touch upon the benefits to product and process integration and also areas in which modularisation enables effective product customisation in meeting market needs. The aim, is to pool and document experience that can then be analysed and presented in a more accessible form by providing guidelines / checklists, evaluation tools and a product strategy based on derivatives.

Introduction

A visible trend in today's marketplace is toward products targeted at specific areas of the market, Shirley(1992), so called 'niche' products, with their associated low production volumes and high variety. To cater for this specific demand many companies have found themselves having to adapt existing products, or undertaking the development of new products, often in an incremental or evolutionary manner. During the normally short timescales involved, this leads to re-engineering of their products and finding ad-hoc solutions for customisation. Thus companies are left with a large array of product variations showing much in common in function but little in design.

The aim of this paper is to address the issue of product variation and the requirements for product customisation through the use of modularity as a structured design technique. The approach taken is to analyse the advantages and disadvantages of such a strategy, to determine a range of suitable case studies in which to apply the technique and monitor its implications, and to extract the generic elements in a form that would be more broadly applicable.

Modularity

In general, product variation has given rise to conflicting aims for a product's development. There is a need to adapt to the customer requirements and provide versatility, yet variation is detrimental to manufacturing concerns. One solution to this conflict is the introduction of variation as late as possible, to maintain a high degree of product variation, with the minimum of impact on manufacturing. There are however other considerations. Manufacturing flexibility can be seen as a means to integrate product variation. Manufacturing flexibility however, only addresses the problem in the short term, usually associated with high monetary and complexity costs. Alternatively by achieving product flexibility, the use of existing products and technologies will be maximised, the manufacturing system will be inherently more flexible, and flexible systems will then aid in the overall design to manufacture process. It must be recognised that the problem of flexibility is a combination of product and process, and the integration of the two will directly address many of the problems currently encountered.

The method of product and process integration considered in this paper is that of modularity. Here we consider a product composed of self contained units or modules that are manufactured as sub-assemblies and assembled together. Modularisation, to create a product composed of modules, provides product flexibility by means of combining developed modules together in various ways to extend the product range, Erixon and Östgren (1993). By implementing a modular strategy, product and process will naturally become more interlinked by providing a stable and common platform to design and manufacture. Modularity should thus increase the robustness and flexibility of a product and its associated manufacturing system.

An extension to the theory of modularity for product design relates the module concept to processes and also to businesses. The benefits gained by a modular product design can also be mirrored in the concept of holonic manufacturing systems and also holonic enterprises. Holonic manufacture is part of the Intelligent Manufacturing System (IMS) programme, Valckenaers and Van Brussel (1994), that addresses the so called 'fragility' of today's manufacturing systems. In general, the manufacturing systems of today suffer from inflexibility and generally perform poorly when they must operate outside their normal / expected conditions. By replacing rigid and inflexible hierarchical manufacturing systems with those that are much more adaptable to change, holons act to fulfil the role of hierarchical intermediaries. Thus, holons are autonomous, discrete and co-operative units, that are capable of dealing with disturbances and yet provide the functionality to support the greater whole, and thus increase the robustness of the system. Holons may be seen as the building blocks of a manufacturing system. The holonic concept can also be taken one step further by examining the holonic enterprise. This builds on the theory of Business Process Reengineering, by defining a holonic network as a group of businesses that, cooperate in an integrated and organic manner, forming a system able to configure itself to manage each business opportunity that a customer presents, McHugh, Merli and Wheeler (1995). Holonic enterprises, holonic manufacture and modular design share many similar concepts and objectives. The development of such concepts as the holon will further aid in the integration of product and process by providing an increased awareness of manufacturing concerns, and a means of implementing them at an early stage, in addition to a system that will be able to integrate changes much more easily and rapidly throughout a products life-cycle.

Investigation and Case Studies

The investigative work done into modularity has focused on three products that are different in function, design, and scale of production. The products considered consist of; a future small car from a major automobile manufacturer, an optical scanner for the pre-press printing industry manufactured by Crosfield Electronics, and a geophysical measuring system that is used for down-hole drilling, from Geo Measurement Systems. These products also presented a range of enabling technologies; both mechanical, electronic and optical.

The investigation, complementary to existing initiatives within the companies, initially realised a number of pro's and con's that modularity would provide to a product and its associated process. In addition to the rational introduction of variation in a structured and systematic manner, modularisation provides further utility in design, manufacture and also, to the customer.

1. To product development, modularisation means reduced lead times due to the possibility for parallel design and manufacture of modules, and the use of bought-in modules that require no further attention.
2. Manufacture will benefit from a JIT friendly system, leaner production from reduced WIP and finished article stocks, and improved and more consistent quality-with associated reduction in test overheads.
3. Assembly benefits from a product inherently designed for assembly with modules being; of manageable size, and identical within each type (e.g. no adjustment required for fit). Modularity can also facilitate assembly by a reduction in

part numbers and part variety, and also the possibility for disassembly, if desired for service (DFS).

4. Management considerations are simplified, by allowing a project to be naturally broken down into smaller components, and increased product planning accuracy, Erlandsson and Yxkull (1993). In addition, the necessity to consider modules early on, as a design and manufacturing concern, will reduce the downstream activity overhead.
5. Environmental aspects may be addressed (DFE), through the ability to group similar materials for recycling, or the ability to reclaim the most desirable elements.
6. Finally, the customer benefits from a modular product by the range of product choice or customisation at no extra cost, and in significantly reduced time scales, both in terms of delivery and also development of new products. They will also gain improved quality, ease of service and replacement of parts, and a simple upgrade path.

On the negative side, the modularisation of a product will immediately increase the problems with interfaces. Module interfaces will require careful consideration as a key enabler of the technique. Though initially the extra effort up front in defining the interfaces will seem excessive it will facilitate downstream processes and will also promote the discipline of team working and simultaneous engineering by design and manufacture personnel.

It is possible to demonstrate the benefits of a modular strategy to product development and manufacture by examining a number of products that have considered modularity to be a desirable objective. None of these products were developed using strict guidelines on how to implement modularity yet they show how the consideration of a technique such as modularity may be used to promote the discipline of product and process integration.

Figure 1. shows a colour scanner from Crosfield Electronics. The company focused on a new project and developed the product to be modular. During the project the seeds of a strategy were developed to aid in the process of module definition and a means to identify and analyse module interfaces and the interactions that occur. Working with cross functional teams and ensuring up-front effort, provided Crosfield electronics with considerably less problems downstream, and iterations within product development. Other advantages include; significant reductions in part numbers and variety, assembly operations and adjustment, floor space, testing, and complexity of the product.

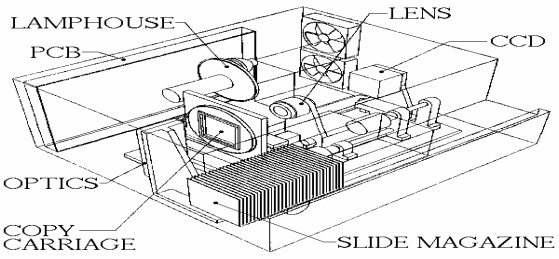

Figure 1. A modular scanner assembly.

Figure 2. shows a typical product by GMS. This illustrates a perfect opportunity for modularity. The product must be designed in this form to offer the flexibility required, but up until now the predominant way of working has been to re-engineer many parts or modules of the product, with little overall standardisation in the mechanical aspects which have proven to be secondary to the electronic concerns. The company are now into the early stages of developing a new mechatronic product, and this is being used as an opportunity to modify their development phase. They aim to take advantage of previous work and designs so modules that make up many of their products are standardised and interchangeable. A key consideration in this case is the nature of the business; GMS do not sell their products, but operate them to provide a Measurement Whilst Drilling (MWD) service, thus they must constantly be able to support existing equipment and provide for large degree of customer requirements. With a structured approach to modularisation GMS will be able to address their main concerns and also refine their overall product.

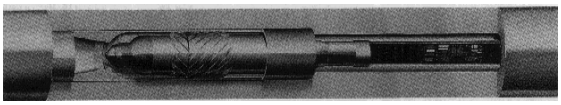

Figure 2. A modular (MWD) sensor and drilling string.

Figure 3. shows a concept for modules incorporated into a new small car. The use of modules in the automobile industry provides a number of advantages in both product and process. The assembly of the automobile benefits greatly through reduced handling, fewer process steps, and component integration, increased flexibility in tooling, equipment and processes and higher productivity through the integration of DFA, DFM, DFS, and DFE disciplines. Quality is improved, and through the ease of interchangeability of modules, so too is customer satisfaction in features and attributes.

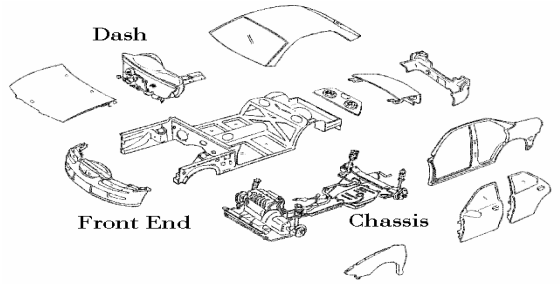

Figure 3. The modules of a small car.

Conclusion

This paper documents the initial investigations into modularisation as a technique for product development. The case studies shown offer an opportunity; to examine the benefits of having applied the technique, to apply the technique within a company who are not untypical in their current product development process, and to study a company who are examining a broader strategy in meeting customer demands for the next millennium. It has been shown that the implementation of modularisation provides many advantages over incremental design and manufacture. Modularisation, product or company wide under the guise of the holon, directly meets the needs for custom specifications, and provides mutual benefit to the producer and the customer from the optimum development of the product through companies who are able to configure themselves to meet specific demands. The paper documents the ground work done in furthering the aim to provide guidelines or checklists for the suitability and implementation of modularisation within a context. Modularisation provides the way forward for product development, achieving a product and process that is capable of dealing with customer driven needs, and that it will prove to be an extremely valuable technique in the future manufacturing industry.

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