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Paths for Modularization

Modularization for Flexible Structural Platform for Boats

Bjørnar Henriksen¹ and Carl Christian Røstad¹

¹ SINTEF Technology and Society, 7465 Trondheim, Norway
{bjornar.henriksen, carl.c.rostad}@sintef.no

Abstract. Rapid product introduction and customization are keywords for competitiveness in many industries. This is often associated with modularization, where the objective is to create a flexible product design, not requiring changes in the overall product design every time a new variant is introduced. Modularization could be approached in many ways with focus on different enablers. This paper describes different approaches that are relevant to create a flexible, modularized structural platform for boats. The paper is based on the project "Marine Platform", where manufacturers for the professional and leisure market, are focusing on different, but complementary, paths towards modularization. This conceptual paper describes how high-speed innovation in the boating industry could be approached through modularization in material technology, moulds, and production processes, but where the most important enabler for a flexible structural platform for boats is knowledge – modularized knowledge.

Keywords: Product development, modularization, boating industry

1 Introduction

Customization is one of the potentially most important competitive advantages for manufacturers in high cost countries such as Norway, especially when it is combined with innovations and frequent product introductions. However, this is challenging for example in the design and development of boats when also efficient production processes are required. "Mass customization" and modularized design/production would normally be key elements in a strategy to meet such challenges.

The overall objective for the R&D project "Marine Platform" is to reveal, create and combine the different presumptions and requirements into efficient development and production processes for boats. This is based on a new approach to design and the development of flexible standardized structural platforms as a basis for defined inter-phases for the different modules in boats. This then leads to new approaches to production and customization improving the companies' competitiveness. In our definitions of modules we have to go behind the traditional view of modules as physical parts and systems. Modularized processes, both in product development and production, and increasingly modularized knowledge (e.g documentation) are emphasized in modularization. Even though all of the above perspectives are interrelated and should

be covered in a holistic modularization strategy, they are often not explicitly described and approached. An important part of the project is to develop methodologies and solutions enabling these objectives.

The purpose of this conceptual paper is to illustrate different ways modularization could be approached using cases from the boatbuilding industry, where the overall aim is to enable rapid product development processes. The paper is based on a R&D project involving manufacturers of leisure boats and boats for the professional markets. The project is at an early stage and so far the activities have mainly been to develop hypothesis, challenges, and how to approach them in concrete contexts. The project is closely related to what is happening in the companies (case studies) and the researchers aim to participate in the product development processes in order to improve them through action research. Literature studies have also been important for the project (and this paper) at this early stage.

Section 2 presents theoretical perspectives on innovation and modularization. Section 3 presents the R&D-project while Section 4 focuses the different focus areas in the modularization of a structural platform for boats. Section 5 concludes.

2 Theoretical Perspectives

2.1 Product development and modularization

Module-based design founded on platform-thinking enables faster development processes e.g. through reuse of solutions. We can also assure robust design solutions from modules that have been tested and optimized over a long period of time. Modularity allows part of the product to be made in volume as standard modules while product distinctiveness is achieved through combinations or modifications of modules [1]. Modularization could bridge the advantages of: (1) standardization and rationalization, (2) customization and flexibility, and (3) reducing complexity [2].

The cost effects through reduced product development lead time and volume effects from standardization are important, but there are also revenue aspects of modularization: With a modular product platform structure, a set of building blocks (modules) are created where a great number of final products can be built, without increasing a company's internal complexity.

Parallel development activities are possible once the interfaces between the modules have been defined, and subsequent work conforms to the established interface specifications [3]. This reduces overall development time and resource requirements by eliminating the time-consuming redesigns when component interfaces are not fully defined and standardized during component development processes [4].

2.2 Components and functions

We often find module-based design within incremental product development, where e.g. not all innovations or "novelties" are introduced at the same time. However, if modularity is identified and exploited in the initial conceptual or reverse engineering effort, the immediate product design reaps benefits in several strategically important

areas [5]. However, an early focus on products and components could freeze product architecture and solutions, making it less flexible for future requirements.



Fig 1 Component oriented modularization

Products are normally supposed to fulfill functions or requirements defined by "someone". This could be from standards or regulations, but most often this is about meeting customer requirements. A function oriented approach implies focus on functions and organizing/prioritizing them before the physical function containers are defined. This could be perceived as a demanding and theoretical process, but today modularization based on functionality has become a common approach and methods have been introduced to cut out a module from function structures using module heuristics [3]. These methods, such as Modular Function Deployment (MFD™), identify modules from a functional model of a product, create rough geometric layouts and group products into families based on function [6]. Rather than a fixed product platform upon which derivative products are created through substitution of add-on modules, this approach permits the platform itself to be one of several possible options. After comparing function structures for common and unique functions, rules are applied to determine possible modules. This "inverse" process defines possible architectures. This approach increase the flexibility as it also represents a modularization of the basic platform [7].



Fig 2 Function oriented modularization

2.3 Modules - knowledge containers

A systematic approach needs knowledge from people that know customer demands, service requirements, and from those producing the products. Concurrent engineering could be a key to mobilize and capture this knowledge [8]. An important part of the knowledge of the company is embedded in the products and reusing modules knowledge saves time and money. Also, the reuse of engineering specifications, testing, process engineering etc, may lead to the desired effects by blurring the boundary between knowledge management and traditional modularization [9].

The tendency towards a more abstract understanding of modularity is further strengthened by the fact that modularization in an industrial context can be seen as reuse of engineering and employee resources for companies that are increasingly aware of knowledge as a competitive advantage [10]. An important part of the

knowledge of the company is embedded in the products and reusing modules. It is not necessarily the finished, physical modules that are reused in order to gain the benefits. Also, so-called *intellectual reuse* of earlier stages, like reuse of engineering specifications, testing, process engineering etc, may lead to the desired effects by blurring the boundary between knowledge management and traditional modularization [11].

2.4 Holistic approach to modularization

To get the desired effect of module-based design processes they have to be standardized in a way that matches the requirements from the physical products and modules. Processes could be production, but also product development or administrative processes such as documentation and system-support. Also the knowledge modules are premises e.g. for production or product development since they could give input on for example cost efficiency of the processes.

For the product development process modularization could give time and cost savings in addition to quality improvements since modules could be developed separately through testing, modules could be reused in subsequent development processes etc. One of the advantages of a holistic modularized product strategy is that modules could be "sub optimized" without risking reducing the performance of other modules or the product as a whole.

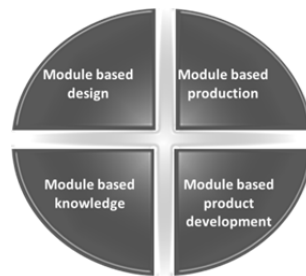


Fig 3 Holistic approach to modularization

Modules and platforms are terms closely related and often mixed. One distinction is that while a module has a product- or function focus, platform are often more abstract, related to processes or basic principles. A platform could be basic geometry (e.g space between components), fixation, materials, common ways of dealing with interfaces and tolerance. In this way a platform have a longer life time than modules and could as is the case for the Marine Platform contain several modules.

3 The Marine Platform project

Marine Platform is a 4-year R&D project co-financed by The Norwegian Research Council that started in 2012. The overall objective is to radically improve the product development process focusing on the critical and resource demanding phases related

to the structural elements of the boat. The project aims to define the premises and solutions for a flexible structural platform.

The project has four Norwegian industrial partners, two SMEs producing for leisure boat markets, one large company producing for the professional market, and a SME supplier which is a key actor in the boatbuilding industry as it is the biggest and most important supplier of their products in the Scandinavian boatbuilding industry. The supplier is within the mechanical engineering industry, but still has many of the same characteristics of craft manufacturing as the other partners.

SINTEF is project coordinator and two other research partners are also contributing to the action research, namely The University of Agder and Inventas.

4 Different paths towards a flexible structural platform

4.1 Criteria for structural platforms

Flexibility and modularization enabling rapid product development can be achieved by using the different perspectives on modularization in different areas. In the Marine Platform project business cases have been defined for each industrial. This provides the objective for the research carried out and thus results in a higher technology readiness level [12]. The business cases are strongly revolving around how to make the development process for new models more efficient and more cost-effective in addition to catering for the ability to customize the products and thereby competitively fulfilling customer requirements. This requires a study of success factors, enablers, capabilities, the possible configurations and the possible critical issues [14].

As the knowledge aspect is crucial for modularization, an important criteria for modularity is that performance, data collection and knowledge could be linked to modules or be property-modules themselves in the product architecture.

Investigating and developing a structural platform that can act as a basis for several different models is well known in other industries like the automotive sector. However, with regard to boat manufacturing where there are very high demands for customization and where the number of boats sold of one model is significantly lower than in other industries, the need for a flexible structural platform arises. Such a structural platform can both consist of the hull/inner-liner/support structure themselves and modules on the boat acting as structural components providing stability and strength.

In the following, the project's focus-areas for establishing a flexible structural platform for boats are presented. Specifically, this paper addresses the following areas; standardization and outsourcing, material technology and adaptive process moulding.

4.2 Standardization and outsourcing as basis for a structural platform

Identifying structural properties for interiors, furniture, doors, windows, bulkheads are just some examples that to a large degree will have to be carried out in cooperation with suppliers and where one can achieve simplification through standardization and uniform quality requirements. By establishing concise structural properties and re-

requirements for different modules and components in a boat, it will be easier to create requirement specifications to suppliers. The establishment will also make it easier and more efficient to identify suppliers and products that adhere to the sought-after product properties. Standardization also addresses strength requirements which in turn more clearly defines the single components and modules and thereby simplifies the work on the overall structure in boats. The main advantages with standardization are that a company achieve a holistic approach and have more available data with regards to a boat's structure. The greatest challenge is the amount of work needed in order to standardize, especially in craft manufacturing where there are many unique and one-of-a-kind solutions developed for single products.

Standardization also must capture customer needs of today and tomorrow in defined (and not defined) market segments. The Concurrent Innovation Process has been developed for involving customers and document needs and requirements. One of the boat producers used this methodology as basis for developing modularized concepts for a new range of boats for the professional markets and proved that common platform based on standardized solutions was a viable approach.

The project addresses standards and common solutions for interfaces, material solutions etc. This enables a higher degree of flexibility in supply chains and outsourcing, but will require extensive documentation and a general acceptance of standards.

4.3 Material technology as basis for a structural platform

By focusing on material properties, new material-solutions that provide strength and structural properties are within reach. Also, materials as enablers for modularization are equally important. Different materials with different kinds of properties can have different structural functions that may be utilized in order to ensure flexibility and structure. Examples are self-supported hulls, use of innerliners or grids.

New laminates and new or adapted materials provide greater possibilities to avoid the cost-driver of special reinforcement like ribs and/or innerliners. Also, a fact-based approach to the use of materials is needed in order to avoid over-dimensioning and excessive use of materials, resulting in higher material costs and e.g. heavier products (resulting in e.g. higher energy consumption). However, it should be noted that e.g. leisure boats are built based on strict international standards where the designers are restricted in choosing e.g. material thicknesses. One of the project's aims is to contribute towards new standard developments. The project has carried out several tests on new materials showing the possibilities that may be possible. One of the first business cases has been to develop, simulate and build a new modular boat using aluminum. The main objective of this endeavor was to take a new modular approach to the use of a fairly known material in the boating industry. Marine Platform also has a focus on laminate composites. Being able to describe and understand the relationship between the structure and composition of a material, its processing parameters and its properties is an important knowledge module for flexible and effective product developments of boats.

However, material testing and documentation is resource demanding and Marine Platform is now investigating methods for "multi-testing". Through a combination of lab-tests, reuse and simulation the aim is to be able to test and document a larger amount of different material properties from one panel.

4.4 Adaptive moulds as basis for a structural platform

Usually a new boat-model is developed on the drawing board and a prototype is made. The prototype is usually made as a mock-up and will later form the basis for cutting e.g. the hull on order to make a mould. However, the mould is very inflexible as you can only produce the specific hull. The ultimate objective of the project is to explore and develop adaptive moulds that fulfill the requirements for design, structure and strength. In theory this indicates that it should be possible to develop adaptive moulds that can facilitate an unlimited number of boat-designs by splitting the boat-design into modules. The project aims to develop and prove that adaptive moulds for smaller ranges of boats are possible and the work so far seems to confirm this. As the advances are still on a theoretical level there is still work to do in the business case connected to high-speed boats.

Several advances seem promising and fitting as starters for adaptive moulding. Using additive manufacturing is one such approach [13]. Here it is possible to create prototypes without cutting moulds. However, the sizes available for additive manufacturing will pose some challenges and one need to address interface-issues between modules made in order to create a structure that might be used as template for build 1 of the boat. In effect, the project has found that additive manufacturing is usable for prototyping and production of smaller hull-parts and modules.

A promising approach is flatbeds. Here one has a set of moulds that ensures that the basic requirements for a boat are addressed. The greatest advantages will be that it will no longer be necessary to cut moulds, thus removing a very costly and time-consuming process. It will also provide the possibility to merge modules that can create new models much more rapidly than before. "Flat bed methodologies" are showing great prospects, however there is still a long way to achieve what the project are aiming for; the flexible adaptive structural platform.

3 Conclusion

The flexibility and the cost effective aspects enabled by modularity could be an important driver for cost effective product development. In Marine Platform the focus is on the structural platform of the boats and the project has identified several paths for this. These paths' could be based on modularity in products/services, processes, and increasingly important, knowledge. In Marine Platform we have shown how standardization and outsourcing could represent a cost effective way to distribute development cost. Focus on material technology could give us a set of solutions representing modules in a structural platform for boats. Moulds from modules could also be a basis for modularity.

In Marine Platform all of these focus areas for modularity are combined and investigated. However, the basic element is modularized knowledge. Documentation and knowledge is fundamental for standards, for material solutions and how to design/assemble mould elements (modules). It is the knowledge modules that are the main enabler for fast creating the structural elements of the boats. The knowledge modules are also much more proprietary than the physical modules, hence more difficult to copy by competitors.

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