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Methods and tools that support a fast and efficient design-to-order process for parameterized product families

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ABSTRACT

For many companies, mass-customized products have become the *de facto* standard products. For these companies, "non-standard" or "customized" means products that even the most sophisticated of product or process configuration tools for parameterized product families cannot define in advance. Products like this need a design-to-order production environment (DTO). This paper starts by presenting industrial examples that need the quickest and most efficient engineering process before releasing the customized manufacturing order. It then goes on to examine the organizational requirements, methods and tools that support a fast and efficient DTO process that comes close to the needs of mass customization.

1. Introduction

According to [1, chapter 3.5.2], mass customization (MC) is a production principle that emphasizes customized products that do not cost more than mass-produced products. Product and process configurators and parameterized product families play a key role in MC [2]. MC is now widely used, especially in sectors such as construction, machinery and equipment, the automotive sector and fashion [3–5].

Product configurators were being used as early as the late 1970s [6]. Their full benefits came to light in the late 1980s, through the parameterized description of product families, including in CAD/CAM software [7]. This made it possible to quickly show the customer a virtual product at the quote stage, and to then produce a production order and program the CNC machines.

Although MC products are nearly all physically different, many companies that consider MC usage to be one of their core competencies view their MC products as standard products. This is because they can all be produced using an MTO process (make-to-order). "Non-standard" or "customized" are terms that refer to products that cannot be described with the configurator, and thus need a DTO (design-to-order) environment. The customers' requirements here, in terms of speed and cost, are not as stringent as for standard (MC) products, but they are close to MC requirements.

This area of customization in product manufacturing is addressed by this paper. It first gives some industrial examples of the construction and machinery sector, and then addresses the organizational requirements to enable a DTO process to work quickly and efficiently. It then concentrates on current and innovative tools that can be used when firms (as most do) maximize their use of the configurator in generating their DTO products, and thereupon implement a DTO process. New methods, so-called modular-generative methods, which include the reuse of parameters and the commonality of parameterized component families, support fast and efficient DTO processes.

2. Industrial examples

Fig. 1 shows the variety of turbo chargers. These devices are used to boost marine diesel engines, for example, and must be carefully matched to them. New customers often have new needs, which cannot always be met using the existing configurator. But that is precisely when the speed with which a quote (and then the prototype using DTO) can be produced is important.

Fig. 2 shows the parameterization of the doors of an elevator. An elevator has to suit the building that it is in. And in the top range segment, the door area must fit with the architect's personal taste. The DTO process requirements are thus similar to the fashion sector. Authors in this field also speak of mass personalization [8], and of personalized production [9, chapter 5].

The companies in both of those examples are larger firms. But there are plenty of SMEs that have been successfully using MC for decades. Today, they all have an increasing number of customer orders with DTO requirements. These go beyond what can be covered by their product families and configurators.

3. Organizational requirements for fast and efficient DTO

Fig. 3 shows a typical DTO business process in a company. The sales phase (including quoting) is followed by receipt of the customer's order, followed in turn by design, production and delivery. In practice, fast and efficient DTO calls for the consistent, long-term use of an enabling process. Fig. 3 calls this process a *permanent DTO enabling process*. This process means that queries from the ongoing DTO business process are answered through a form of know-how transfer. If additional know-how is gained during implementation, it is fed back to the enabling process in the form of *lessons learnt*.

- At the organization level, this means expertise and experience of dealing with the customer's DTO requirements. This involves the business models between the company and external customers

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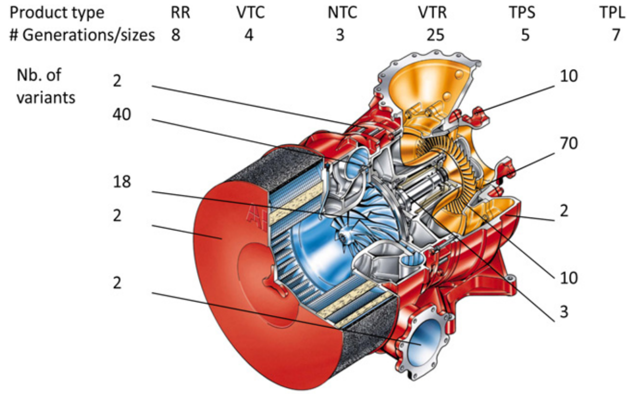

Fig. 1. ABB turbo-charger product family.

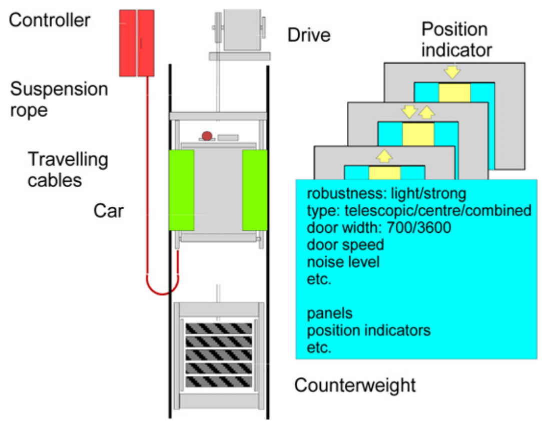

Fig. 2. Schindler elevator components.

and suppliers, but it also means the "business model" around the internal customer–supplier relationships between Sales, Engineering and Production, at all levels.

- At process level, this means expertise and experience of managing how the company works with external customers during the product specification and manufacturing phases, but also how internal customers work with suppliers. Another point is know-how of user interaction with the product in a virtual status, i.e. before and during the physical manufacturing.
- Expertise and experience with suitable technical methods and tools (e.g. product configurators) is used the individual *sell*, *design* and *make* processes. Even as early as the sales process, configuration allows for an initial cost calculation and for a virtual product, which allows the customer to experience something as close as possible to the physical product.

While it has been possible over the years to concentrate the MC expertise across fewer people and to focus on the design process (and, to an extent, on the sales process) in the classic MC culture, a quick and efficient DTO system needs this expertise shared among more people, and it must in turn be extended to the workshop. So we can talk here of a distinct DTO culture.

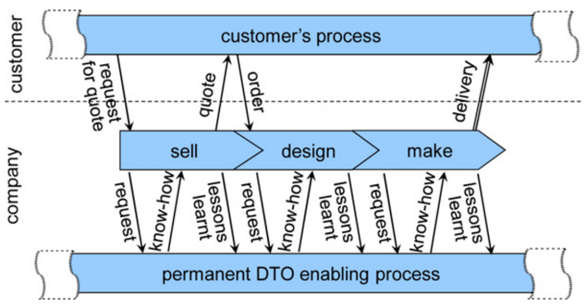

Fig. 3. The need of a permanent DTO enabling process.

There are differences in DTO culture across different regions. The lift manufacturer, for example, was able to quickly fulfill a non-standard request from a client in their workshops in a high-wage country on the basis of a simple outline drawing. To be produced in their workshops in a low-wage country, the same request would have had to be specified in detail. In a global set-up of a company, we thus must find ways to deal with external customers on a market-specific basis, as well as to use different approaches, methods and techniques for the internal customer–supplier relationships. This increases the complexity of the organizational challenges that must be fulfilled in parallel.

4. Technical methods and tools currently used for the DTO process for parameterized product families

All of the following DTO approaches have their impact in today's practice. To illustrate, Fig. 4 shows a typified example of a family of umbrellas, an MC product with six parameters.

4.1. Adaptive methods – the classical DTO approach

Adaptive methods entail two steps. The first step determines a suitable "parent version" from the existing variants. In the second step, the parent version is adapted according to the requirements of the variant. There are two options:

- *An outline drawing, along with plus/minus bills of material or routing sheets*: You start with the product family from which the product configurator can best produce the non-standard product that you identify from the parameter values in the customer's order. This gives you a "parent version" that you could manufacture "as is". In a second step, you adapt the parent version straight in the workshop by means of an outline drawing, or beforehand by developing plus/minus bills of material or routing sheets (i.e. lists of positions that can be added to, changed in or removed from the product structure). So looking at Fig. 4 again, we could use the red umbrella as a parent version, replace the red material with a pink material, and add extra trim, plus an operation to apply the trim.
- *Dummy positions in product structure templates*: You define product families with an unfinished product structure. These might contain materials which a company (e.g. a sheet metal working firm) typically uses as a starting point for a product (e.g. various aluminium or steel sheets), and a sequence of loosely described operations in which the firm has recognized expertise (e.g. *cutting*, *bending*, *assembly*) or which they get done by external suppliers (e.g. *surface treatment*). These components may also be entered as dummy positions. The customer's order parameters are used by the configurator to identify as much as possible. Unidentified positions appear as gaps. The result looks unfinished, like a template for a product structure. This is often useful for initial cost calculations (for example, where ±10% accuracy is sufficient) and for logistical control if the order is

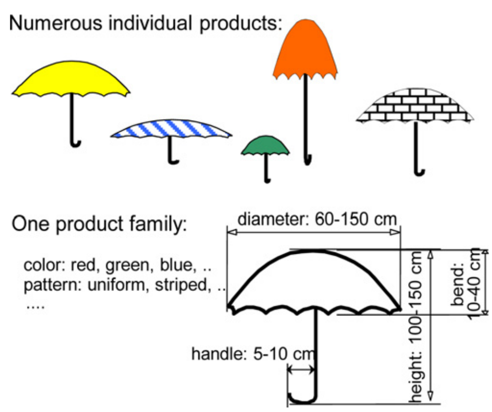

Fig. 4. A typified product family *normal umbrella*.