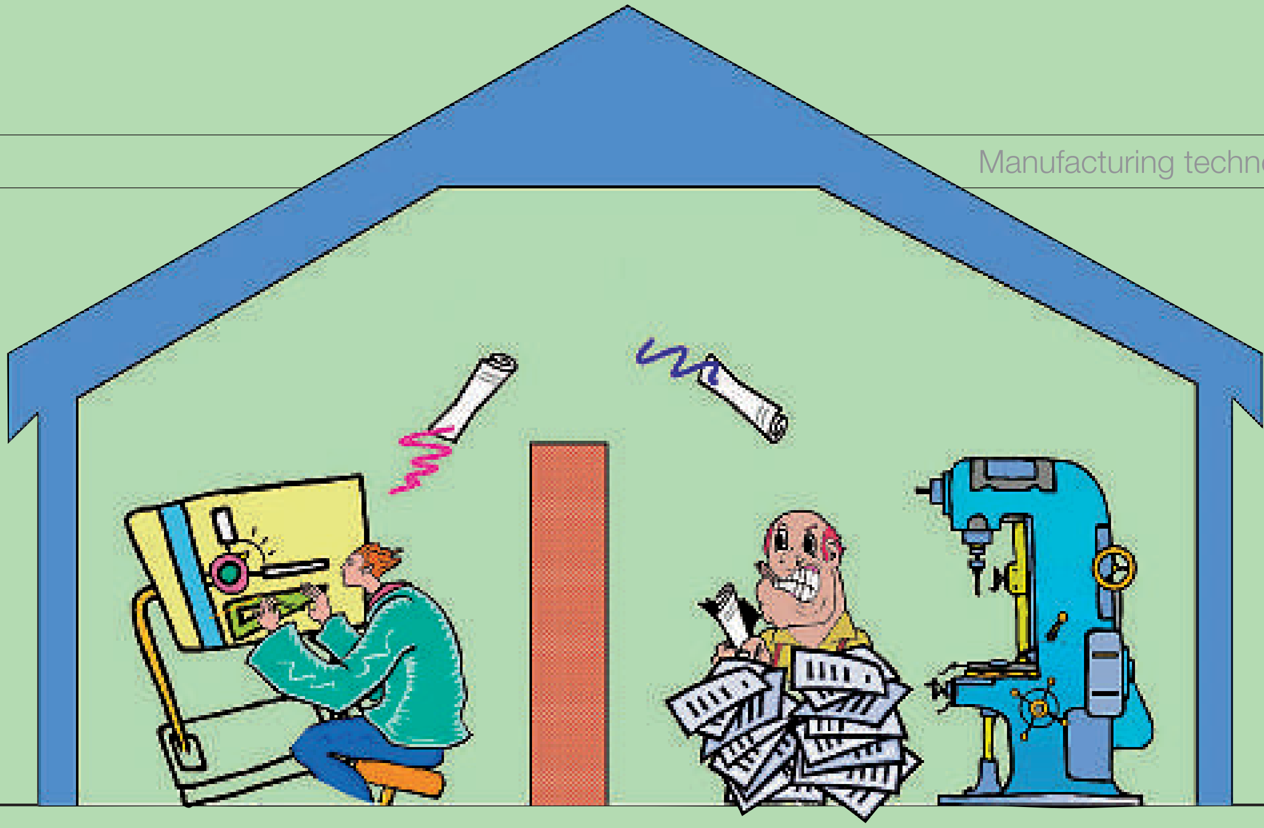

Simplicity pays

Design for manufacturing and assembly (DFMA) in ABB

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Increasing competitiveness is an accepted fact of company life. For as long a people can remember, companies have been exclaiming how competitive the current world market is. There is no doubt this same sentiment will be uttered in the foreseeable future and beyond.

The ability to efficiently develop and produce high quality, reasonably priced products that meet customer expectations is essential to continued profitability and global competitiveness.

However, the ways in which companies have been doing this have been changing with time. The methods that worked yesterday will not necessarily suit today's or tomorrow's market. In this context, manufacturing and assembly oriented product design plays an important role.

ABB has realized this simple engineering philosophy and is applying "Design for Manufacturing and Assembly" (DFMA) techniques to great benefit.

Back in the early days of product design and manufacture, sequential engineering, with its specialized, but separated development steps (ie, "I design, you produce" philosophy), took pride of place. Development activities such as design, technology, testing, and service were performed by different departments. This approach worked very well for Ford's first manufacturing line at the beginning of 20th century where the Model T car was produced. The Frederick Taylor philosophy – any complicated job can be transformed into a sequence of straightforward seperated steps – was also applied to product development processes. These approaches still work today for production processes where simple, standard goods are created.

However, the inadequacies of sequential engineering became apparent as: companies grew and expanded into other continents; technologies advanced; and problems became more complex. For one thing, organizational structures within a company meant many departments were no longer in the same country let alone under the same roof. At best, vital communication and collaboration was reduced to an absolute minimum.

This, added to technical problems of increasing complexity – not to mention shorter time-to-market – very often resulted in designs that, put simply, could not be manufactured!

What was needed therefore was a concurrent engineering approach that focused more on teamwork and information exchange between the various departments, no matter where the location. In recent years, several methods have been proposed, including Quality Function Deployment, Robust Design, Collaborative Manufacturing, Rapid Prototyping, and Design for Manufacturing and Assembly (DFMA). Of all these methods, DFMA probably stands out as being the most powerful.

In very general terms, DFMA is a set of methodologies and principles that guide the process of proactively designing products to optimize all lifecycle functions (fabrication, assembly, test, procurement, delivery and service).

DFMA for novices

Reducing costs and time-to-market has become two of the most important elements for a company's success. Crucial to achieving this is the reduction in the number of prototypes created. For this to happen a culture of analysis must become the norm.

During the development stages of a new product, cost and cost drivers must be carefully considered. Yet they tend to be neglected simply because designers lack a reliable method of managing and understanding them. DFMA helps project teams analyze and understand the cost effects of their design decisions anytime during the product development cycle. It provides a strategy for identifying early cost drivers and develops tactics to reduce their impact throughout the manufacturing process.

DFMA consists of two complementary methodologies: Design for Assembly (DFA) and Design for Manufacturing (DFM).

Design for Assembly (DFA)

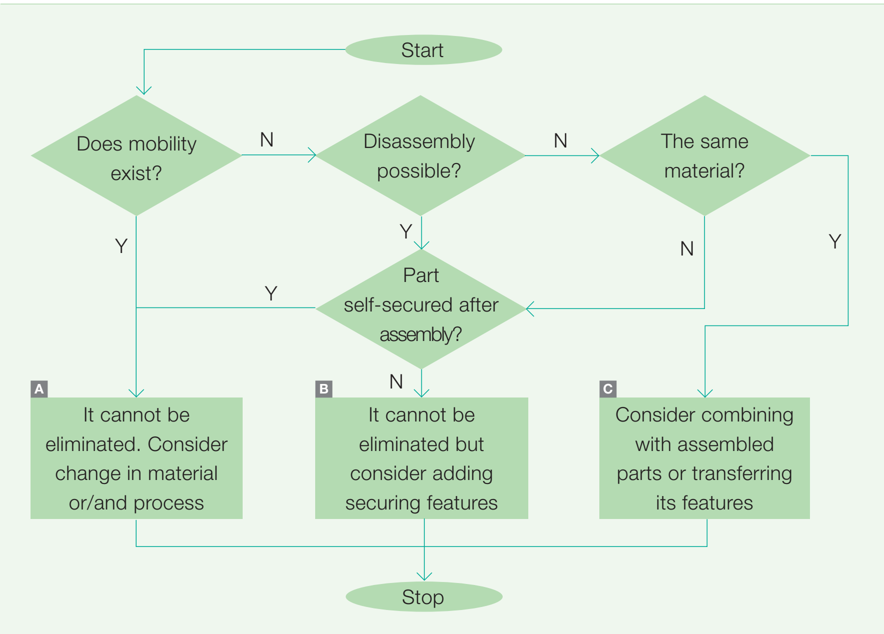
During the early stages of design, control of part count is paramount to maintaining cost targets. DFA is a technique that helps simplify products by focusing the attention of design teams on part count and part count reduction. It allows engineers to determine the theoretical minimum number of parts that must be in the design for the product to function as required. When unnecessary parts are identified and eliminated, unnecessary manufacturing and assembly costs can also be eliminated. In other words, fewer fabrication and assembly steps are required, and manufacturing processes can be integrated or even reduced. Costs related to purchasing, stocking, and servicing also decrease as the number of parts is reduced. Additionally, inventory and work-in-process levels will go down with fewer parts.

There are two basic principles to DFA:
- The best-engineered part is no part at all!
- If the part cannot be eliminated, minimize the time required to grasp, align and assemble it.

Part reduction strategies involve incorporating multiple functions, if possible, into single parts 1. In particular, this applies to components which are not absolutely essential for product operation, or which are not required by standards (norms) or customers.

DFA recognises the need to analyse both the part design and the whole product for any assembly problems early in the design process. DFA analysis looks for three aspects:
- Relative movement: if there is an essential relative movement between active components, then it is likely different parts are needed (or part count reduction becomes impossible). However, some changes in component material and the manufacturing process must also be considered. Small movements may also be achieved in other ways, for example, through plastic hinges, flexing or alternative joining methods.

1 Design for Assembly (DFA) – analysis of unnecessary parts



DFMA

ABB has recently begun collaborating with Professor Robert Sturges of Virginia Tech to train present and future ABB leaders in DFMA practices. What Prof. Sturges says about DFMA:
"A number of myths seem to pervade the production field, keeping us from the serious business of fundamentally understanding our processes:
- If you designed it, you can manufacture it.
- If you can draw it, you can manufacture it.
- DFMA is a non-problem, since manufacturing is performed in a structured environment.

We contrast these ideas with the realities of modern manufacturing:
- Parts are manufactured by machines but (largely) handled by people.
- If we make it easy for a machine to handle, a person can handle it better.
- If a person can't handle it easily, design the product and the process together.

DFMA gives us the tools and techniques to manage both product design and process design from a quantitative, analytic, and economic perspective."

- Need for disassembly (service): Although there may be no relative movement during operation, a component may require adjustment or replacement.
- Different materials: If there is no important need for neighboring components to have different material properties, such as electrical or mechanical, the part reduction strategy may be applied.

Finally, it is neccessary to see if the part is self-secured after assembly. In this case, the elimination of fasteners and joining elements must be analyzed.

Once part reduction has been taken as far as possible, DFA then turns its attention to simplifying the assembly process. How the assembly process is realized depends largely on component design and the interfaces between parts. Therefore the geometrical characteristics of a particular component, such as shape, tolerances, and weight and size, must be analyzed. In addition, assembly aspects such as fastening, assembly motion, insertion, and alignment methods must also be considered.

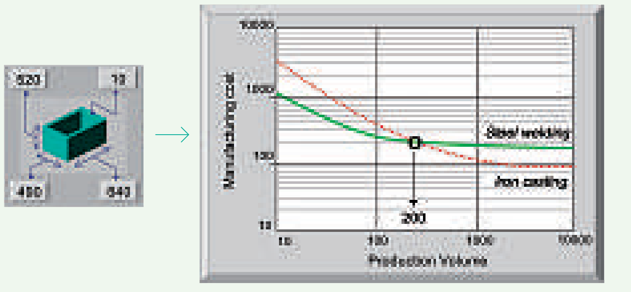
The concept of assembly process analysis relies on so-called "penalty time", a kind of artificial weight which evaluates potential assembly difficulties. Each assembly aspect is judged and awarded a time score. The exemplary penalty times for the fastening aspect of an assembly process is shown in Table 1 .

A thorough DFA analysis should result in an elegant assembly process with

Table 1 Penalty time for manual fastening operations.

Fastening method	Penalty Time
No fastening method or snap fit only (the part is placed on or in an already assembled part)	0 s
Screwing or pressing opertion	3 s
Adhesive fastening method, welding, riveting, soldering	8 s

2 Design for Manufacturing (DFM) – break-even calculations



fewer components that are both functionally efficient and easy to assemble.

DFM is a systematic approach that allows engineers to anticipate manufacturing costs early in the design process, even when only rough product geometries are available.

Design for Manufacturing (DFM)

DFM is a systematic approach that allows engineers to anticipate manufacturing costs early in the design process, even when only rough product geometries are available.

Engineers tend to design for manufacturing processes with which they are familiar. DFM, however, encourages development teams to go further by investigating all the major shape-forming processes and different materials so that components or products can be more economically produced. Consider, for example, the fabrication of a simple product frame. A DFM analysis shows that it is more economical to use steel welding with a production volume of less than 200 pieces. Above this volume, iron casting is deemed more economical 2.

DFM also offers specific guidelines for different fabrication processes, and this is illustrated by a simple example shown in 3. The following guidelines are suggested for a machining process:

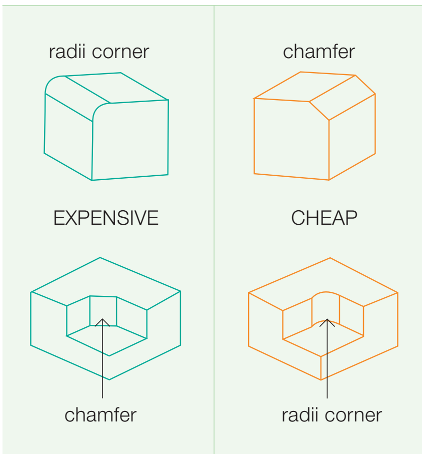
- Consider castings or stampings to reduce the machining required for higher volume parts.
- To minimize machining, near net shapes for parts that have been molded or forged are recommended.
- Design for ease of attachment by providing a large solid mounting surface and parallel clamping surfaces
- Avoid designs with sharp corners or points as these put more strain on the cutting tools.
- Thin walls, thin webs, deep pockets or deep holes should be avoided because of the risk of distortion during the clamping and machining process.
- Favor rectangular shapes over tapers and contours if possible.
- Avoid hardened or difficult-to-machine materials unless absolutely necessary.
- Put machined surfaces on the same plane, or together with the same diameter to minimize the number of operations.
- Design workpieces to use standard cutters, drill bit sizes or other tools.

Both, DFA and DFM use everyday units and easy-to-read metrics (eg, seconds, dollars), making it easier for engineers to evaluate different design and assembly alternatives, and to quickly judge production costs and times.

How DFMA works for ABB

It is sometimes the case that a typical product offered by a company is: functional but complex; reliable but

3 Design for Manufacturing (DFM) – suggestions for the machining process



over-dimensioned; of high quality but expensive; and very often exceeds the requirements of developing markets (and is therefore beaten by cheaper competitors). The answer to this problem is to simplify the product design because, put plainly, "simplicity pays off".

There are numerous examples within ABB where proper manufacturing and assembly oriented design has not only brought about significant quality improvements but cost reductions as well. One such example is ABB's Passive Voltage Indicator (PVI). The DMFA method was successfully applied at a very early stage in the project, ie, when the preliminary design of the new product was defined. The end result was a significant reduction in the number of parts needed (from 11 down to 7), which in turn cut manufacturing costs and assembly times 4.

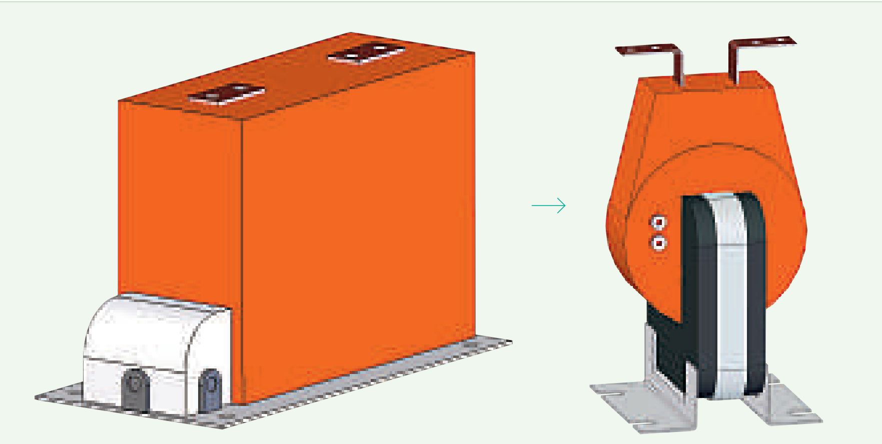
Another example concerned the redesign of ABB's TPU medium voltage current transformer, which needed to be simplified to reduce manufacturing costs. The application of DFMA, together with some innovative design, helped bring about new design and manufacturing possibilities for this well-known and standard ABB product 5.

Other DFMA examples cover the redesign of products for global markets, for example: NCX Open-Fuse Cutout for the Chinese market; a new design concept for Flame Scanners developed in the USA and Italy; and the redesign of Atomizers produced in Japan.

With regard to the redesign of NCX Open-Fuse Cutout, DFMA identified three areas where engineers needed to focus to produce a low-cost competitive product: parts reduction; the use of a more economical material; and the improvement of parts manufacturability. After the redesign activities, 13 ideas grouped into two design concepts with the 10–15 percent cost saving were achieved.

4 Passive Voltage Indicator (PVI) – DMFA applied at the conceptual stage

5 TPU Current Transformer – Standard design (left) versus possible low-cost design for global markets (right)



DFMA Decalogue

- Design for the minimum number of parts
- Design parts to be multifunctional
- Use standard components, materials and processes
- Develop a modular design approach
- Minimize orientation of parts
- Apply stackable – uni-directional assembly
- Facilitate insertion and alignment of all parts
- Avoid threaded fasteners
- Eliminate adjustments
- Work as a TEAM

Summary
When it comes to new products, customers demand functionality and high quality at a reasonable price. The ability to meet these expectations at low cost is essential to continued profitability and global competitiveness. In this context, manufacturing and assembly oriented product design plays a very important role. ABB has realized this simple engineering philosophy and is continuously benefiting from it. The DFMA technique has been successfully applied to several projects, proving that collaborative design and better interaction between engineering and manufacturing departments reduces production costs by an impressive 10–15 percent without any heavy investments. "Teamwork and simplicity pay off!"

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