THE VIRTUAL ARTISAN: A PRODUCT DEVELOPMENT FULL CIRCLE THEORY

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Abstract: Historically, product design and development has gone from being craft-based to process dominated through the application of mass production. However, today, where the voice of the customer is now seen to be paramount, the gap between the various product engineering functions in the product development cycle has been reduced through the use of many design and manufacturing methods, techniques and technologies. These also embrace the product's manufacturing needs and requirements. This paper hypothesises that, by examining the historical record, a new product development paradigm is becoming apparent through the use of globalised virtual-technologies and method and outlines a novel “full circle” model that predicts the future evolution of competitive product design methods.

Key words: product development, virtual reality, virtual environment, artisan, history, design, design methods, manufacture.

1. Introduction

The industrial world has undergone a multitude of changes since the beginning of the industrial revolution in the middle 18th century. Caused by what has arguably been described as a mainly process driven phenomenon, all of these changes generated in a historically short period of time the transition from a feudal craft-based society to that of a world dominated by globalised, market-oriented, customer-led companies making manufactured goods. However, with regard to discrete product manufacturing, an examination of the historical period seems to indicate that modern product design and manufacturing methods are now tending towards those employed by the original craft-based expert. For them, the 'voice of the customer’ was paramount, the product development process was concurrent and the data transfer between the different stages of the engineering product cycle was continuous. It is proposed that multi-skilled artisan of the craft-based era, who performed all of the functions of the product development cycle, has evolved towards the total virtual artisan of the future who will carry out the same type of tasks, albeit with other key interfaces in the process. This individual will, in integrated virtual environments of all kinds, perform the same functions as the original artisan with maximum customer involvement. After years of trying to split the product engineering cycle into easy to define and controlled steps, within well determined limits and interfaces in between the different stages, technology is such that the lessons of concurrent, integrated product development have been re-learnt. These lessons can be applied more readily in the future. This hypothesis is justified by examining the relative historical
influences of both the customer and the manufacturing process throughout five key historical periods, namely (Figure 1):

- craft-based industry;
- the Industrial Revolution;
- mass production;
- Japanese methods;
- customer-led design and manufacturing methods.

2. Craft Based Industry

As illustrated in Figure 1, before the industrial revolution, the world of designed and manufactured products was much simpler for a number of reasons. Products tended to be more straightforward with a limited range of process options available for manufacture. The designer, or artisan, was solely responsible for supervising and carrying out the design and manufacture of an artefact whilst closely liaising with the customer. Materials were plentiful, labour cheap and the artefacts produced possessed a functional complexity achieved without consciously separate design, planning or manufacturing activities. There was no need for separate managers, salesmen, manufacturing engineers or any other ‘specialists’. As well as being designers, these artisans were innovators, market researchers, manufacturing engineers, production planners, etc. with an integrated tool and skill set. Customers could express their requirements by being exposed to this combination of engineering competencies; thus, customer influence was very strong in this type of manufacturing society (1). The straightforward nature of the processes available to the artisan meant that it was possible for him to carry out all of the manufacturing necessary to complete the product to final customer specification but without a conscious product engineering strategy.

3. The Industrial Revolution

3.1. Processes, Innovation and Invention

Taylor gives us a number of reasons why this began in the UK (2). The initial part of the industrial revolution focused on the textile industry with automated processes being used to produce textiles at a faster rate. The process came to dominate, as shown in Figure 1 by the increasing width of the process arrow, and the customer became almost secondary. Large, water-powered factories were built employing hundreds of people, continuously outputting thousands of tonnes of product. The inherent economies of scale made the process predominant and, by the mid-18th century, almost all of the modern machine tool processes were invented. Powered by steam driven overhead lines in large factories, even more complicated forms and products could be made. The process became paramount and industry tended to allow this to influence product types. No one person could be responsible for all the stages required for designing and making complex artefacts. Increased specialisation became the norm and design became a separate discipline. Early in the 19th century, new ‘inexperienced’ middle class consumers were faced with a proliferation of sellers’ market manufactured goods of dubious quality. This was only achieved through improvements in process design at the expense of product design (3).

3.2. Factories, Products and Early Manufacturing Systems

By the 1850s the factory system was well established. As the steam engine came into full use as a source for power and transport, economic growth in the West accelerated rapidly. Stock markets and world banking became prevalent in and shareholders’ needs took precedence over product development. Even higher volumes were demanded and the process had to cope.

During the 19th century, Eli Whitney’s ideas of interchangeability and Eli Root’s concept of assembly lines revolutionised product design and manufacture, proving that product quality and output could be increased substantially with a significant reduction in cost (4). However, the lessons associated with concurrency and integrated design and manufacture were lost, the engineering functions were still separate and there was no direct interaction between the designer and the customer. Form and fitness-for-purpose were ignored since there was no customer-led demand (5). Process influence dominated.

4. Mass Production

4.1. Stage 1 – Mass Markets and Control of the Process and the Workforce

The concept of mass production was well established for a wide range of products before Henry Ford. However, Ford’s system made a highly complex product available to the general public (6). Unpredictability was overcome by applying Taylor’s ‘Scientific Management’ (7) techniques, which enabled Ford to set up a highly automated tightly
controlled plant. This control of the process, and its people, led to an even wider division of labour and of engineering functions. One of the main outcomes was the almost total de-skilling of the task, leaving the human operator with the mundane unskilled loading and unloading activities, which could not be automated. The ‘artisan’ of the craft-based industry had been completely eradicated. Taylorist methods also underpinned cost accounting methods and led to a concentration on process ‘efficiency’. Economic order quantities became paramount. Hard automation dominated and the mass production of all kinds of consumer and military goods became possible; as shown in Figure 1, *process influence* was in its heyday.

4.2. Stage 2 – The Influence of Computer Technology

After the Second World War, the American economy geared up to supply the rest of the world. The huge expansion in consumer good availability due to the use of Ford and Taylor’s mass production methods, the investment in Western European social programmes, the rebuilding of European industry on American lines meant that a long-lasting economic boom took place up until the early 1970s. Buyers became aware that they too had a choice and some of the old craft-based product attributes began to influence customer choice. During the cold war period (1950s-1980s) there was an ever-increasing demand for a new technology. In the 1950s, the transistor was invented and, subsequently, the computer which dramatically affected both design and manufacturing technology and systems.

4.2.1. Computer Aided Engineering

Computers were used to support hard automation. Numerical control (NC) machine tools and robots made their appearance in the 1950s and 1960s. By the end of 1970s, CNC (computer numerical control) machines were well established with the eventual advent of flexible manufacturing systems (FMSs), the West’s process-based response to the Japanese threat. Group Technology (GT) or cellular manufacturing, although not computer-based, led to some firms gaining significant improvements in manufacturing output and the beginning of a realisation that, using existing resources, significant productivity gains were possible. Even with the impact of CAD/CAM, 3D modelling, prototyping and process planning (8, 9, 10) that enabled the effective re-use of data, design still tended to be divorced from manufacturing. Again, the emphasis was on de-skilling of the task, increasing output and efficiency, the idea being to replace people with automated processes.

4.2.2. Computer Aided Production Management

The Western application of computerisation in CAE technology was mirrored in the use of computer aided production management (CAPM) systems. Central Planning and control was also introduced in the form of Material Requirements Planning (MRP) and Manufacturing Resource Planning (MRPII) software (11). People on the shop floor still had to be told what to do and capacities had to be planned to make processes and people more ‘efficient’. Technological solutions were also chosen to tackle the problem of increasing market competition from East Asia. Even though techniques such as Total Quality Management and cellular manufacturing were well known in the USA and Europe, it was the Japanese who took them up. With a customer-focused approach to their product development processes and manufacturing systems they dominated the West’s commercial product markets. The expansion of the Japanese economy from the 1960s due to the use of American production methods and its vulnerability to the massive oil price increase in the 1970s forced Japan to gear up its design and manufacturing base in order to survive economically. Learning the lessons from the weaknesses of Western companies’ approaches to product design and production they developed an aggressive approach to the introduction of new, culturally inclusive design and manufacturing methods (12).

5. The Dominance of Japanese Methods

By recognising the abilities of workers, the Japanese produced dramatic economic changes. A culture of innovation was created coinciding with a huge expansion in the commercial market for Japanese goods. Deming’s quality methods, which were well known after the 2nd World War, were pursued vigorously (13) and this had a considerable impact on the quality and output of their products. Production systems were simplified and combined with techniques such as TQM, empowerment and continuous improvement, enabling a more cost-effective improvement in the process, product quality, reductions in lead times, the elimination of waste and smaller batch sizes (12). Make to order became the
norm, as did meeting the needs of the customer. The initial Western approach to the threat from Japan was for companies to use labour reductions and high technology solutions, thus discarding some of their key assets and focusing on the complete automation of production systems. CAD/CAM/CIM were developed as strategic company-wide approaches for new technology but ended up adding to already complex and unpredictable manufacturing systems, thus exacerbating the many of the problems. By the late 1980s the Internet added a whole new array of tools to the armory of engineering businesses.

Japanese industry also designed in quality through making their products compatible with both their markets and manufacturing systems. Learning from the Japanese, design began to receive more attention in the West as a critical front-end activity in the product development process. Many design methods came to the fore (14, 15) and concurrent engineering became the new vogue in product and process design. Customer-influenced product engineering was slowly but surely arriving as seen by the increasing arrow width in Figure 1. Process domination was beginning to wane again.

6. Customer-Led Markets

In the 1990s all of these developments have meant that the customer is again being exposed to the same set of skills in the concurrent engineering team that used to exist in the experience and skills of the pre-industrial revolution craftsman. The voice of the customer is paramount, products are being developed in a concurrent and integrated environment, with little distinction between the design and manufacturing functions of the product development cycle. The combination and application of available technology and modern methods will eventually support a new (or rediscovered) type of product design environment. One in which new products will, in part, be designed and 'manufactured', by a multi-skilled individual called the virtual artisan. As immersive VR becomes as flexible a design tool as modern CAD/CAM systems it will be possible for a designer to modify a virtual prototype to suit the customer’s needs and, when complete, reuse the design data generated to validate its manufacturability. Transparency will exist between the virtual design and analysis interface and the virtual sculpting, machining and assembly capabilities to give a new array of tools to the virtual multi-skilled craftsman to develop new products enabling engineers to make intuitive and educated engineering decisions. These artisans will, however, be dealing with complex products. So it is likely that they will only be responsible for parts of a product. They will still have a need to interface with OEM design teams, suppliers and other people as part of globally-distributed virtual concurrent engineering teams situated in different part of the world.

The main question is, how far away from this are we? Do we already have the necessary capabilities to set up such environments? What is missing in order to fully complete return to a fully artisan-based approach to product development? This is currently being studied as part of this research project.

VR has the advantage of allowing users to visualise, feel involved and interact with virtual representations of real world activities in real time (20). What VR is lacking at this stage is the same integration that some CAD/CAM systems have; this would allow modifications made to the CAD model to be visualised in the virtual environment and vice versa.

7. Conclusion: The Virtual Artisan: Total Computer-Aided Product Development

This paper has highlighted how, in today’s society, the customer is again being exposed to the same set of skills in the concurrent engineering team that used to exist in the experience and skills of the pre-industrial revolution craftsman. The voice of the customer is paramount, products are being developed in a concurrent and integrated environment, with little distinction between the design and manufacturing functions of the product development cycle. The combination and application of available technology and modern methods will eventually support a new (or rediscovered) type of product design environment. One in which new products will, in part, be designed and 'manufactured', by a multi-skilled individual called the virtual artisan. As immersive VR becomes as flexible a design tool as modern CAD/CAM systems it will be possible for a designer to modify a virtual prototype to suit the customer’s needs and, when complete, reuse the design data generated to validate its manufacturability. Transparency will exist between the virtual design and analysis interface and the virtual sculpting, machining and assembly capabilities to give a new array of tools to the virtual multi-skilled craftsman to develop new products enabling engineers to make intuitive and educated engineering decisions. These artisans will, however, be dealing with complex products. So it is likely that they will only be responsible for parts of a product. They will still have a need to interface with OEM design teams, suppliers and other people as part of globally-distributed virtual concurrent engineering teams situated in different part of the world.

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8. Future Work

In order to obtain broad-based information on the use of the computer-aided tools and their analytical capabilities, a survey methodology/case study approach will be used to evaluate the state-of-the-art in the Mechanical Engineering field. The focus will be on the level of integration of CAD/CAPP/CAM and the application of VR/VEs to support the integrated product development and the ways in which data dependency and data transfer between different stages of the product development cycle is being performed.

It is hoped that, based on this extended study, it will be possible to determine how close the virtual artisan is to becoming reality and making the product design and manufacturing cycle turn full circle.

Bibliography

Fig. 1: The Historical Product Engineering Full Circle Diagram