COST MODEL FOR RAPID MANUFACTURING

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ABSTRACT

At Helsinki University of Technology rapid prototyping, rapid tooling and rapid manufacturing technologies and applications have been researched since late 1980s. The Integrated Design and Manufacturing research group has concentrated on new industrial Rapid Prototyping and Manufacturing (RP&M) applications within product development and manufacturing. This paper is based on research projects realized in 2001 – 2004 in cooperation with several industrial companies. New developments within industrial product development paradigms and processes will be discussed. The paper attempts to link current industrial management sciences research with latest developments within rapid manufacturing technologies. Product platforms, product customization and networked manufacturing have become common product development management paradigms in many industrial sectors. These paradigms have lead to an increasing number of product configurations and variations. Traditionally cost comparisons between RP&M processes and conventional manufacturing processes have been based on break even point calculations. The latest product development and manufacturing paradigms places agility in production and efficient prototyping technologies among others in an important role. Conventional cost per part comparison methods to value rapid manufacturing need to be re-engineered. In those comparisons the first break even point does not describe the overall rapid manufacturing economy. For example, effects of neccesity for product change, tool wear or tool defect have to be taken into consideration. In this paper the new cost modeling technology and some industrial case studies will be described.

Keywords: Rapid prototyping, Rapid manufacturing, product development, cost modelling.

1. RAPID MANUFACTURING

Conventionally RP&M methods were classified according to the technology that were used to create parts. Examples of such technologies are Stereolithography (SL), Selective Laser Sintering (SLS), Laminated Object Manufacturing (LOM) and Fused Deposition Modeling (FDM). Technology based classification also has an application oriented meaning, for example technology and material combinations were associated mainly to prototype, tool or end product manufacturing.

Currently some technologies and materials can be applied for several purposes such as prototyping, concept modeling, tooling and production (Figure 1). The industrial economics application oriented classification of RP&M technologies provides a suitable base for industrial applications economics research. For this study a rough application oriented classification of RP&M has been used. The main classes are

a) Prototyping and concept modelling and
b) Rapid manufacturing (tooling and production applications).

Tooling applications have been classified as a subset of Rapid Manufacturing applications.

Figure 1. EOS DMLS Rapid Prototyping, tooling and manufacturing (production) applications

2. PRODUCT DEVELOPMENT PROCESS

Ulrich and Eppinger [1] have analyzed product development as a process starting from market opportunity and ending in the production, sale and delivery of a product. In view of the business process this timeframe has been divided into product development phases from concept development to production ramp-up. Ulrich and Eppinger [1] have listed five general success factors for product development:

Product quality
Product cost
Development time
Development cost and
Development capability

Ulrich and Eppinger [1] suggest that one should construct a base-case financial model of a product life cycle to estimate the time-to-market related benefits. In our previous research time savings when applying Rapid Prototyping in product development have been quantified. During this research the base-case financial model of the product life cycle to estimate time-to-market related benefits was developed [2, 3]. This paper concentrates on the overall financial model of a product life cycle.

According to Rothwell [4] the nature of product development and corporate strategies has changed periodically in five generations during the last decades. The first period (1950s – mid 1960s) was characterised by post-war recovery. New technology-based sectors grew and major new product ranges were introduced. During the second period (mid 1960s – early 1970s) there was a growing level of corporate diversification and growth could be recognized. During this period capacity and demand were in balance and corporate strategic emphasis was on marketing. During the third period (mid 1970s – early 1980s) the inflation was high and the demand saturated. Supply capacity exceeded demand and corporations began to concentrate on scale and proven curve benefits. Cost focus was a keyword in corporate accountancy and financing. The fourth period (mid 1980s –1990s) was an initial period of economic recovery followed by recession. Typical features in corporate strategies and operations at that time were

- Awareness of emerging generic technologies with increased strategic emphasis on technological accumulation,
- Growing emphasis on manufacturing,
- Strategic alliances acquisitions and internationalization,
- High rates of technological change,
- Rapid product cycles and time-based strategies,
- Intra-firm and inter-firm integration i.e. networking and
- Integrated technology and manufacturing strategies.

Today industries are applying the fifth-generation (5G) innovation process. The characteristics of the 5G product development process are integration, flexibility, networking and parallel, real time information processing. An important part of the 5G product development process is the use of sophisticated RP&M technologies. Today the product development process itself and company networks are a competition factor.

Product platforms (Figure 2), product customization and networked manufacturing (Figure 3) have become common product development management paradigms in many industrial sectors. Both of these paradigms lead to raised number of product configurations and variations in product individuals [5].

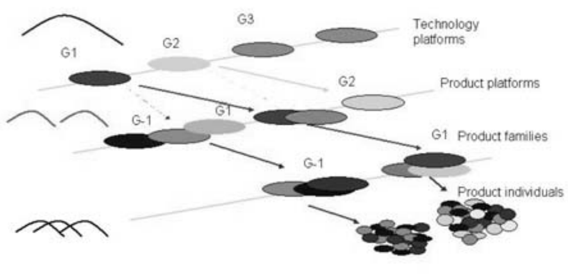

Figure 2. Product development paradigm using technology and product platforms

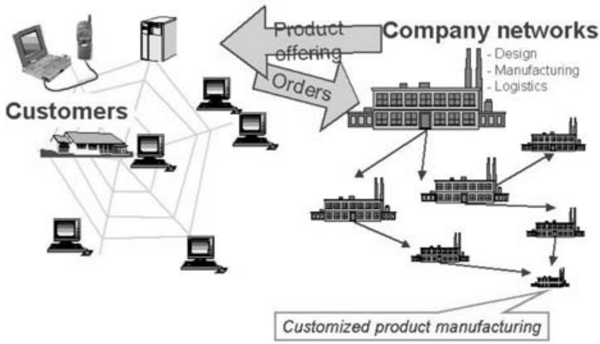

Figure 3. Customized product manufacturing in networked production

3. COST MODEL FOR RAPID MANUFACTURING

Traditionally cost comparisons between RP&M processes and conventional manufacturing processes have been based on break even point calculations. For example Hirt, Ames and Bambach [6] have been estimating the economic and ecological aspects of Incremental Sheet Forming (ISF) compared to deep drawing (Figure 4). According to their calculations ISF is cost effective up to 700 pieces for large parts and up to 250 pieces for small parts. There are several other cost comparisons between RP&M processes and conventional manufacturing processes based on the same type of break even point calculations. [7]

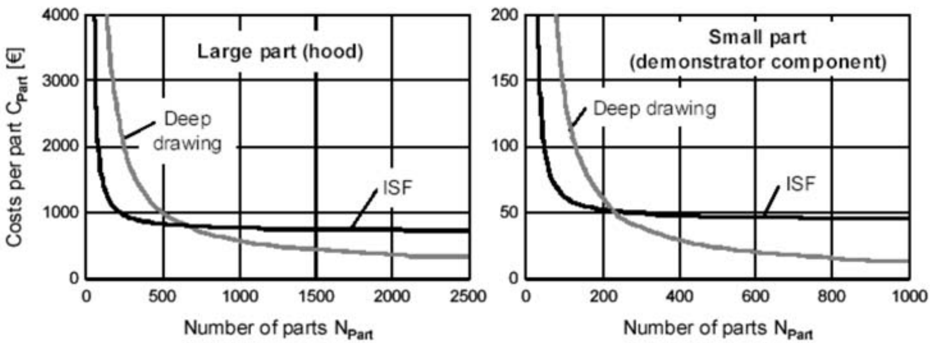

Figure 4. Estimated cost per part in ISF and in deep drawing [6]

According to Syrjälä [8] costs comparisons between traditional manufacturing processes and rapid manufacturing processesshould take the need for product change, tool wear, tool defects and the possibility to increase the sales revenues into account.
In Figure 5 such a base case cost model has been described.

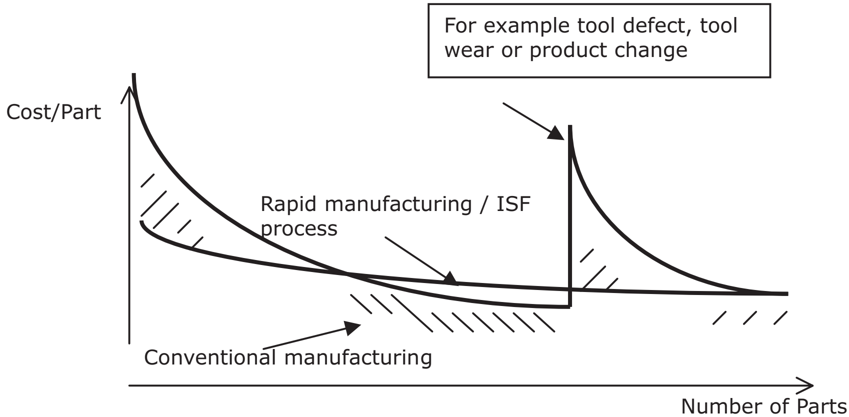

Figure 5. Cost model for Rapid Manufacturing or ISF and conventional manufacturing process comparison [7]

Tables 1, 2, 3 and 4 illustrate the use of a base-case financial model of an electronic industry product (Figure 6) to estimate the total manufacturing cost of the product life cycle. Tables 2 and 4 represent the effect of using Rapid Manufacturing technology instead of using conventional tooling technology. In tables 3 and 4 a scenario of product change and new tooling have been illustrated. Net present value (NPV) is the discounted value of total costs using an annual interest rate of 10%.

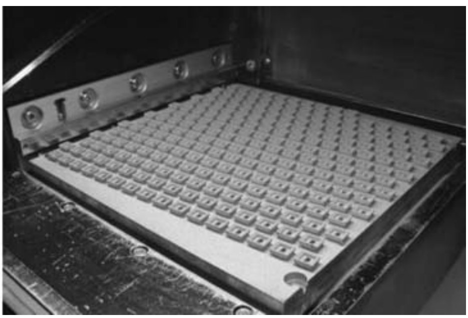

Figure 6. Case study work pieces in DMLS rapid manufacturing process

Table 1 The base-case financial model

Base-case						
Conventional manufacturing technology, die casting						
Year	0	1	2	3	4	5
Sales volume		5000	5000	5000	5000	5000
Unit price	1	1	1	1	1	1
Tooling cost	120000					
Manufacturing cost		5000	5000	5000	5000	5000
Total cost	120000	5000	5000	5000	5000	5000
Costs NPV	138954					

Table 2 The effect of applying rapid manufacturing technology

Rapid manufacturing technology						
Year	0	1	2	3	4	5
Sales volume		5000	5000	5000	5000	5000
Unit price	12	12	12	12	12	12
Tooling cost						
Manufacturing cost		60000	60000	60000	60000	60000
Total cost	0	60000	60000	60000	60000	60000
Costs NPV	227447					
Costs difference	64%					

Table 3 The base-case; product change and new tooling needed in year 2

Scenario 1: Product change and new tooling needed in year 2						
Conventional manufacturing technology, die casting						
Year	0	1	2	3	4	5
Sales volume		1000	1000	5000	9000	9000
Unit price	1	1	1	1	1	1
Tooling cost	120000		120000			
Manufacturing cost		1000	1000	5000	9000	9000
Total cost	120000	1000	121000	5000	9000	9000
Costs NPV	236401					

Table 4 Rapid manufacturing; product change and new tooling needed in year 2

Rapid manufacturing technology						
Year	0	1	2	3	4	5
Sales volume		1000	1000	5000	9000	9000
Unit price	12	12	12	12	12	12
Tooling cost						
Manufacturing cost		12000	12000	60000	108000	108000
Total cost	0	12000	12000	60000	108000	108000
Costs NPV	206730					
Costs difference	-13%					

The NPV comparison in tables 1 and 2 shows that cost difference between conventional manufacturing technology and rapid manufacturing technology in this case is 64%. The scenario where the sales volume is low in the beginning of the product life cycle and product change and new tooling in year 2 is required results in 13% lower cost compared to conventional manufacturing technology. These cost comparisons show that total costs are strongly dependent on unit price and manufacturing volumes. Development of rapid manufacturing technologies and the trend in decreasing unit prices together with uncertainty in product development and production gives opportunity for rapid manufacturing applications in the future. Table 5 shows that if the unit price in Table 4 decreases from 12 to 9 (i.e. a reduction of 25%) rapid manufacturing application NPV costs would be 34% lower than in conventional manufacturing.

Table 5 Rapid manufacturing with decreased unit cost

Rapid manufacturing technology						
Year	0	1	2	3	4	5
Sales volume		1000	1000	5000	9000	9000
Unit price	**9**	**9**	**9**	**9**	**9**	**9**
Tooling cost						
Manufacturing cost		9000	9000	45000	81000	81000
Total cost	0	9000	9000	45000	81000	81000
Costs NPV	155048					
Costs difference	-34%					

4. CONCLUSION

In the product development phase of a product life cycle there are several challenges; companies are competing with product quality, product cost, development time, development cost and development capability. At the same time customers are requiring even more different kinds of product configurations. All this leads to uncertainty and the need to develop flexibility in production. Development of rapid manufacturing technologies offer new methodologies for companies to tackle these challenges. As a tool for analyzing economics of new rapid manufacturing applications, base-case cost modeling methodology is presented. As a next phase of our research program the base-case methodology will be developed to cover sales revenue scenarios. Besides the development of the methodology the models will be tested based on industrial case studies which will be collected globally.

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