Development of an Additive Layer Manufacturing business model: creating an environment to support designers from concept to distribution

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Development of an Additive Layer Manufacturing Business Model: Creating an Environment to Support Designers from Concept to Distribution

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Abstract

The effective end use of ALM products depends on establishing a dynamic business model. The model should encompass end-to-end service from design to selection of technology and a viable means for the supply and demand paradigm to function. This paper presents research into the concept for a Design for ALM technology platform, in which the process for realising a design from concept to manufacturing and distribution using ALM technologies is managed and supported through appropriate environments. A technology selector is included as part of the process/material selection environment to select appropriate ALM technologies. Further, the paper presents, as part of the platform, a trade environment based on e-business principles where the supply and demand of ALM products is matched over a virtual trading system. The concept of the platform provides an opportunity for the entire ALM business community to function in a competitive and mutually beneficial environment. The paper essentially outlines a blueprint where all the components of the supply chain can effectively appropriate value.

Keywords
Additive Layer Manufacturing, Selection Tool, Design Templates, E-business, Reverse Auction

1. INTRODUCTION

Additive Layer Manufacturing (ALM) processes can be defined as automated systems that take 2-dimensional layers of computer data and rebuild them into 3-dimensional (3D) solid objects. Internationally, ALM can also be known as Layer Manufacturing Technologies (LMT), Generative Manufacturing and 3D Printing (3DP) amongst many other names [1]. A more accurate name for the final end-use of ALM as a functional product would be Rapid Manufacturing (RM). This paper will, however, use the term ALM as it seeks to incorporate all potential uses of these technology types/descriptors and for a variety of users. This paper discusses developments of current research on how to create an environment where the benefits of these technologies are best utilised and to identify what the major hindrances may be. The use of these technologies for manufacturing of end use products in terms of speed, cost and quality that can be accepted by the general consumer does not exist at present [2] and thus, it can be argued that a fully functional supply chain for the end-use of ALM technology and its products is yet to be realised. The argument could be extended further to say that the effective end-use of ALM technologies would perhaps depend on the establishment of a sustainable supply chain. The need is therefore obvious, that a business model is required where the supply and demand paradigm can function.

ALM technology lends itself to all types of customisation and is best suited to creating an infinite number of choices for one or more features. This perhaps is one of its biggest benefits. Consumers are becoming increasingly refined in their tastes and desires for new products. One method for tackling the requirements of the consumer is to provide a mass customisation service [3]. The use of mass customisation in order to differentiate products adds significant value to the consumer. Several decades have shown rapid increases in growth in the field of computer peripherals and internet access. This trend, where non-technology compliant customers are increasingly faced with new technology, inevitably leads to consumers being brought closer to the process, or being involved in the creation of their desired product. The internet has provided a viable means for communication between manufacturer and consumer. This enables the consumer to convey their ideas and provide specific input to the product conceptualisation, development and manufacturing process. These technologies demonstrate how they can increase human computer interaction within different steps of the design process [4]. It is clear that a methodology needs to be derived where an inverted approach is taken for products, which let consumers perform aspects of the design and manufacturing by themselves. *Therefore, the question is how to strike a balance between people's will to custom-make products and ALM's scope for customisation?* Another important aspect in the case of ALM is the selection of appropriate technology. An inhibiting factor for the widespread uptake of ALM is the cost of materials and services within ALM as well as the availability of certain machines and materials. Therefore, any efficient business model for ALM has to answer *how selection issues of processes and materials are to be resolved?*

This paper discusses a potential business model for ALM technologies and their product output. The proposed business model is based on the concept of an online platform, to conduct trade, design and provide technical support on material/process selection, for ALM manufactured products. This paper elaborates the platform in terms of three major work environments namely: design, process/material selection and trade, as illustrated in Figure 1.

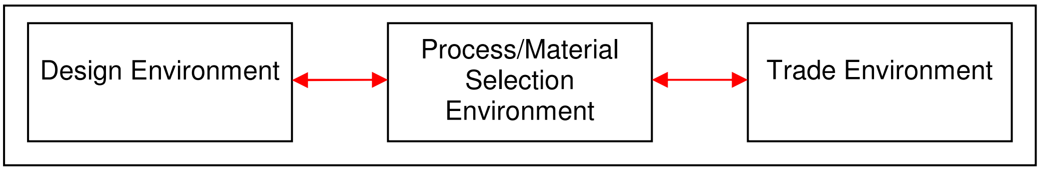

Figure 1. Online platform

2. DESIGN ENVIRONMENT

ALM processes have a powerful effect on design and manufacturing as they can simplify the production stage and bring the consumers closer to the point of manufacture. In addition, processes such as 3D printing, developed at MIT, shows that this technology is easy to use, relatively inexpensive to operate and office friendly.

However, ALM requires 3D data that comes from a 3D design model. This is the bottleneck for ALM as products can be produced on demand in a matter of hours yet can take weeks to design. For this reason, ALM requires a new approach to design systems in the coming years [5]. These design systems need to be developed to be as simplistic to operate as some ALM technologies have. They should be easy to operate by the user (whether experienced or inexperienced) and in the context of this research, by the consumers, so that manufacturers allow them to perform aspects of the design as they desire and potentially manufacture by themselves.

What follows is a description of a design template for the ALM environment to aid a consumer in designing aspects of their own product.

2-1. Design template

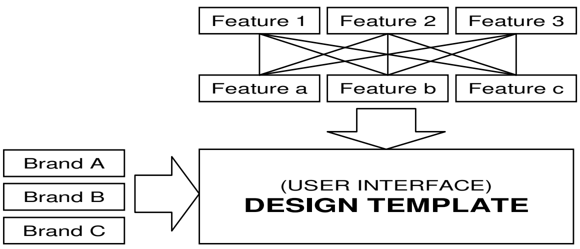

Figure 2. Simple design template

Figure 2 shows a schematic of a simple design template, but is actually an extended version of an e-catalogue from which users not only choose the part they wish to buy, but also can determine the features on the part base to their specification. A practical example is a sports shoe manufacturer, who serves a market via their website by allowing consumers to decide on the colour theme that they desire, locate logos and apply their own text [6].

It is necessary that consumers are provided easy access to the benefits afforded by using ALM technologies through simplified usage of CAD. This can be achieved by using the 3D modelling database available in, for example, the SolidWorks publisher and restricting the interface to a simple html format. The idea is to negate the impact of costly CAD software and concurrently keep the process simple for consumers to review designs through rotation and panning.

2-2. A template mobile phone cover

This paper uses the example of a template mobile phone cover which can be customised using ALM to the consumer specification. In this example, the product is for an individual consumer or very small number of buyers. Upon entering the design template, the consumer will be asked about the brand of their mobile phone, then the particular model type/version. The next step is starting to choose type of covers: for instance, Option 1 is a sock type which the consumer can lay a lithophane image, logo or name in front of screen. Option 2 is fit type, which could be with flip screen cover or not, and as in Option 1, it is also possible to place graphics on the screen cover as well.

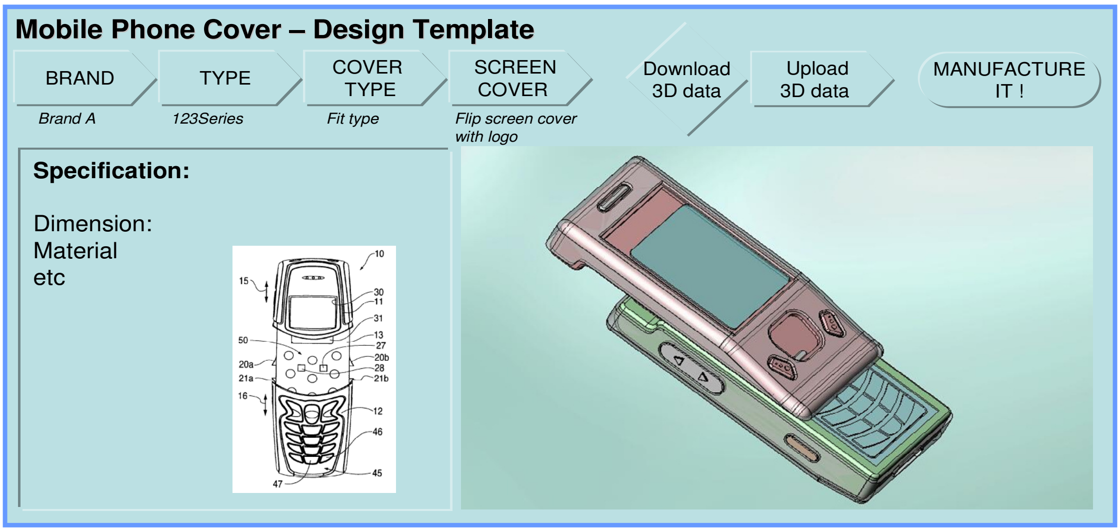

Figure 3. Design template of mobile phone cover

3. PROCESS SELECTOR

Another fundamental tool of a suitable ALM environment is the ALM Process Selector. To decide on a suitable process and then a suitable build material is a challenging task for a consumer or designer with little or no experience of ALM technologies. There are at present over 30 machines that are capable of producing true RM end-use products with a choice of well over 100 materials. Information relating to the combinations of these materials and processes available to manufacture products is sparse, disjointed and for the most part difficult to come by. A process selector for RM brings together current knowledge of available ALM technologies into one database to aid in choosing a suitable manufacturing technology and material and potentially influence design decisions.

3-1. Knowledge base

The knowledge base is a relationship database constructed using Microsoft Access containing all available information regarding process capabilities, material properties, limitations and relevant costs amongst others. The database can be easily updated as new technologies and materials are developed or new information about existing technologies is published. It is the knowledge base that users query through the user interface to find the information they need about a particular ALM technology.

3-2. User interface

Once a user has in mind the product or part that they wish to produce, they can input relevant data through the user interface in order to create a basic profile specification for their part. The system uses this profile specification to search the database for materials and processes that best suit their requirements. This information is then presented to the user in the form of an output datasheet. This process is illustrated in Figure 4.

3-3. Output datasheet

The function of the output data sheets is to give the user enough knowledge to make a decision about the most suitable ALM technology from the process and material choices the system presents to them. It is unlikely that the system will ever give only one recommendation. The output data includes advice on the unique design opportunities ALM offers as well as limitations and some relative costing information.

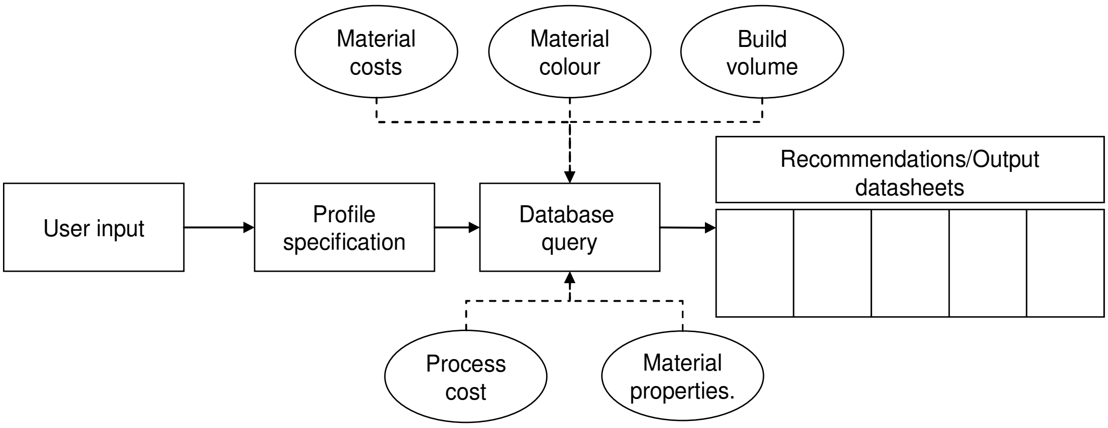

Figure 4. Flow diagram of the ALM selection process

3-4. System integration

As well as aiding in deciding which ALM technology and material to use for any given product, the output data is intended to potentially aid in the redesign of a part through the advice on unique design opportunities. This information can be taken back into the design environment and used to produce a different design, which can then be either put through the selector a second time or moved to the next stage of the process as shown in Figure 5.

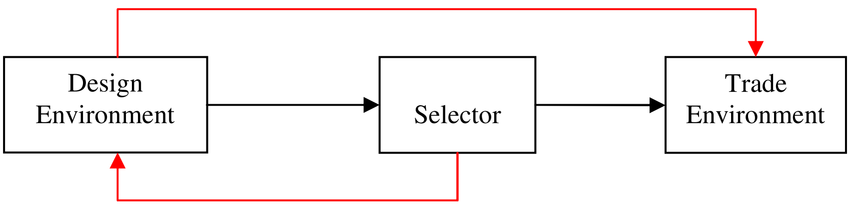

Figure 5. System integration

4. TRADE ENVIRONMENT

The prime task of the trade environment is to ensure that the demand and supply paradigm for ALM manufactured products functions efficiently. It is proposed as an online trading market for such products. The concept of the trade environment is derived from the theories and practices of electronic commerce. Electronic commerce can be defined as any electronic communication that facilitates the exchange of goods, services or other assets between suppliers and buyers. It is also termed as Business-to-Business or (B2B), which can be classified as including sell-side (e-catalogues), e-marketplaces, trading partner agreements and buy-side (e-procurement) [7].

4-1. Reverse auction

The trade environment proposes the use of a reverse auction as a method for settling the demand of ALM products online. At the heart of any auction model is the concept of personal price elasticity. That is, customers will determine the price depending upon the price/value trade-off [8]. Reverse auction can be defined as a process where buyers set up an auction to receive bids from suppliers. Suppliers bid down the price for fulfilling that order [9]. One leading online commerce company, Freemarkets, claims that customers buying through it should be able to save around 20 per cent of expenditure on their supplies. Freemarkets reports that it ran auctions valued at €5.2 billion in Europe alone in 2001, saving customers €860 million. Worldwide auction turnover has reached $30 billion with savings of $6.4 billion [10]. This data suggests that there is good justification for utilising online auctions to conduct purchases of RM products. The format of a possible reverse auction process is tabulated in Table 1.

Table 1. Reverse auction process

1. Prepare detailed electronic product specification. This includes digital CAD data of the proposed product.
2. It is important to produce a clear requirements specification as it will help suppliers in bidding and also make post-auction evaluation more straightforward.
3. The platform is notified of the potential bid sought.
4. The suppliers express their primary interest to participate in the bidding process.
5. The buyer can potentially restrict certain suppliers that can participate in the auction.
6. Start of the reverse auction event. Buyer and suppliers access the event through web. They can log in and out of the event to view and place bid. Suppliers bid anonymously against each other. There is no limit to the number of individual bids and the event can last for a duration prescribed by the buyer.
7. Reverse auction closes. The bids are analysed according to preset criteria available. The buyer can use bid evaluation tools and assessment engines in this regard.
8. The buyer decides on awarding contracts.

4-2. E-catalogue

E-catalogue is another proposed method to buy and sale ALM manufactured products through the environment. The use of online catalogues as a mean of selling products is firmly established in the market (Sweets, AEC info, Barbour Index) [11]. 3D ContentCentral is another example of a web based catalogue, where designers can host their 3D data [12]. The catalogue proposed in this paper is a digital database or pool of parts that can be manufactured utilising ALM technologies. A product in the e-catalogue will have the supplier's information sheet as well as the 3D CAD data. The selection of a product can be described in a three step process 1) Browse the e-catalogue, 2) Select a product to purchase, 3) Contact the appropriate supplier. It is important to note that the catalogue is populated through the design environment, as discussed earlier.

4-3. Potential services and the increase in market size

There are potentially five services that the trade environment can offer as follows:

- **Sourcing or discovery:** giving buyers easy access to a pool of suppliers, a process that can save time and offer buyers better prices due to the increase in competition amongst suppliers.
- **Demand identification:** suppliers can identify customers and their demands in a free market economy.
- **Transaction:** the actual exchange of procurement information, such as purchase orders, between the buyer and supplier.
- **Content:** through the e-catalogue that can contain vast volumes of products, the buyer can acquire the required product.
- **Promotion:** advertisement for suppliers through the e-catalogue.

It is expected that the proposed services mentioned above could provide an alternative way for the supply and demand of ALM products to function. The biggest impact the trade environment could have is perhaps to increase the existing market size for ALM manufactured products. This is because the environment in theory can accommodate different components of the supply chain located globally to execute trade and thus, resulting in a potential worldwide operation.

4-4. RM versus tooling

The top moulding of a hand-held electronic device about the size of a telephone handset was tooled in China in 2007 for €3,000, with each part costing €0.43 based on an order of 1,000 units. The same part presumed suitable for ALM, using Selective Laser Sintering (SLS), would cost around €45.00 for each part. This means that the first 1000 parts would cost a total of €3,430 produced conventionally, or €45,000 produced using ALM. The 'break even' production point, below which ALM would be cheaper than injection moulding, would be 67 parts [13]. The above analogy is bound to raise the question "Why use ALM then?" The answer lies in two of the most important benefits of ALM: that is making complex geometries possible with no apparent additional cost; and customisation. The fact is that there is an increasing market for such products across economies and the break even batch size of 67 or less as it is in the above analogy is not a factor anymore. The environment can capture the market for such exclusive products across different economies and support the demand and production for such products to flourish.

5. CONCLUSION

The discussions that have been put forward in this paper are concepts resulting from current research on identifying solutions for the effective use of ALM technologies in the RM marketplace. The paper has described a plan on how to integrate critical issues such as process/material selection, designing and trading into a common online platform, in order to provide a comprehensive service to all components of the ALM supply chain.

References

[1] Reeves, P. (2008). Econolyst Ltd - Rapid Manufacturing Master Class.

[2] Hopkinson, N., Hague, R.J.M. and Dickens, P.M. (2006), Introduction to Rapid Manufacturing, in Rapid Manufacturing: An Industrial Revolution for the Digital Age. N. Hopkinson, R. J. M. Hague and P. M. Dickens. West Sussex, England, John Wiley & Sons, Ltd.

[3] Pine, J-п. (1993), Mass Customisation – The new frontier in business competition, Harvard Business School Press, Boston, Massachusetts.

[4] Bordegoni, M., Colombo, G., Luca, F. (2006). "Haptic technologies for the conceptual and validation phases of product design." Computers & Graphics 30(3): 377-390.

[5] Knoppers, R. and R. Hague (2006). CAD and Rapid Manufacturing, in Rapid Manufacturing: An Industrial Revolution for the Digital Age. N. Hopkinson, R. J. M. Hague and P. M. Dickens. West Sussex, England, John Wiley & Sons, Ltd.

[6] www.nikeid.com [Accessed 10 May 2008]

[7] Stein, A. and Hawking, P. (2002), "Reverse Auction e-Procurement: A Suppliers Viewpoint", the Eighth Australian World Wide Web Conference, Twin Waters Resort, Sunshine Coast Queensland, 6-10 July. http://ausweb.scu.edu.au/aw02/papers/refereed/stein/index.html [Accessed 14 May 2008].

[8] Friedman, H. H. and Barbara, J. L. (1999) Dynamic Pricing Strategies for Maximizing Customer Satisfaction. The National Public, Accountant 44(1) (Jan-Feb): 8-11. http://www.allbusiness.com/sales/customer-service/161659-1.html [Accessed 14 May 2008].

[9] Wyld, D. (2000). The Auction Model, The PriceWaterhouseCoopers Endowment for the Business of Government, The Business of Government, October. http://www.businessofgovernment.org/pdfs/WyldReport.pdf [Accessed 14 May 2008]

[10] Pritchard, S. (2002) Streamlined benefits for buyers and sellers: ONLINE AUCTIONS. Financial Times. http://search.ft.com/nonFtArticle?id=020313001689&query=freemarkets [Accessed 10 May 2008]

[11] Amor, R. and Kloep, W. (2003) E-Product Catalogues, Proceedings of the EIA9 Conference on E-Activities and Intelligent Support in Design and the Built Environment, Istanbul, Turkey, 8-10 October, pp. 75-82. http://www.cs.auckland.ac.nz/~trebor/papers/AMOR03A.pdf [Accessed 10 May 2008].

[12] http://www.3dcontentcentral.com [Accessed 10 May 2008]

[13] Ayre, M. (2008). Rapid Manufacture: Is it Cost-Effective? The TCT Magazine. 16: 19-20.