Working Papers on Design
Volume 1

L.E.J. Styger and S.R. Reece

Laminated Object Manufacturing: rapid challenge versus traditional model making techniques

Abstract.
Laminated Object Manufacturing was first released commercially in 1992. Since this time it has become one of the leading Rapid Prototyping techniques with over 100 machines sold worldwide.
Case studies exist from many industries showing the benefits of using Rapid Prototyping and LOM in particular. However, the techniques need to be used in the correct manner and need to be viewed as a tool for model creation rather than an end in themselves.
This paper discusses the role of Rapid Prototyping in Rapid Product Development and the reasons for moving from traditional product development philosophies to the new rapid product development cycle.

1.0 Introduction.

Having become established in the mid 1980s the combined technologies of "Rapid Prototyping" are now mature. There are many commercial success stories relating to the techniques [1,2]. The ability to produce models or facsimiles of a chosen design, direct from the CAD data, in a matter of hours compared to weeks or months by traditional means has established this methodology as a desirable tool for Rapid Product Development.

The impact of Rapid Prototyping cannot be understated and indeed its credentials are such that many believe that it is now challenging traditional and established product development methods.

By concentrating on a single technology from the Rapid Prototyping field, namely Laminated Object Manufacturing, this paper will highlight the application and implications of commercially available Rapid Prototyping systems on the traditional product development cycle.

2.0 The Change in the Product Development Cycle.

Before considering the role of Rapid Prototyping in the product development cycle, it is necessary to consider the shift in emphasis and driving factors which lie behind the change in the product development procedure.

Traditionally, product development has been viewed as a multi-disciplined, linear procedure in so far as the concept design has been passed to engineering design who then pass it to the prototyping/model making function. It is then passed to the engineering/ manufacturing engineering section before the design is finally signed off for production. Each function has used two dimensional or three dimensional methods of communication, typically comprising of a concept sketch, a controlled engineering drawing, a three dimensional master model, a detail (or working) drawing, a three dimensional master pattern and any necessary prototype and/or production tooling. This is highlighted schematically in Figure 1.

Any design modifications have to follow a similar path to the initial design, causing excessive time delays and, in some cases, possible commercial product failures because the product has either been too late to market or has proved to be too expensive to manufacture in a given time scale.

With the advent of computer generated data (so-called CAD data), companies have looked to control and shorten the product development cycle. This has typically been concentrated in two discrete areas, these being product design and prototype or production manufacture. This "new traditional" cycle is shown schematically in Figure 2. Both the old and the new traditional product cycles typically allow the fabrication of three dimensional models and facsimiles to be undertaken by manual techniques. This fundamental yet perhaps most important stage of the product development cycle (since it is the first time the product is seen in three dimensions) is typically performed by highly skilled craftsmen. However, the traditional techniques used rely on a manual interpretation of the original design data and therefore provide no guarantee of consistency between the original data and the three dimensional facsimile. When consideration is made of the notorious "model makers' licence" or pattern makers' "fudge factor" it becomes apparent that the validity of both the traditional approaches must be questioned by the customer and user alike. Also, the main commercial driver of time should be considered and accounted for in revenue terms by the company concerned.

The introduction of novel "Rapid Prototyping" techniques has enabled facsimile parts and master patterns to be produced directly and accurately from computer generated information in hours compared to weeks or months traditionally. These techniques have thus enabled designs to become more elegant and manufacturing procedures to become slicker because more time is available "up front" to allow companies to place real investment in the product at the stage where it counts - that is, in the concept design stage. Rapid Prototyping techniques have also enabled companies to sign their designs off sooner since non-technically minded decision makers know that what they hold in their hand at the concept stage is exactly what they will receive as their final product [3].

In short, Rapid Prototyping has enabled industry to engineer a product development procedure and remove the "black art" and "fudge factors" from product development.

3.0 Rapid Prototyping Systems.

There are many commercial Rapid Prototyping systems available. Recent studies have placed the number as high as 40 different machines from various manufacturers [4]. Although often assumed by the novice to be similar in functionality and application, each system is typically finding its own niche in terms of industrial application and benefit. However, most systems share the same basic characteristics. These are [5] :

- facsimiles produced directly from CAD data;
- facsimiles which are an accurate representation of the CAD data;
- facsimiles that are quick to produce compared with models produced by traditional means;
- facsimiles which may be of unlimited complexity;
- facsimiles which are not necessarily produced in the final engineering material.

4.0 Laminated Object Manufacturing.

Studies have shown that the Laminated Object Manufacturing (LOM) process is typically the first Rapid Prototyping process which traditional model makers find an affinity with [6]. This is believed to be due to the fact that, at first sight, the LOM facsimiles appear to look, finish and behave in a similar manner to traditional wooden models and patterns. Although not based on any scientific evidence, this tentative link with traditional techniques at least provides the skilled craftsman with a level of confidence to explore the technologies more fully.

4.1 How the Process Works.

A Laminated Object Manufacturing model is constructed from the base up, on top of a moving platform contained within the working area of the LOM Machine. Figure 3 shows the layout of the LOM process. The platform is lowered slightly to allow the material (usually paper coated on one side with low density polyethylene which acts as a heat sensitive adhesive) to advance into the working position of the system. The platform then rises to allow the material to be bonded to the previous layer of the model. It is then simultaneously compressed and heated by means of a heated roller which passes over the laminated area (model) and then retracts to a standby position.

A CO_2 laser (25 Watt on the LOM 1015 and 50 Watt on the LOM 2030) operated in conjunction with an X-Y plotter arrangement traverses over the bonded laminate to cut the external "box" and external and internal profiles of any cross section that has been generated from the CAD data. The model build sequence is repeated as the platform descends to allow more and more material to advance into and be deposited within the work area.

Each successive lamination has its nominal thickness calculated when it is bonded in place. This on-line calculation is designed to ensure that, despite the potential for variation in material thickness, the profile which is cut is consistent with the height of the CAD model at that stage of the build process. The calculation is enabled by a feedback system on the Z-axis of the machine, albeit localised to the area traversed by the feedback roller.

Waste material is created in the working area of the machine during the build process. This material is not required as a part of the finished model and is cut into cubes by the laser. The cube formation is a deliberate part of the procedure and allows the removal of the waste from the model perimeter once the build process is completed. The cubes are intended to provide support for the model during the lamination operation. This technique ensures that the roller passes over a complete sheet of laminate and that the model sections are adequately supported during cutting operations.

5.0 The Challenge to Traditional Model Making.

At first sight a technology such as LOM would appear to have no technical opposition in the traditional model making industry. However this is not the case when consideration is given to other so-called rapid prototyping techniques and, perhaps more appropriately in this case, CNC rapid machining techniques. The commercial advantage is evident when we consider the myriad of small and large model making shops who have gained an international reputation and a lion's share of the commercial market by exploiting these techniques "in-house". These companies have not only consolidated their home markets but have gained an international reputation by offering a world class service in new, diverse sectors and indeed seem to be leaving the less technically able companies to fight for the remaining crumbs.

The ultimate business driver lies in a company's need to get their products to market sooner, cheaper and better than ever before. With the recognition of this driving force comes the realisation that this can only be achieved through its investment in and control of the product development cycle, the enabling technique being Rapid Prototyping. Companies now demand that their suppliers accept their controlling or CAD data directly and that they use this information to produce faithful reproductions of the design.

For most companies investing in Rapid Prototyping for the first time, the problem does not revolve around the company's ability to perceive these techniques as a threat or opportunity to their business but rather the company's ability to understand their core activities and their ability to marry these activities with the new "tools of the trade" [7]. Rapid Prototyping is no longer a "high tech" toy but rather a business necessity for those who are serious about competing in the industrial marketplace.

6.0 Conclusions.

Rapid Prototyping techniques are now an established part of the product design cycle and have been shown to reduce the time to market for new products. The savings in time have also been shown to save money at the product design stage and thereby allow new products to be introduced more competitively.

For companies who are already using them, Rapid Prototyping techniques have proved to be of commercial benefit. The techniques have also proved to be a threat to the profitability of those companies not taking advantage of them. However, Rapid Prototyping is ultimately a tool which relies upon the competency of its operators and practitioners for its success. Perhaps present users of Rapid Prototyping are leading the way and demonstrating by example where the future evolution of industrial model making lies.

7.0 References.

[1] Upton, J. The Application of Rapid Prototyping within Rover Group Proceedings of Rapid Prototyping in the UK, IEE Seminar, March 1994.

[2] Kochan, A. Parangon Uses LOM Technology to Cut Product Development Times. Assembly Automation, 4 (2) 32-34, 1994.

[3] Kerrigan, K.T. & Wells, K.V. Approaching Rapid Modelling in the 90's - Rapid Prototyping - Automotive Case Study. Proceedings of the Second European Conference on Rapid Prototyping and Manufacturing, Nottingham, UK, July 1993.

[4] Wimpenny, D.I. Research into Rapid Prototyping Rapid News, 3 (1), 1995.

[5] Styger, L.E.J. Influences Affecting the Stability and Accuracy of Laminated Object Manufacturing Models. MSc. Thesis, University of Warwick, August 1994.

[6] Susor, J. The Benefits of Rapid Prototyping in a Prototype Manufacturing Environment. Proceedings of SME Rapid Prototyping Clinic, SME, April 1992.

[7] Styger, L.E.J. A Place for Everything, and Everything in its Place Rapid News, 3 (3), 1995.

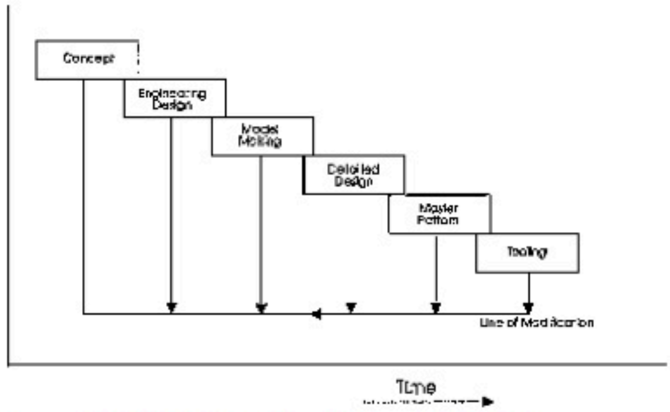

Figure 1: "Old" Traditional Product Cycle.

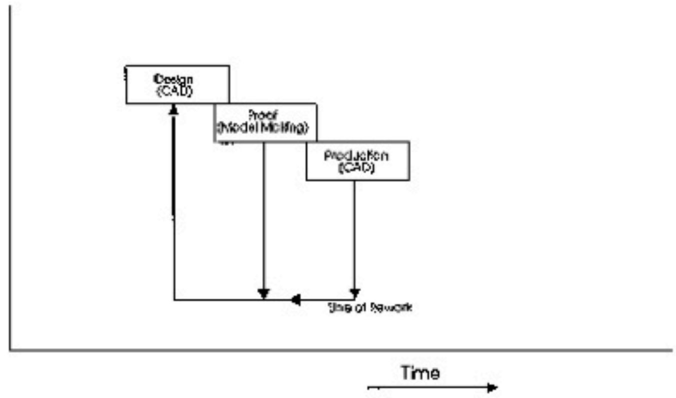

Figure 2 - "New" Traditional Product Cycle.

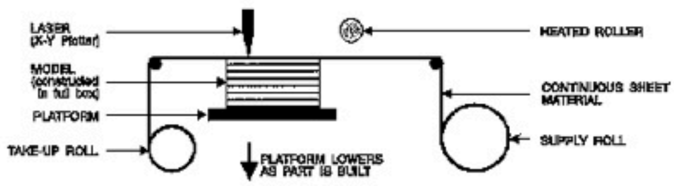

Figure 3 - The Laminated Object Manufacturing Process.

L.E.J. Styger,
Warwick Manufacturing Group,
University of Warwick,
Coventry, CV4 7AL
Steven Reece,
Computer Centre,
University of Leicester,
University Road,
Leicester, LE1 7RH