The Impact of Low-Cost AM Systems

12

Abstract

Media attention over additive manufacturing is at an all-time high. Much of this is to do with the vast increase in the availability of the technology due to massive reductions in the technology costs. By making it possible for individuals to afford them for their own personal use, the true potential has been, to some extent, uncovered. This chapter will discuss some of the issues surrounding the low-cost technologies, including machine developments due to patent expiry, the rise of the Maker movement and some of the new business models that have resulted.

12.1 Introduction

When the first additive manufacturing machines came on to the market for the purposes of rapid prototyping, they were, not surprisingly, very expensive. The fact that they were aimed at early adopters, based around complex and new technologies, like lasers, and only produced in small volumes meant that purchase of such machines left you with little change from a quarter of a million US dollars or even more. Furthermore, the perceived value of these machines to these early adopters was also very high. Even at these prices the Return on Investment (ROI) was often only a matter of months or attributable to a small selection of high-value projects. An automotive manufacturer could, for example, achieve the ROI just by proving the AM technology ensured a new vehicle was launched on or ahead of time. Such perceived value did little to bring the prices of these machines down.

As the technology became more popular, the market became more competitive. However, demand for these new machines was also high, particularly from the traditional market drivers of automotive, aerospace, and medicine as mentioned in previous chapters. Vendors did find themselves in competition with each other, but there were many different customers. Furthermore, different machines were exhibiting different strengths and weaknesses that the vendors exploited to develop

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differing markets. For most of these markets, the more successful vendors also ensured they had excellent intellectual property (IP) protection. All of this served to maintain the technology at a high cost.

Ultimately it was the issues surrounding IP that led to the current situation. Many of the original technologies were protected by patents that prevented other companies from copying them. The vendor companies were also very aggressive in defending their IP as well as buying up related IP and their associated companies where they existed. This competitive market did have the effect of slowly eroding the vendor companies' profit margins, but huge changes have recently taken place as a result of these patents lapsing. We will go on in this chapter to discuss how this has impacted the low-cost AM technology marketplace. The key patents will be discussed as well as the more prominent players in this field. This activity has fuelled a huge amount of interest by the media, which will be discussed in terms of how it has in turn impacted the industry. Much of this interest can be associated with what is becoming known as disruptive innovation. AM certainly fits with a number of other technologies to form the basis for disruptive business models, which we will discuss. AM also is a huge enabling technology that has assisted many home users to solve many of their own technical problems at home. Sharing these experiences and even profiting from them has spearheaded what is being commonly called the Maker Movement, which we shall also examine. We will go on to consider how this branch of AM may develop in the future.

12.2 Intellectual Property

As mentioned in the introduction and in other parts of this book, the key patents with the most protection originated in the USA. While there was activity in other countries, 3D Systems, Stratasys, DTM, and Helisys were the principal vendor names for much of the world in the early days. Other companies were also present, like EOS, Sony, Sanders, and Objet, but they either came along at a later date or were in close IP conflict with these American vendors.

European and US patent law for technology are somewhat similar to each other in that they refer to a 20-year term from the initial filing date of the patent in most cases. Charles Hull filed his first Stereolithography patent in 1984 [1], which therefore expired in 2004. Scott Crump patented the Fused Deposition Modeling process in 1989 [2], which means that patent expired in 2009. The major difference between these technologies, in this context, is that the melt extrusion process is much easier to replicate at a low cost compared with the laser-cured photopolymer systems. It is evident therefore that while the door to widespread development was opened in 2004, it was not opened wide until 2009 and beyond. This is evident from the figures quoted by Terry Wohlers from 2008 to 2013, shown in Fig. 12.1, concerning the number of low-cost AM machines purchased over that period [3].

Of course this is not the complete story. While the original patents were filed in the 1980s, additional patents have been constantly filed ever since. If one notices that there have been many copies of the original FDM patent, all the resulting

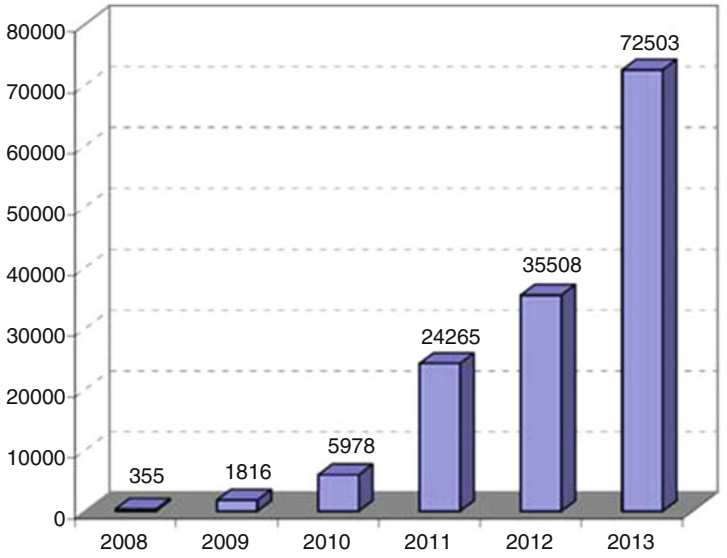

Fig. 12.1 Wohlers' data showing how the numbers of low-cost AM machines has increased from virtually nothing in 2008

machines have thus far not implemented an environmental control apparatus. This is because the patent for this development was not filed by Crump until a few years later.

There is an excellent review of the recently expiring and shortly expiring patents carried out by Hornick and Roland [4]. In it they make a number of interesting observations that lead to the following discussion:

- There is a huge number of patents involved and it is a very difficult process to navigate through them. Many patents make multiple claims across numerous platforms. They often do not adhere to a single process.
- Earlier patents discuss broad-based approaches that are in fact quite easy to defend and/or find ways around. It is quite easy to distinguish one process from another since they do not have the benefits that are gained through experience of actual application of the technology. Later patents obviously result from discoveries resulting from use of these base technologies, which discuss subtle features like soluble supports or fill patterns.
- While 3D Systems patents are among the earliest to expire, there are obvious technical complexities in them that would make them difficult to replicate without significant industrial backing. An example relates to the formulation of resins to speed up the curing and build process or another to facilitate even spreading of resins.

– Some key droplet deposition and powder sintering by laser patents expired in late 2014, early 2015. Expiration of these patents may help to open up the high-end, high-quality AM market by bringing the machine costs down.

At the time of writing this chapter it is merely speculation, but it will be interesting to see how some of the large printing or equipment manufacturing companies view these as opportunities. One can anticipate that a large printer company may possess the necessary knowledge, resources, and infrastructure to produce high-quality AM equipment in volume at very reasonable costs. It is worth noting that although low-cost AM started with material extrusion technology, since they were the easiest to produce and some of the first patents to expire, low-cost versions of photopolymerization (Formlabs), polymer laser sintering (Norge), and even metal machines such as metal laser sintering (Matterfab) and lower-cost directed energy deposition heads (Hybrid Manufacturing Technologies or the LENS print engine) are starting to proliferate.

12.3 Disruptive Innovation

12.3.1 Disruptive Business Opportunities

Disruptive innovation and disruptive technology are terms that were originally defined by Christensen to describe activities or technology that create new markets [5]. A very obvious example of this is how the Internet made it possible to create online businesses which could not have existed before. However, the effects may be much more subtle and it is possible to create a disruptive business merely by using existing technology in a different way. Often this process can be achieved by early adopters of technology or by those who have skills that are either difficult to learn or not commonly used in a disruptive way. Here we can say that although there are many musicians, there is only one David Bowie or Lady Gaga, who made use of their artistic talents to generate additional business opportunities.

There is no doubt that AM is a disruptive technology, which can be combined with other technologies to generate new businesses. Improvements and more widespread use of CAD technology has made it possible for individuals to design products with minimal cost and training. Google Sketchup and Tinkercad are online design tools that are basically free to use. While they are not as powerful and versatile as paid CAD software, these accessible and simple to use tools have opened up a new market for home designers, who would then like to find outlets for these designs. While eventually this may mean all of these people will have machines in their homes, we are not quite there yet. Some people may have a low-cost AM machine at home, but even these may not meet the functional requirements and so will look to outside services to build and supply their designs. This has led to the establishment of companies who provide online services where designers can not only have their models made but also find an outlet where their designs can also be sold. Shapeways and i.materialise (see Fig. 12.2) both operate in

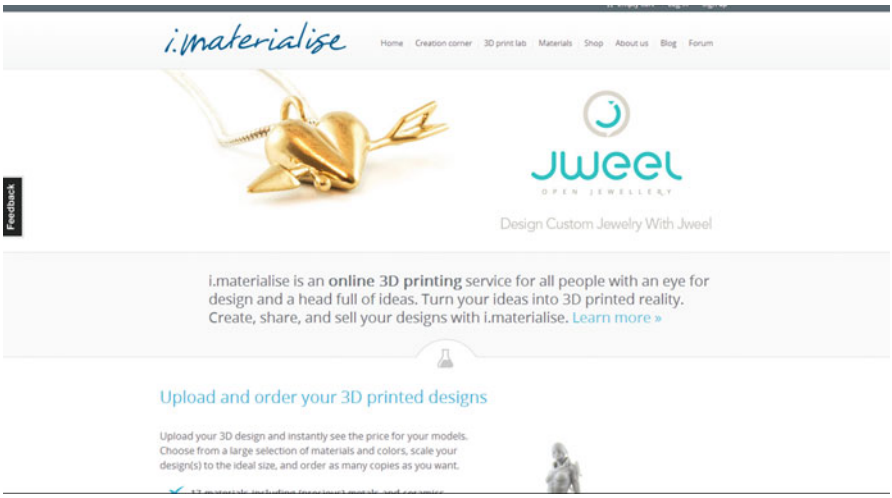

Fig. 12.2 Web site image for i.materialise, showing how designers can post their ideas on the web and have them built and made available for others to buy

this space, using techniques developed for social media platforms, where viewers can "like" other people's designs as well as discuss, share, and promote them. For those wishing to share designs but not concerned with the commercial aspects, there are also portals like the Thingiverse web site. Issues surrounding copyright of designs are regularly discussed around these web sites. Replicas or models inspired by merchandising for TV and movie shows for example can be regularly found on these sites and some sharing sites will have more or less control than others.

12.3.2 Media Attention

Since disruptive innovation is always going to attract media attention, it is worth considering some of the more prominent stories that have attracted interest and therefore structured how the general public view AM.

The first example that springs to many people's minds would be the use of AM to create firearms. A great deal of attention was directed towards AM when it was realized that it was possible to create firearms using the technology, the most well-known of these being the Liberator, single-shot pistol [6]. Here, it was discovered that this gun could be largely manufactured using an AM machine and that the plans for its manufacture were posted online. A primary reason for this attracting so much attention was the obvious contentious nature of the topic, backed up by the fact that this design can be easily shared on the Internet. It was particularly interesting to note that the attention was focused on the negative impact of AM rather than that of the Internet. There are a number of issues that are worth discussing here:

- While the gun was indeed built, certain items like the firing pin and obviously the ammunition would need to be added to the design.
- The original gun was created using a relatively high-end AM machine by a skilled operator. Sharing of the design online does not include the build parameters and a study by the New South Wales police in Australia revealed that the user is at great risk if the gun is not built correctly [7].
- Improvised firearms have been possible for many years and can be constructed by anyone with a small amount of technical knowledge and access to simple manufacturing equipment [8].

Admittedly, AM can be used like any technology, for good or for bad. However, we can see here how the media can latch on to one example and confuse the public image. These examples did bring the technology into a much wider public domain than previously and therefore allowed specialists in the field the opportunity to more properly explain the true impact of AM.

In stark contrast to the use of AM for destructive purposes, there have been numerous articles that describe how AM can be used to create replacement body parts [9]. As described in the chapter on Applications in this book, there is a huge potential for AM to contribute in this direction. The problem in the media coverage however is the time frame attached to this. Some applications have been implemented where AM has made significant improvements in medical and healthcare. However, this cannot be easily generalized into a conclusion that all medical problems can be solved this way. We must expect significant developments in the technology before we can make that conclusion and the AM machines of the future will look nothing like the machines we have today. Furthermore, we need parallel efforts in the biomedical sciences as well because they are far from being ready to plug in directly to AM devices. Specialists in these fields need to understand that, while it is reasonable to speculate that AM for body parts is on the horizon, they must be wary of that message being misconstrued.

Another sector that has attracted the media attention is the "cool gadget" area. One early example that again elevated general public awareness was The Economist magazine front-page article titled "Print me a Stradivarius" (see Fig. 12.3). This was probably the first mass-market article that highlighted how AM could be used for truly functional applications. While other media sites have included similar articles somewhere in their portfolios, the fact that this was on the front-page of an international magazine certainly had an impact. It is also worthwhile taking note that the BBC have published regular articles about AM over the years, averaging around 1 every 2 months or so in a wide variety of areas.

In relation to this chapter, the reason for including these articles is because of the increasing number of personal users of AM machines. All of these articles have one thing in common: they imply that you will eventually be able to create solutions for yourself.

Fig. 12.3 The Economist magazine front cover

12.4 The Maker Movement

As alluded to earlier in this chapter, the number of users who have their own AM machines has increased dramatically and they are driving much of the innovation that we are seeing. The technology is often aimed originally at providing solutions for problems that the user has experienced around his or her home or workplace. Social media and other outlets have allowed these users to demonstrate these solutions and thus inspire other users to do the same. While social media does help in dissemination, physical demonstration is usually a much more effective way of presenting your designs. To this effect, Maker Faires® have almost literally taken the world by storm, as can be seen in Fig. 12.4.

Maker Faires® are events where "Makers" congregate to display, demonstrate, and trade in items that they have designed and built themselves. While there is a lot of emphasis on technology, there is equal emphasis on design, environment, engagement, and fun in these fairs. Additive manufacturing is certainly a component in this, but so are Arduino and Raspberry Pi microcontrollers, laser cutting, conventional machine and hand tools, and home crafting skills like carving, sewing, and knitting. Many Makers merge technology with more conventional craft and design to come up with often personalized, often quirky systems that they would like others to see. The low-cost AM technologies have found a huge following

Fig 12.4 Maker Faire web page

within this Maker movement that is fuelling a large amount of innovation and even spinning off into new commercial ventures.

Perhaps not surprisingly this Maker movement originated in the USA, originally promoted by Make magazine [10] for the first event in California in 2006. The USA has a long and distinguished culture of innovation, perhaps spawning from the original frontier mentality of having to make do with whatever is around you, and this can also be seen in terms of how innovation is an accepted part of everyday life there. However, the concept of the fair is now a worldwide phenomenon with dozens of events held yearly attracting thousands of exhibitors and hundreds of thousands of attendees. The Maker Faire® has become the spiritual home for the Makerbot and other similar low-cost AM technologies, including the RepRap designs [11], and for design sharing portals like Thingiverse.

A huge number of commercial entry-level machines can thank the RepRap project for their origins. It would be almost impossible to identify every company, there are so many with varying levels of success. Designs have evolved considerably from the original RepRap machines, but the basic principle remains very much the same, exploiting the hot-melt extrusion process that was facilitated by the FDM patent expiry.

The Maker movement, along with the FabLab [12] and Idea to Product (I2P [13]) concepts, has done much to highlight the benefits of AM and associated technologies to the general public. The FabLab and the I2P labs are walk-in facilities aimed at providing an environment that encourages people to experiment with accessible manufacturing technologies and develop their ideas. Often the costs are at least partially absorbed by local authorities or donations. These are different from what is referred to as hardware incubators, where the costs are sourced from an investor network. All of these recognize in some way that there is a need to foster the creative processes.

12.5 The Future of Low-Cost AM

Low-cost AM has done much to bring the technology into the public domain. While it may be that it has taken some time to get to this stage with many of the current issues having been dealt with by early adopters, there has never been a better time to get involved in AM. A lot of confusion still surrounds what AM can and cannot do but even some of the negative press coverage has helped to promote the technology in some manner. While the majority of AM machines have exploited the Stratasys FDM, melt extrusion process, recent patent expirations of other AM technologies have started to open the doors to some interesting new low-cost technologies in the near future.

12.6 Exercises

1. What low-cost technologies are available in your area? Are there any local vendors and are their machines different in any way to the standard Makerbot and RepRap variants?
2. Examine articles about AM in the press. Is the information presented accurate? Would you write the article in a different way? Does inaccurate reporting have any impact on how the general public views AM technology?
3. What other technologies are represented at Maker Faires?
4. Consider the copyright infringement issues that surrounded the development of YouTube. Could similar things happen with respect to model sharing sites in the future? How can this be regulated?

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