Worldwide Trends in Additive Manufacturing

Terry Wohlers
Wohlers Associates, Inc., Fort Collins, Colorado 80525 USA
(tw@wohlersassociates.com)

Abstract - **Additive manufacturing (AM) technology is causing monumental change in product development. Its use for modeling and prototyping applications is well developed and understood and it is now impacting the actual manufacture of products. Organizations of all sizes are exploring how AM technology might be used to open up new opportunities in business, research, and education.**

Keywords – **Additive Manufacturing, 3D Printing**

I. INTRODUCTION

After many years of little organization, key individuals in the industry are beginning to cooperate at a high level to develop direction and standards for AM. In March 2009, 65 experts from academia, industry, and government attended the Roadmap for Additive Manufacturing (RAM) Workshop in Washington, DC. Its purpose was to develop a roadmap for research in additive manufacturing for the next 10-12 years. The effort was led by David Bourell of the University of Texas at Austin, Ming Leu of Missouri University of Science and Technology, and David Rosen of Georgia Institute of Technology. These three individuals, and those who attended the workshop, created the roadmap. Sponsors were the National Science Foundation and the Office of Naval Research, both agencies in the USA.

In January 2009, a group of more than 70 individuals from the U.S., Europe, Japan, and South Africa approved the formation of an official ASTM International Committee to create industry standards around additive manufacturing technologies. The need for standards has been discussed for at least a decade. In a spirit of cooperation and with a sense of urgency, standards are being developed around AM terminology, testing, processes, materials, and design (including file formats). Creating standard methods of testing and comparing additive systems and materials is arguably the most important activity of this effort. In the foreseeable future, users of these systems will have standards that guide them through a process that has been, at best, haphazard in the past, and certainly not universally accepted.

II. INDUSTRY GROWTH

Overall, the demand for products and services from additive-manufacturing technology has been strong. Average annual growth over the past three years was an estimated 13.8%, although 2008 was the worse year of the three. The first half of 2008 was good, but sales at many companies began to decline in Q3 and that trend continued through the end of the year. This brought down what would have otherwise have been a good year.

Figure 1 gives estimated revenues (in millions of dollars) for AM products and services worldwide. The bars for 2009 and 2010 are forecasts.

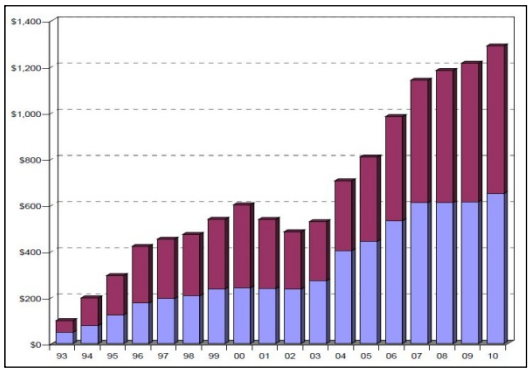

Fig. 1. Growth of the additive manufacturing industry

The lower portion of the bars indicates products, while the upper portion indicates services. *Products* include AM systems, system upgrades, materials, and aftermarket products, such as third-party software, lasers, and print heads. *Services* include revenues generated from parts produced on AM systems by service providers, system maintenance contracts, training, seminars, conferences, expositions, advertising, publications, contract research, and consulting. Neither category includes revenues from secondary tooling, molded parts, or castings.

III. WORLDWIDE ADOPTION

Figure 2 shows the cumulative systems installed by country from 1988 through the end of 2008. The percentages for the majority of the countries remained mostly unchanged except for

Japan, which declined from 15.1% in 2005 to 14.3% in 2006, and then to 13.6% in 2007, and finally to 12.2% in 2008.

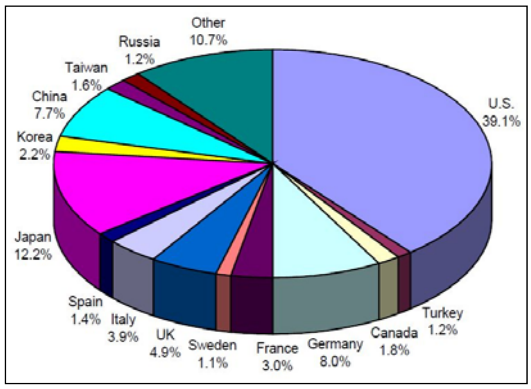

Fig. 2. Countries that have adopted additive manufacturing technology

IV. DISCUSSION

Twenty-nine AM system manufacturers and 65 service providers worldwide responded to a survey conducted by Wohlers Associates. These 94 companies represent an estimated 5,000+ users and customers and provided information based on their knowledge of them. The responses were used to produce the information in Figure 3. It shows how organizations are using additive manufacturing for a range of applications. The information in the chart came from the question "How do your customers use the additive parts that you provide?"

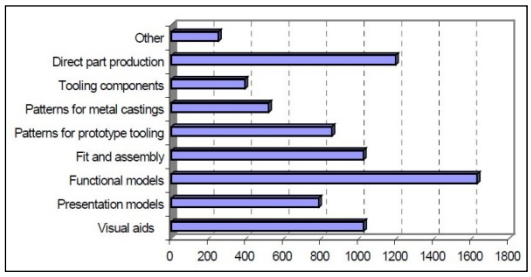

Fig. 3. Popularity of additive manufacturing applications

As you can see, the use of functional models is the most popular application, followed by the direct production of parts from AM systems.

V. PART PRODUCTION APPLICATIONS

The industry has grown in the double digits for most of its 20+ years, yet there is tremendous untapped potential, especially when considering the role that additive manufacturing is expected to play in custom and short-run part production. Producing end-use parts is more challenging than building models and prototypes, so this application will take time to fully develop. Even so, it has caught the attention of many and is expected to become the largest application of AM technology in the future.

AM systems will be used increasingly to create initial production parts as tooling is being completed. Even though the parts from AM systems may be more expensive than conventionally manufactured parts, the cost will be justified because it will allow the customer to receive products weeks or months sooner. In these days of short product life cycles, receiving even limited quantities much faster can be extremely valuable. Such use is already common practice in the investment-casting industry, where foundries use AM patterns to deliver initial castings while conventional molded wax pattern tooling is being built. As material properties and capabilities of AM systems improve, they will be used increasingly for parts that ultimately will be injection molded.

AM systems are an excellent and inexpensive way to create custom jigs, fixtures, alignment and drill guides, and other manufacturing and assembly tools. The market for such items is expected to grow significantly over the next few years. The limitations in materials that prevent greater AM use in production parts are not nearly so significant for these applications.

Organizations in the additive-manufacturing business are optimistic about the future growth of AM for part production applications. Companies responding to a survey on the subject believe that AM part production will represent 35.9% of their business in five years, as shown in Figure 4. In 10 years, the same companies believe that it will represent more than half (50.5%) of their business. The survey respondents said that AM part production was 15.6% of their business in 2008.

VI. OPPORTUNITIES AND CHALLENGES

Expect to see lattice configurations used to create strong but lightweight structures. Such structures are used in large devices such as construction cranes, but are difficult to manufacture on a smaller scale. AM makes it possible to build such structures easily and will create opportunities for strong, lightweight structures for aerospace, defense, automotive, and medical applications.

Already, a few organizations are using AM technology to produce lightweight structures.

For example, Dr. Stephen Rouse and others at Walter Reed Army Medical Center have successfully produced and implanted 37 porous cranial plates made by EBM, as of March 2009.

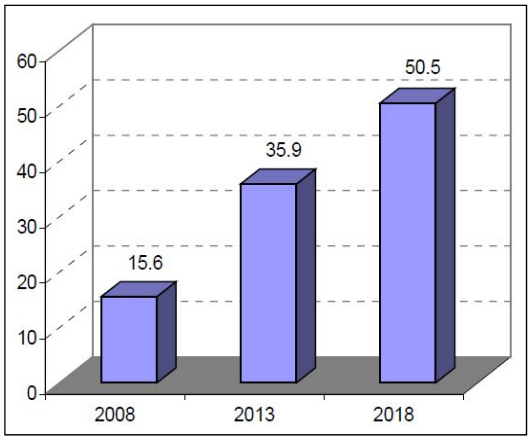

Fig. 4. Future growth potential of using AM for part production

AM technology presents a wide range of opportunities and challenges in research. The March 2009 RAM workshop, discussed near the beginning of this paper, resulted in 26 research recommendations. Among them: 1) produce a new foundation for CAD systems to overcome modeling limitations associated with building AM parts, 2) create closed-loop and adaptive control systems with feed-forward and feedback capabilities for AM machines, 3) develop and identify sustainable (green) materials that are recyclable, reusable, and biodegradable, 4) develop training programs with certifications for industry practitioners, 5) develop and adopt internationally recognized standards, such as those initiated by ASTM International, and 6) establish a national test bed center with AM machines and expert users to leverage equipment and human resources in future research

VII. SUMMARY

After more than two decades of research, development, and use, the additive manufacturing industry continues to expand with the introduction of new technologies, methods, and applications. A growing number of industrial sectors and geographic regions are embracing the use of AM. Additive processes have had a tremendous impact on design and manufacturing, and this impact will continue to grow in the coming years.

Many organizations—some very small—are successfully applying the technology to the production of finished goods. Wohlers Associates believes that this practice will grow and eventually become the largest single application. In the future, many organizations will use AM to manufacture a wide range of custom and limited edition products and replacement parts. Companies will also use AM for short-run and series production for part quantities ranging from a few to thousands.

Note: Most parts of this paper were taken from *Wohlers Report 2009*, an industry study that provides an analysis of additive manufacturing worldwide.

REFERENCE

T. Wohlers, *Wohlers Report 2009*, Wohlers Associates, Inc., Fort Collins, Colorado USA