

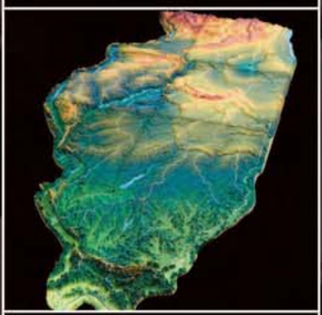
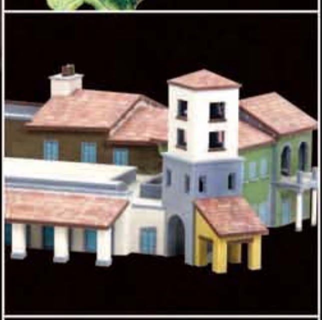
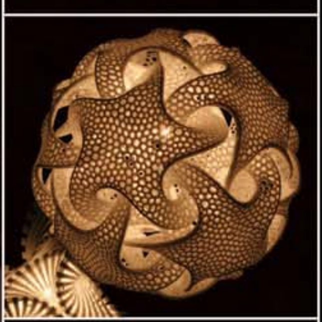

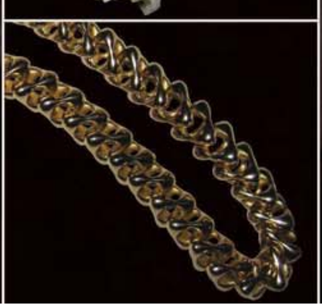

EXECUTIVE SUMMARY

Wohlers Report 2006

Rapid Prototyping and Manufacturing State of the Industry

Annual Worldwide Progress Report

TERRY WOHLERS

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Wohlers Report 2006

This eight-page executive summary provides an overview of the information contained in *Wohlers Report 2006*, a 250-page, softbound publication. The report offers a worldwide review and analysis of additive fabrication (also known as rapid prototyping). The technology encompasses modeling, prototyping, tooling, and series production applications. The report covers the growing range of applications and technologies, as well as the challenges that organizations face when trying to understand and make use of this fast-developing technology.

Wohlers Report 2006 addresses many facets of additive fabrication, including its history, the wide mix of applications, the industries embracing the technology, annual revenues from products and services, growth estimates, sales forecasts, and investor information. It also provides current information on trends and developments in the areas of service providers, system manufacturers, cast metal parts, direct metal fabrication, advanced approaches to tooling, and exciting new applications of rapid manufacturing.

This study provides updates on new developments in the U.S., Europe, Asia, and other parts of the world, follows the growth of CAD solid modeling, reports on the advances in materials used for additive processes, highlights opportunities in medical modeling, and lists applications and technologies for 3D scanning and reverse engineering.

The final parts of the report cover emerging technologies, government-sponsored research and development, and college and university education and research. *Wohlers Report 2006* concludes with a discussion on the future of additive fabrication—where it is headed and what to expect—to assist in strategic planning and investing. To support the review and analysis, the report includes 26 charts and graphs, 44 tables, and 131 photographs and illustrations.

Introduction

Additive fabrication refers to a group of technologies used for building physical models, prototypes, tooling components, and finished series production parts—all from 3D computer-aided design (CAD) data, CT or MRI scans, or data from 3D scanning systems. Unlike machining processes, which are subtractive in nature, additive systems join together liquid, powder, or sheet materials to form parts. Parts that may be difficult or even impossible to manufacture by any other method can be produced by additive systems. Based on thin, horizontal cross sections taken from a 3D computer model, they produce plastic, metal, ceramic, or composite parts, layer upon layer.

Around the world, additive fabrication is changing the way organizations design and manufacture products. When used correctly, it can save impressive amounts of time and money. Companies maintain that additive processes have helped them trim weeks and even months of design, prototyping, and manufacturing time, while enhancing the quality and range of their products. Bringing a product to market weeks or months before your competitors can mean the difference between success and failure. Companies that choose to apply additive technologies are able to compete more effectively.

After more than 15 years of research, development, and use, the industry continues to grow with the addition of new technologies, methods, and applications. Additive processes have had a tremendous impact on design and manufacturing, and will continue to expand over the coming years. The goal of *Wohlers Report 2006* is to offer a thorough, yet concise, review and analysis of this dynamic industry. We hope the report will assist organizations in developing plans and competitive strategies that build on the advances in additive fabrication for prototyping, tooling, and manufacturing.

Industry growth

The industry has remained solid after a spectacular 2004. Systems, materials, and services experienced double-digit growth in 2005, although it was nothing like the previous year. Interest in 3D printers continues to drive demand in the 70 countries in which systems were sold last year.

Years ago, the machine manufacturers felt little competitive pressure to lower prices. This is not true today. Over the past couple of years, prices have been forced downward, even as capabilities improve. As sales volumes swell, prices will drop further. This trend will increase further as companies such as Desktop Factory introduce 3D printers in the $5,000 to $7,000 range.

Growing a large installed base is more important than ever as companies build businesses around recurring revenues from consumables. Also, the larger the customer base, the easier it is to sell future products and services. Recent sales activity by Stratasys and Z Corp. show that these two companies are currently leading the pack in achieving this objective.

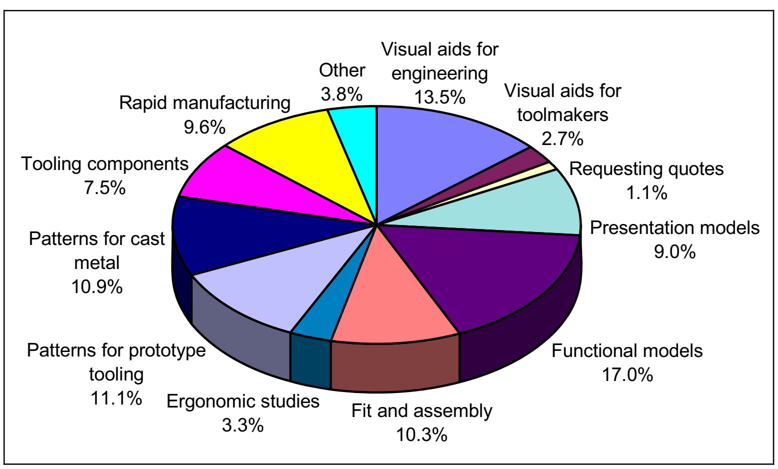
The use of systems for rapid manufacturing is also gaining momentum. Successfully fabricating end-use parts is a much more demanding proposition than using 3D printers for concept design and modeling, so it will require time to develop. Even so, rapid manufacturing has caught the attention of many and is expected to become the largest application of additive technology in the future.

The services segment of the industry remains healthy. In 2003, service providers experienced a moderate turnaround. In 2004, this segment mounted a very impressive comeback. Results from 2005 show that the companies in the services business have positioned themselves for sustained growth, which was quite uncertain prior to 2003.

The many ways in which manufacturing organizations are applying additive fabrication are capturing the attention of many groups. Investors, analysts, and members of the press are taking note of the vast potential that additive processes have on product design and modeling, custom products, and rapid manufacturing.

How companies are applying additive processes

The following chart shows that fit and function applications continue to be a popular use of additive systems. This category—derived by combining the “functional models” and “fit and assembly” segments—represents 27.3%. Meanwhile, visual applications account for 26.3%.



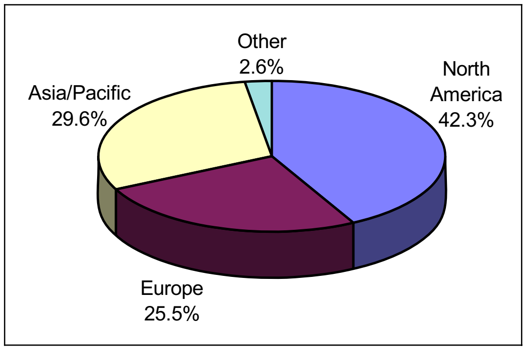
Source: Wohlers Report 2006

Nearly one-third (29.5%) of customers use the parts for tooling- or pattern-related applications. The parts are used for prototype tooling and metal casting, as well as for tooling inserts. Meanwhile, rapid manufacturing continues to grow impressively, rising to 9.6% in 2006.

Activity around the world

The following chart shows the percentage of systems installed in the major regions of the world. North America is home to more than 42% of the systems installed worldwide.

In 1997, North America accounted for 52.6% of the systems installed. Its share declined to 43.8% in the four years that followed, but has changed very little over the past four years. It is expected to slowly decline in the years to come, as China, India, and other developing countries modernize product development methods and embrace additive fabrication.



Source: Wohlers Report 2006

In 2005, the number of installations in the Asia/Pacific region grew by 12.1% to 975 machines. This is down from the 43% growth in 2004 and 22.7% growth in 2003. The cumulative installed base for the region now stands at 5,254 machines through the end of 2005. An estimated 29.6% of all machines were installed in this region at the end of 2005.

Additive processes are established at various levels in many countries in Europe. Organizations in these countries are conducting world-class research and development and using the technology for prototyping, tooling, and manufacturing. Much collaboration between industry, academia, and local and national government is taking place. The experience and expertise from these projects are leading to new products and services.

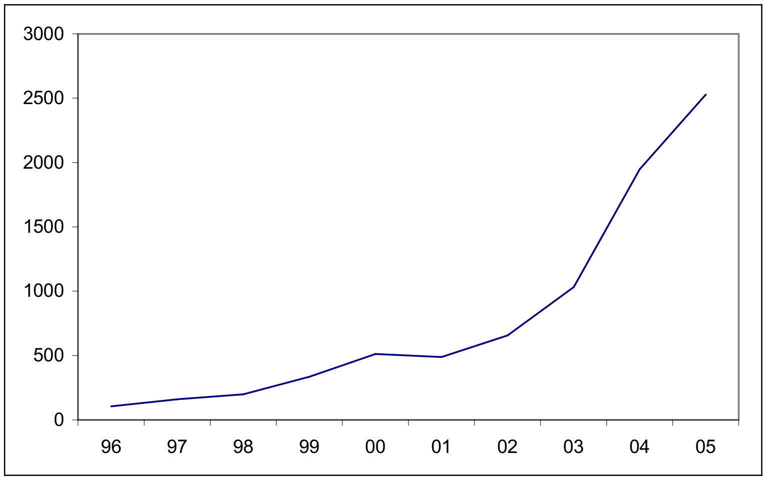
Europe as a whole had a good 2005 as measured by new installations, although the region cooled some from its extraordinary growth of 2004. In 2005, the number of installations in Europe grew by 34.6%, compared to 95.2% the year before. Through the end of 2005, an estimated 3,455 machines were installed in Germany, France, Italy, and the UK. This is up 26.2% from the end of 2004.

Countries that have historically installed few systems each year are beginning to purchase more substantial quantities. Most notable is South Africa with 24 new systems in 2005 and 15 in 2004. Previously, no more than two systems per year were sold and installed in the country.

3D printers

Wohlers Associates estimates that Stratasys, Z Corp., 3D Systems, Objet Geometries, Envisiontec, and Solidimension sold 3D printers valued at $100.2 million in 2005. This is up 35.2% from the $74.1 million in 3D printers sold in 2004, although down from the 99.5% growth in 2004.

In unit sales, most 3D printer manufacturers had another solid year. The following graph shows the impressive growth in recent years.



Source: Wohlers Report 2006

3D printers represent 44.3% of all additive systems installed worldwide through the end of 2005. This is up from 37.9% in 2004, 30.7% in 2003, and 25.8% in 2002.

Several indicators suggest strong growth for 3D printers over the next several years. If the worldwide economy remains relatively strong, an estimated 15,000 3D printers are expected to sell annually by 2010.

Rapid manufacturing

Over the past few years, the term "rapid manufacturing" has gained acceptance. It is generally used to refer to the use of additive processes to manufacture series production parts rather than models or prototypes. In some ways, RM is a solution in search of a problem. It is tempting to compare rapid manufacturing to well-established manufacturing processes such as injection molding, blow molding, die casting, sand casting, investment casting, and so on. When they are compared, RM falls short in capabilities. In fact, no matter how much additive processes are improved, RM may never be a serious threat to well-established manufacturing processes. Rapid manufacturing instead will become the preferred choice for new kinds of products that are not feasible with existing manufacturing processes. Also, RM can be an attractive option when product volumes are relatively low.

What kind of products are candidates for rapid manufacturing? While it is impossible to predict all of the possibilities, logical application areas are suggested by the unique capabilities of additive processes: Objects that additive processes can produce that conventional manufacturing processes cannot.

Except for machining, nearly all other manufacturing processes require tooling of some sort to give shape to the part being manufactured. The cost and time required to create the tooling is a significant part of the cost of bringing a new product to market. Thus, tooling becomes a significant factor in product decisions. Additive processes do not require tooling, so the economics of tooling are not even a consideration with rapid manufacturing.

All manufacturing processes have limitations in the types of parts they can produce. Some features, such as undercuts and varying section thickness, significantly increase the difficulty of manufacture and may even make it impossible to manufacture by conventional processes. Additive manufacturing processes have no such limitations and can create virtually any shape that is physically possible.

A number of additive technologies are used to produce metal parts and are providing an interesting alternative to CNC machining and metal casting for some organizations. Direct metal fabrication technologies are used in a wide variety of industries, from automotive and aerospace to electronics and dentistry. As the range of technologies and materials expand, the rapid manufacture of metal parts will become increasingly popular.

Research and development

Through the years, educational and research institutions worldwide have played a crucial role in all aspects of additive fabrication-related education and research. Academia has assisted in the startup, education, collaboration, process advancement, and the development of new applications. Academia will continue to be a critical part of additive processes in the future.

Many government agencies around the world actively support research in additive fabrication and its many applications. In the U.S., the National Science Foundation funds the broadest range of research projects in this area. Other U.S. agencies such as the Department of Defense, the Department of Energy, the Department of Health and Human Services, and NASA also support research and development projects related to additive fabrication. These organizations fund academic institutions as well as corporations on topics ranging from fundamental science to actual product and application development.

Research in additive fabrication continues to be broad-based and international. A recent focus is the area of rapid manufacturing—an application that has been enabled through advances in machine development and materials. Current applications of rapid manufactured parts include aerospace, motor sports, and industrial machinery. Research efforts are widening this field of applications to include biomedical, electronic, and micro and mesoscaled products.

The future

Additive fabrication has come a long way in the nearly two decades since stereolithography was introduced. The first systems were crude, and the parts built on them were not accurate dimensionally and had horrible material properties. Nonetheless, enterprising engineers found ways to benefit from the range of product development applications these early machines provided.

A wide variety of systems is now available. They vary from small, inexpensive machines that are office friendly to high-end industrial machines with many capabilities. It is anticipated that a number of new systems dedicated to part manufacturing will be on the market in the next few years. Recent products from some of the system manufacturers have revealed steps in this direction.

Parallels can be drawn between additive systems and the range of document printers currently available. High-speed (and expensive) printers and printing presses, centralized in a dedicated facility, easily handle high-volume document printing of thousands of pages for magazines and newspapers. Corporate and government offices and universities use mid-range systems that can handle the volumes of many people and are moderately expensive. For much smaller, personal printing jobs, inexpensive inkjet and laser printers work well. Many are found in our home offices. Expect much of the same to occur with additive fabrication systems in the future.

Acknowledgments

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provide members with opportunities to learn about the latest advances and share best practices with others who share similar interests in these technical areas. For more information on RTAM, visit www.sme.org/rtam or call SME at 313-271-1500, ext. 4500.

About the author

Industry consultant, analyst, author, and speaker Terry Wohlers is president of Wohlers Associates, Inc., an independent consulting firm he founded 20 years ago. Through this company, Terry has provided consulting assistance to more than 140 organizations in 15 countries. He as been quoted in countless domestic and foreign publications including *BusinessWeek*, *Chicago Tribune*, *The Economist*, *FORTUNE*, *Forbes*, *Los Angeles Times*, and *Scientific American*.

Terry has authored more than 300 books, articles, and technical papers on engineering and manufacturing automation. In the past five years, he has given 20 keynote presentations on four continents in cities ranging from Frankfurt and Cape Town to Beijing and Tokyo.

His appetite for adventure has driven him to climb the Great Wall of China, hike the rain forests of New Zealand, dive among sharks in Belize, and bathe in the Dead Sea. He has also ridden elephants in Thailand, encountered lions and rhinos in Africa, and explored ancient pyramids in Egypt.

In May 2004, Terry received an Honorary Doctoral Degree of Mechanical Engineering from Central University of Technology, Free State (Bloemfontein, South Africa). Nelson Mandela, former president of South Africa and Nobel Peace Prize winner, was presented with this honorary degree in 2002.

In 2004, Terry initiated the Bright Minds Mentor Program for high school students in the U.S. At the Society of Manufacturing Engineers' Rapid Prototyping & Manufacturing 2006 Conference & Exposition, nearly 50 Chicago-area students benefited from the experience and guidance of 25 practicing professionals and industry leaders.

In 2005, Terry became an active participant of RP4Baghdad, a humanitarian effort focused on assisting severely injured civilians in Iraq. In 2006, he initiated a scholarship program for students in South Africa through the Rapid Product Development Association of South Africa.

Terry has been an active member of the Society of Manufacturing Engineers for 26 years. In 2005, he became a Fellow of SME, a distinction granted to less than 1% of the membership, making it one of the most prestigious honors presented by the Society.

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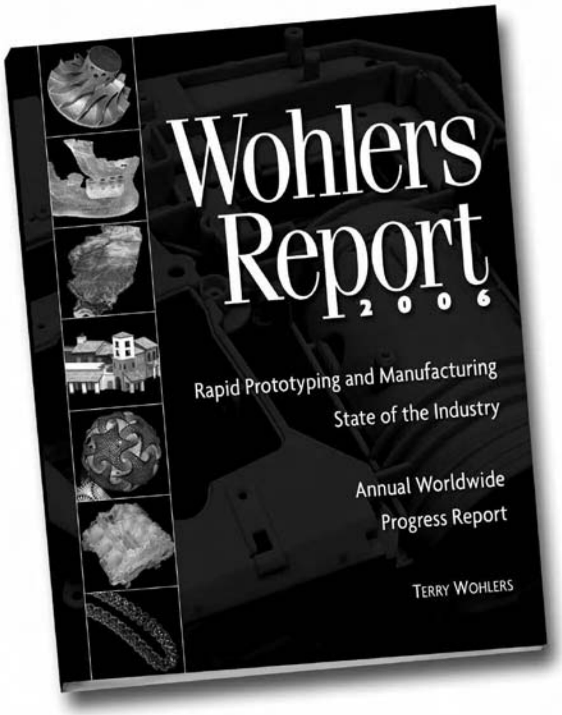

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