EXECUTIVE SUMMARY

Wohlers Report 2005

Rapid Prototyping,
Tooling &
Manufacturing
State of the Industry

Annual Worldwide
Progress Report

TERRY WOHLERS

WOHLERS ASSOCIATES

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Unless otherwise noted, the sections in this report were authored by Terry Wohlers of Wohlers Associates, Inc.

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Wohlers Report 2005

This eight-page executive summary provides an overview of the information published in *Wohlers Report 2005*, a 250-page, softbound publication. The report offers a worldwide review and analysis of additive fabrication (also known as rapid prototyping). The technology encompasses prototyping, tooling, and series manufacturing applications. The report has been expanded to cover the growing range of applications and technologies, as well as the challenges that organizations face when encountering this fast-developing technology.

Wohlers Report 2005 addresses many aspects 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 and direct metal fabrication, advanced approaches to tooling, and exciting new applications of rapid manufacturing.

The study also provides updates on new developments in the U.S., Europe, Asia, and other parts of the world, the growth of CAD solid modeling, advances in materials for additive processes, opportunities in medical modeling, and applications and technologies for 3D digitizing 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 2005* 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 24 charts and graphs, 36 tables, and 97 photographs and illustrations.

Introduction

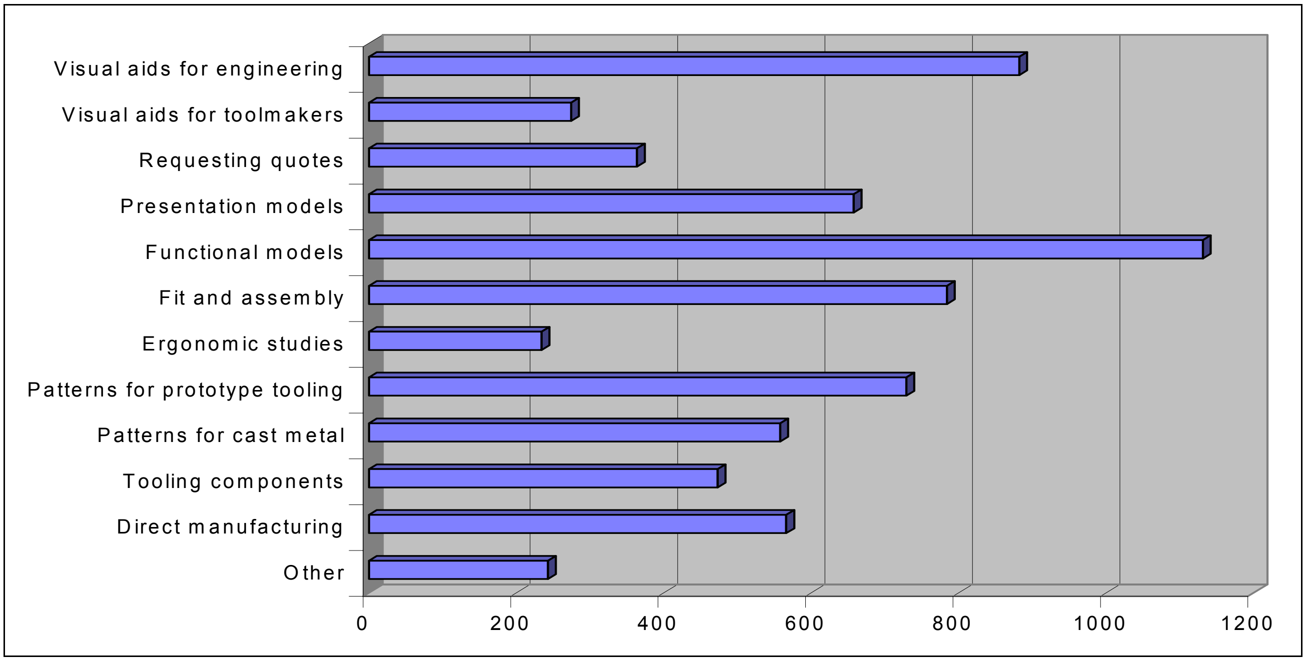
Additive fabrication refers to a group of technologies used for building physical models, prototypes, tooling components, and even finished series production parts—all from 3D computer-aided design (CAD) data, CT or MRI scans, or data from 3D digitizing systems. Unlike CNC machines, which are subtractive in nature, additive systems join together liquid, powder, or sheet materials to form parts that may be impossible to fabricate by any other method. 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 effectively, 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, so companies that choose to apply additive fabrication can compete more aggressively.

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 fabrication has had a tremendous impact on design and manufacturing, and it will continue to expand over the coming years. The goal of *Wohlers Report 2005* is to offer a thorough, yet concise review and analysis of this dynamic industry. It is our hope that the report assists organizations in the development of plans and competitive strategies that build on the advances in additive fabrication for prototyping, tooling, and manufacturing.

How companies are applying additive processes

Manufacturing industries are using additive fabrication for a wide range of applications, as shown in the following graph. The length of each bar reflects the numerical responses received from those surveyed. What is not shown is that the model and prototype parts are often used for two or more applications.



Source: Wohlers Associates, Inc.

Twenty-four system manufacturers and 47 service providers provided the data used to produce the previous chart. These 71 companies provided estimates based on knowledge of their customers.

Industry growth

In early 2004, the rockets were ignited and liftoff was imminent. This year was met with a spectacular launch. All data shows that the industry is once again on a steep, upward trajectory. Revenues and unit sales are strong and material sales are better than ever. And the number of parts being produced annually is astounding.

Sales of 3D printers nearly doubled, with machine sales ascending to unparalleled heights. Stratasys is again leading the pack. Z Corp. has secured second place in the annual unit sales race for the second consecutive year, and 3D Systems is back on the radar screen. 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.

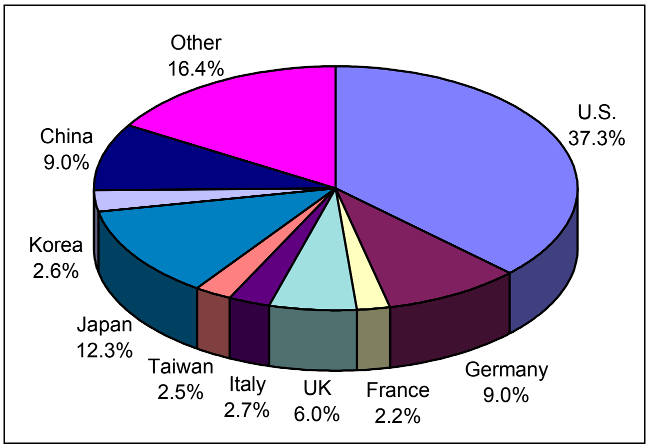
The services segment of the industry is healthier than it has been in years. In 2003, service providers staged a moderate turnaround. In 2004, these companies—many small, family-owned operations—mounted a very impressive comeback.

Competitive pressures are forcing prices of machines and materials to drop further, even as capabilities continue to improve. If you are unsure whether you should purchase a machine, now may be the time. The alternative is to wait for lower prices, but that might mean lost opportunities.

The range of industries and applications associated with additive fabrication has made an impression on private and institutional investors, as well as analysts and members of the press. With rapid manufacturing as the next frontier, companies are positioning themselves and their products for a growing wave of activity. In the future, the technology will be applied in ways that are difficult to fathom today. So fasten your seat belt and hold on, because we are in for an exhilarating ride.

Installations by country

The following chart shows the systems sold and installed by country in 2004. The U.S. lost the most ground, dropping from 43% to 37.3%. Germany increased by 1.8% while the UK increased by 1.6%.



Source: Wohlers Associates, Inc.

When looking purely at unit sales, several countries showed strong growth in 2004, some with extraordinary increases. Canada grew from 19 machines sold in 2003 to 83 sold in 2004. That's growth of nearly 4.4 times in a single year.

Installations in the UK grew by 113.4%, Germany by 95.6%, and France by 65%. Parts of Asia also saw strong growth. Installations in Japan grew by 53.6%, while China grew by 35.9%.

Countries that have historically purchased very few systems each year are beginning to purchase larger quantities. South Africa, for example, went from 2 installations each in 2002 and 2003 to 15 in 2004. Mexico grew from 5 to 26 and Russia went from 9 to 29.

Growth in Asia

Applications of additive fabrication, such as rapid prototyping, continue to grow in Asia and are on par with or better than the rest of the world. This is hardly surprising, since much of the world's manufacturing now occurs in Asia.

In 2004, the number of installations in the Asia/Pacific region grew 42% to 870 machines, up from 22.7% growth the year before. The cumulative installed base for the region now stands at 4,279 machines through the end of 2004. More than 30% of all machines are now installed in this region of the world.

3D printers

3D printers have become critical to the success at some companies. For 1999–2001, ThermoJet printers accounted for a substantial percentage of units sold by 3D Systems, but not in 2002 and 2003. The company got back on track in 2004 with its InVision 3D printer. However, it will be difficult to match the impressive sales figures for the Dimension product from Stratasys. In 2004, Stratasys sold a record 865 Dimension machines.

Indeed, sales of 3D printers have grown tremendously since their introduction a few years ago. As the machines improve and prices drop further, expect strong sales in the future. All indications are that prices will eventually decline to four figures. One can anticipate a very bright future for this segment of the market.

3D printers still lag higher-end systems in typical measures of quality, including accuracy, surface finish, and the properties of available materials. However, the gap is narrowing. The majority of the research and development money in additive fabrication is being spent at this end of the market. Consequently, the accuracy and surface finish of 3D printers have improved significantly. The materials available have also improved. Given the growing sales and R&D spending on these systems, expect further improvements in machines and the parts they produce over the next several years.

As the gap narrows between the capabilities of 3D printers and higher-end systems, 3D printers will increasingly rob market share. As this occurs, it will become increasingly difficult to justify the additional cost of higher-end systems.

Metal parts and tooling

A number of additive processes are used to produce both metal parts and metal tools. As of April 2005, 14 companies in North America and Europe offered systems that produce metal parts with additive processes. Many of them use a laser to melt metal powder to produce near fully dense parts. In some cases, these technologies provide a viable alternative to CNC machining and metal casting. A few of the processes are being used for the repair of existing parts and tooling.

Direct metal fabrication technologies are used in a wide variety of industries, from automotive and aerospace to electronics and dentistry. As the technologies and range of materials develop, the number of applications will increase.

Some methods of rapid tooling are relatively new, are still in development, and have not reached the point where they are commercially viable. It is important to note that some may never reach that point. In fact, a number of approaches that were introduced over the past several years have since been pulled from the market.

Methods that produce high-performance tools have generated interest in the recent past. With high-performance tools, molding cycle time is more important than the time it takes to produce the tool. EOS, ProMetal, Trumpf, and others are applying ideas and technologies to the creation of tooling that reduces the cycle time of molding plastic parts or die casting metal parts. When done successfully, these time and cost savings can dramatically outweigh the benefits of producing tools quickly.

Rapid manufacturing

Rapid manufacturing (RM) is a vision of the future for many and a reality for a few. RM is the direct production of finished goods from additive fabrication. The technique uses additive processes to deliver finished parts directly from digital data, which eliminates all tooling.

In conventional manufacturing, tooling is needed to produce parts. This represents one of the most restrictive factors for today's product developers. When additive fabrication is used to manufacture, the need for tooling is eliminated, along with the constraints of design-for-manufacture. This freedom of design is one of the most significant elements of RM. Parts with complex shapes and features are delivered in less time at a lower overall manufacturing cost.

When tooling is eliminated, there is no longer a need to produce many thousands of parts to justify the cost of tooling. Thus, cost-effective, custom manufacturing is becoming an attractive option. When a single part can be produced economically, widespread personalization becomes feasible, creating the opportunity for premium margins on sales and much greater customer satisfaction.

MG Rover in the UK has manufactured many parts by laser sintering for its automobiles. The company was facing a delay of six weeks for the manufacture of a plastic clip due to the time needed for tooling and injection molding. The company instead used laser sintering to produce 1,800 parts (two per vehicle) in 48 hours. The work required six builds of 300 pieces each and saved the company weeks of time and $81,000.

Rapid manufacturing has tremendous potential. However, for it to succeed and prosper, the limitations of additive processes must be overcome—limitations such as speed, surface finish, repeatability, and material properties. Material cost is also a consideration. Rapid manufacturing systems, with the desired speed, cost, and quality, are not yet available. However, this will change in the future as entrepreneurial companies capitalize on the opportunities that RM presents.

Research and development

Research and development projects continued to increase in 2004. The same is true for the number of patents and patent applications. Federal agencies in the U.S. support research in additive fabrication and its many applications. As in previous years, the National Science Foundation (NSF) funds the broadest range of research projects in this area. Funding over the past year has shifted toward existing process improvements, as well as the development and support of small-scale structures. Continuing NSF-funded projects include biomedical uses of additive processes, multifunctional material development, and uses in education.

Higher education is pushing the limits and exploring new concepts while mapping out the underlying theory to support emerging systems for additive fabrication. Through the years, colleges and universities worldwide have played a crucial role in all aspects of additive fabrication education and research. Academia has assisted in the startup, education, collaboration, process advancement, and the development of new applications. It will continue to be a critical part of additive processes in the future.

The future

Additive fabrication has had a profound impact on design and manufacturing, and has become ingrained in product development processes around the world. Those currently sitting on the sidelines will become involved in the future as additive processes become irresistible. In the past year, many small companies that would have never considered owning a machine before have bought one and are making effective use of it.

The application of additive fabrication is vast and unlimited. Perhaps the most significant barrier to realizing new applications and powerful benefits is our reluctance to change. Established processes and procedures are difficult to displace. When forward-thinking individuals apply additive processes in new and exciting ways, however, it is possible to achieve astonishing results.

As the technology matures, new applications will emerge for system manufacturers, investors, and others. Industries and applications that are poised to embrace the technology are as diverse as medicine, dentistry, architecture, geographical information systems (GIS), and mapping. Others include microsystems, forensics, space exploration, art and sculpture, filmmaking, and entertainment. Many have their finger on the trigger as they wait for the right time to cash in on a new and promising application.

Acknowledgments

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About the author

Industry consultant, analyst, author, and speaker Terry Wohlers is president of Wohlers Associates, Inc., an independent consulting firm he founded nearly 19 years ago. For the majority of this time, he has served as a voice in the additive fabrication industry. He as been quoted in countless domestic and foreign publications including the *Chicago Tribune*, *The Economist*, *FORTUNE*, *Forbes*, and *Los Angeles Times*.

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, received this honorary degree in 2002.

Terry has authored 290 books, articles, reports, 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, bathe in the Dead Sea, ride elephants in Thailand, and encounter lions and rhinos in Africa.

In 1992, Terry led a group of 14 individuals from industry and academia to form the first association dedicated to additive fabrication. In 1993, the association joined the Society of Manufacturing Engineers (SME) to become the Rapid Prototyping Association (RPA) of SME. In 1998, Terry co-founded the Global Alliance of Rapid Prototyping Associations (GARPA) involving 18 member nations around the world.

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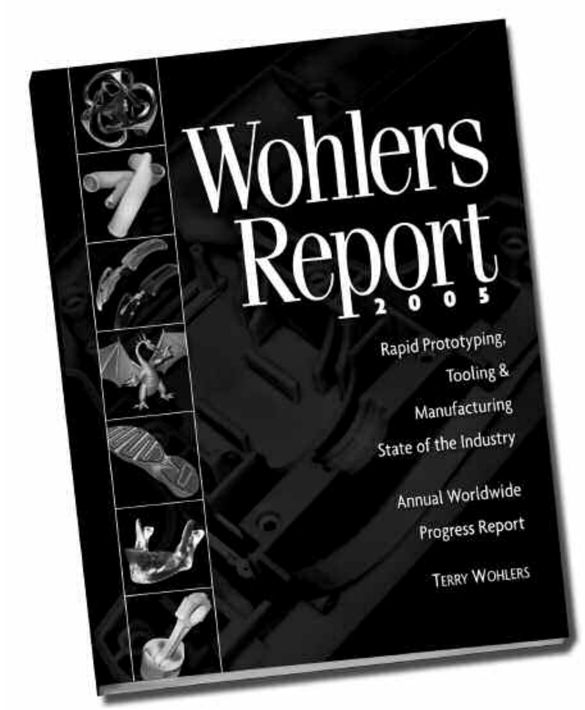

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