





EXECUTIVE SUMMARY

Wohlers Report 2004

Rapid Prototyping, Tooling & Manufacturing State of the Industry

Annual Worldwide Progress Report

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Wohlers Report 2004

This eight-page executive summary provides an overview of the information published in *Wohlers Report 2004*, a 270-page, softbound publication. The report offers a detailed review and analysis of the rapid prototyping industry. The technology is not limited to prototyping, but also encompasses tooling and the manufacture of series production parts. Consequently, the report has expanded to cover the wide range of applications, technologies, and challenges.

The report addresses many aspects of rapid prototyping, including the industries being served, annual revenues, machine sales, and forecasts. It also provides current information on industry trends and developments in the areas of service providers, advanced approaches to tooling, system manufacturers, and technology advances in the U.S., Europe, Asia, and other parts of the world.

The report covers research and development activities, growth trends in CAD solid modeling, rapid prototyping materials, medical modeling, rapid manufacturing, and reverse engineering. *Wohlers Report 2004* concludes with a discussion of the future of rapid prototyping—where it is headed and what to expect—to assist in strategic and tactical planning. To support the review and analysis, the report includes 23 charts and graphs, 38 tables, and 79 photographs and illustrations.

Introduction

Rapid prototyping (RP) refers to the physical modeling of a design using digitally driven, additive processes. RP systems quickly produce models and prototype parts from 3D CAD data, CT and MRI scans, and data from 3D digitizing systems. Using an additive approach, RP systems join liquid, powder, or sheet materials to form physical objects. Layer by layer, RP machines process plastic, paper, ceramic, metal, and composite materials from thin, horizontal cross sections of a computer model.

Design and manufacturing organizations use RP to produce models, parts, and patterns for products in the consumer, industrial, medical, and military markets, to name just a few. Photocopiers, cameras, electronic games, mobile phones, automobile engines, airplane subassemblies, power tools, and medical devices are just the beginning of a long list of products that have benefited from RP.

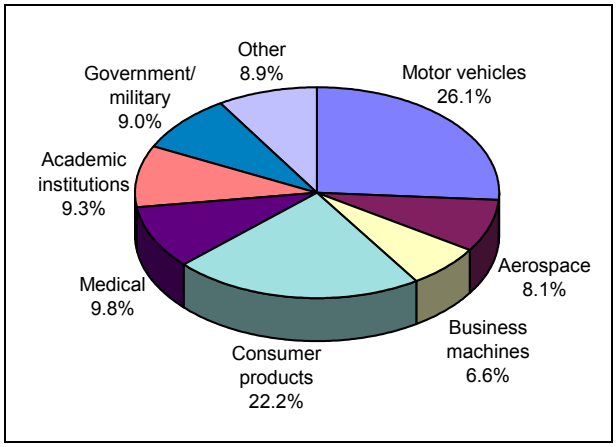
Methods, processes, and systems for *rapid tooling (RT)* are also developing. While early efforts were focused on faster delivery of tooling, new developments are underway that improve the performance of short-run and production tooling. Many of these new concepts involve the additive RP process to achieve results that are impossible in machined tooling.

RP has a profound impact on the way companies produce models, prototype parts, and tooling. Companies are now extending the application of the technology to the production of finished products. This practice, termed *rapid manufacturing (RM)*, has the potential to grow rapidly and ultimately overshadow the rapid prototyping and rapid tooling markets.

RP has had a tremendous impact on design and manufacturing, and it will continue to expand over the next decade. The goal of *Wohlers Report 2004* 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 prototyping, tooling, and manufacturing.

Industries being served

Most manufacturing industries have embraced rapid prototyping at some level. The following chart shows the major industrial sectors, with motor vehicles and consumer products dominating. Combined, these two represent nearly half of the total, down 2.8% from one year ago. Meanwhile, academic institutions and government/military, combined, grew by 4.1% over the past year.



Source: Wohlers Associates, Inc.

The "Other" category includes industries such as collegiate and professional sporting goods, non-consumer and non-military marine products, and various other industries that do not fit into the named categories. Twenty RP system manufacturers and 42 RP service providers provided the data used to produce the previous chart. These 62 companies provided estimates based on knowledge of their customers.

Industry growth

Last year, the rapid prototyping industry reversed its downward trend. Revenues returned to levels of the past, with product revenues gaining impressively. Low-end machine sales soared to unprecedented heights, with 3D printers becoming the crown jewel of the RP industry. With the increase in the number of machines sold and installed, the total number of models being produced annually also grew. Consequently, material sales were strong.

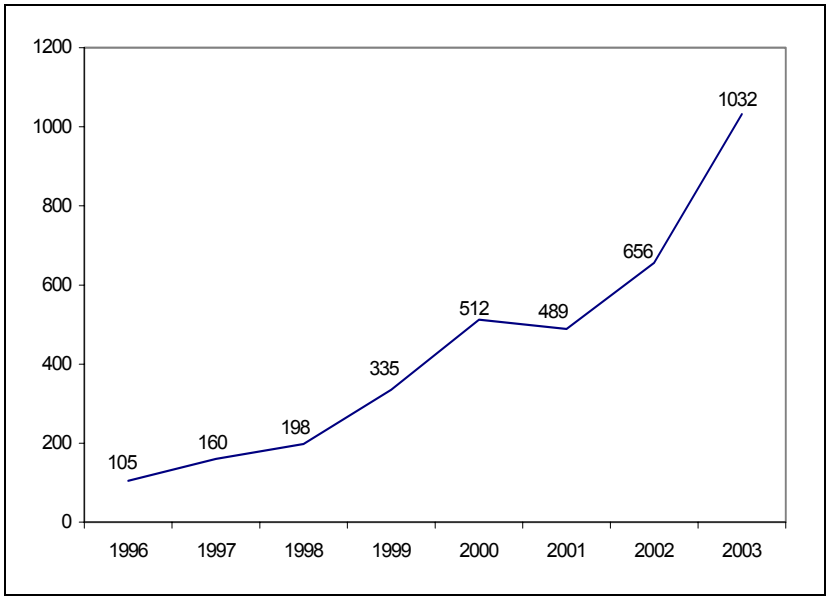
Service revenues improved too, but only slightly. Still, any gain is encouraging when considering the past few years. Service providers staged a moderate turnaround, although many companies in this business segment will require a complete transformation if they have any hope of thriving long term.

Stratasys is inching its way toward dominance as it unseats 3D Systems as the king of rapid prototyping. And Z Corp. has moved up to the number two position in annual unit sales. Meanwhile, the U.S. continues to maintain its grip on both the production and consumption of RP systems.

3D printers

Wohlers Associates estimates that Stratasys, Z Corp., 3D Systems, Objet Geometries, and Envisiontec sold $37.4 million worth of 3D printers last year. In unit sales, the combined total was an estimated 1,032 machines, breaking the "1,000" mark for the first time. The estimate represents an unprecedented increase of 57.3% over the year before, a jump that compares to growth of 34.2% in 2002.

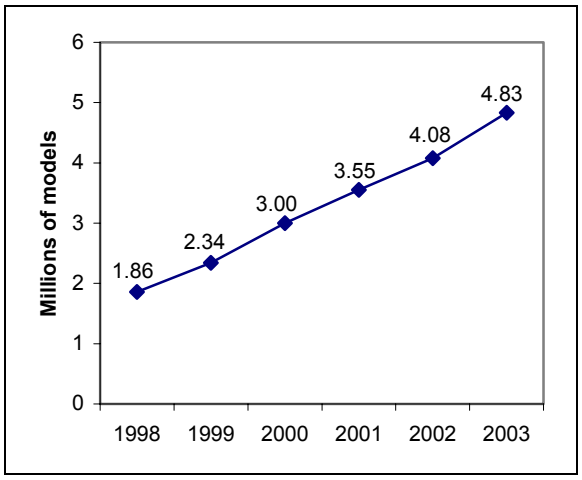
The following graph shows the growth of 3D printer sales from 1996 to 2003. 3D printers now represent 30.7% of all RP systems installed worldwide, up from 25.8% the year before.



Source: Wohlers Associates, Inc.

Number of models being produced

Users of RP systems worldwide produced an estimated 4.83 million models and prototype parts last year, as shown in the following graph. This is up 18.4% from the 4.08 million parts produced in 2002. An estimated 3.55 million parts were produced in 2001.



Source: Wohlers Associates, Inc.

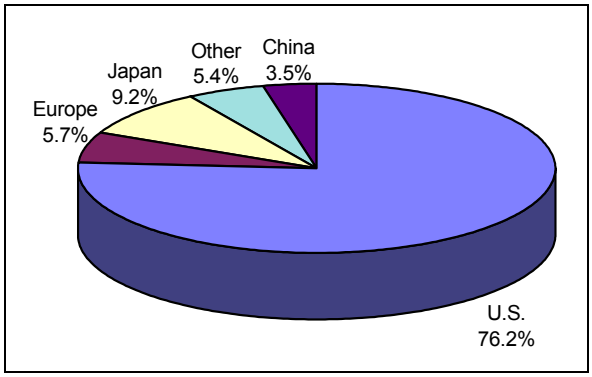
Research at Wohlers Associates has found that on average, about two copies (2.06 to be exact) of a unique design are built. This means that an estimated 2.34 million distinctive parts were produced in 2003. By all accounts, this is an astounding number of parts being produced.

Using its SLA 7000 machines, Align Technology produces hundreds of thousands of clear plastic aligners for straightening teeth. The company does not publish annual production totals, so the 2003 estimate of 4.83 million parts excludes those produced by Align Technology.

System manufacturers

In 2003, 28 manufacturers around the world sold RP systems. Ten of them sold fewer than 10 machines each and only six sold more than 50 each. Some of the companies introduced new machines last year, but not as many as the year before. For many companies, business was as good or better than the year before. Seventeen of the companies improved their unit sales from 2002 to 2003, but 11 did not.

The U.S. leads the production and sales of RP systems, as shown in the following chart. More than three quarters (76.2%) of the systems sold in 2003 came from U.S. manufacturers, down 0.8% from 2002. China's segment grew from 2.7% in 2002 to 3.5% in 2003. Meanwhile, Japan's share declined from 11.7% to 9.2%. Systems sold by Objet Geometries (Israel) and Kinergy (Singapore) are included in the "Other" segment.



Source: Wohlers Associates, Inc.

Rapid manufacturing

Rapid manufacturing (RM) has a promising future, with a compelling list of potential benefits. With RM, tooling is eliminated, thus reducing substantial time and cost. However, there are other powerful advantages that result from the absence of tooling, including increased design freedom, heterogeneous materials, custom products, just-in-time production, and decentralization of production.

The principal advantage of the RP processes—including most of the currently available RP techniques—is the ability to construct prototypes of virtually any complexity without the need for tooling or machining. When this principal is applied to manufacturing processes, the opportunities for product design and manufacturing are immense.

Today, RP systems are being used successfully in RM applications for the production of final, end-use parts, but these RP machines were not designed for manufacturing. For RM to succeed and flourish, the limitations of RP systems must be addressed—limitations such as speed, surface finish, repeatability, and material properties.

The industry is currently in a transitional phase where RP systems, in spite of their limitations, are used for low-volume production and custom parts. Rapid manufacturing systems with the desired speed, cost, and quality are not yet available. This will change in the future as entrepreneurial companies capitalize on the opportunities that RM presents.

Research & development

Several R&D trends have emerged. There is a significant effort in applying layer-by-layer construction technologies to biological applications. The greatest emphasis is in tissue scaffolding and hard matter generation. Other topics of medical R&D include prosthetics and orthodics, surgical models, dental applications, and even deposition of live cells.

Direct writing of devices for the microelectronics and fiber-optics industries is another trend in R&D. Currently, it is difficult to create a variety of structures in a cost-effective manner. These structures include waveguides, gratings, print heads, fiber-optic coupling devices, splitters, and conducting lines. They share in common small size, geometric complexity, and amenability to lithographic construction.

The third area of increasing R&D interest is in the formation of microscaled and nanoscaled objects. Many governments have national initiatives in nanotechnology, with a wide range of applications and large potential payoffs.

And finally, significant R&D efforts in rapid manufacturing are underway. Efficient creation of one-off parts, coupled with advances in new materials, allows for the production of articles that can directly enter the stream of commerce. In some cases, this is further enabled by the application of secondary processes that reproduce the RP part in a more commercially viable material.

Future

The industry is on the brink of monumental change. No longer just a technical curiosity, rapid prototyping has become ingrained in product development processes around the world. It is a rare company that has not employed the technology and enjoyed its benefits. Rather than reaching a plateau of maturity, the industry seems ready to surge forward with new processes, new materials, and new systems that will lead to new customers and new applications.

RP technology has developed into three basic categories: 3D printing for concept modeling; mainstream rapid prototyping for fit and function applications, as well as master patterns; and the rapid manufacture of finished parts. As these categories and "sub-industries" develop, the machines and their manufacturers will become much more specialized and sophisticated.

In the years to come, 3D printing will capture a significant portion of its potential user base and will eventually experience the slowed growth that comes with maturity. Meanwhile, RM will experience double-digit growth. RP will be caught in the middle, as 3D printing and RM systems on both sides perform the prototyping function. As developments in medicine, MEMS, art, and science grow, new classes of additive manufacturing technology will emerge.

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 18 years ago. For the majority of this time, he has served as a voice in the rapid prototyping and manufacturing industry and has been quoted in countless domestic and foreign magazines, journals, and newspapers.

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, and Trevor Manuel, South Africa's Minister of Finance, received this honorary degree in 2002 and 2003, respectively.

Terry has authored 280 books, articles, reports, and technical papers on engineering and manufacturing automation. In the past five years, he has given 24 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 rapid prototyping. In 1993, the association joined the Society of Manufacturing Engineers (SME) to become the Rapid Prototyping Association (RPA) of SME. In 2004, Terry

was appointed to SME's Manufacturing Enterprise Council (MEC), a 10-person group that includes top executives from Boeing, Cummins Engine, Kohler Company, and Walt Disney Studios. In 1998, Terry co-founded the Global Alliance of Rapid Prototyping Associations (GARPA) involving 17 member nations around the world.

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