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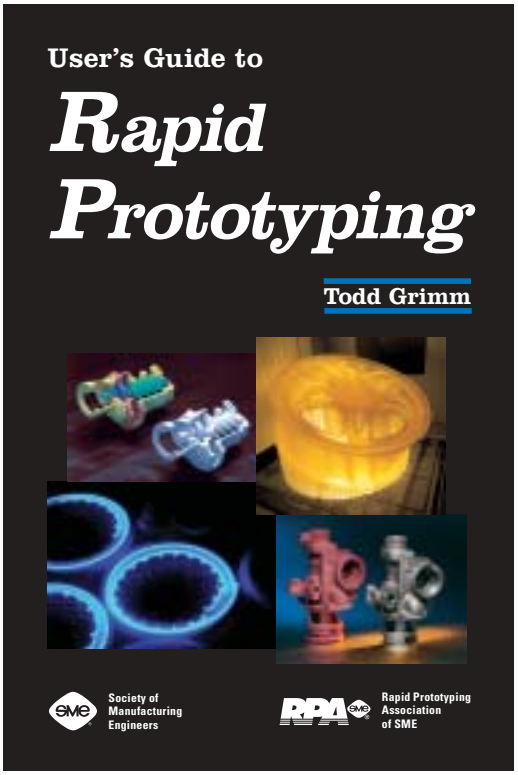
User's Guide to Rapid Prototyping.



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CHAPTER 1

Introduction

Rapid prototyping is amazing, powerful, and revolutionary. Since the delivery of the first rapid prototyping system, the scope of applications and breadth of use have grown beyond belief. Virtually every industry that designs and manufactures mechanical components has used rapid prototyping. The technology is so pervasive that most people will use at least one product, on a daily basis, to which rapid prototyping has been applied.

Rapid prototyping is nearly a billion-dollar industry with more than 30 system vendors that have installed more than 9,500 machines around the globe (Wohlers 2003). With growth in the application of the technology for prototype development, other applications have come to light, namely rapid tooling and rapid manufacturing.

While the industry has grown, it is not without challenges. The general consensus is that less than 20% of the design and product development community uses rapid prototyping. In the manufacturing and manufacturing engineering disciplines, the level of use is far less.

If the technology is so powerful, why do so few companies use it? Why were early predictions—phenomenal, rapid growth and the replacement of conventional processes—never realized?

Rapid prototyping is a tool for design, engineering, and manufacturing. As with any tool, there are barriers and obstacles that impede its growth, and there are strengths and weaknesses that limit its use. It is amazing that prototypes can rise from a vat of resin or chamber of powder. It is

powerful to produce parts without machining, molding, or casting. However, rapid prototyping is just a tool: an alternative solution to design and manufacturing challenges. The benefits and value of the technology are realized only when it is applied to suitable applications.

Determining when to apply rapid prototyping requires an understanding of the technology, the process, and its strengths and weaknesses. Industry leaders believe that this may be the key barrier to the rapid ascent of the technology. Many have concluded that a lack of awareness, understanding, and appreciation of rapid prototyping are critical barriers to its adoption and growth.

The goal of this introduction is to assist companies and individuals in assessing the merits of rapid prototyping and developing a full understanding of this unique and powerful tool. With this description, each can make an informed, personal decision regarding the applicability or necessity of rapid prototyping in the product development process.

CREATING UNDERSTANDING AND AWARENESS

Magazine articles, conferences, technical articles, books, and even television news programs have featured and discussed rapid prototyping. Nearly every trade show that serves the design and manufacturing communities has a rapid prototyping presence. There are thousands of web pages available on the Internet that promote and discuss the technology. Yet, there continues to be a scarcity of information that offers detailed analysis, review, and comparison.

Much of the publicly available information addresses the obvious advantages of rapid prototyping, focusing on the remarkable ability to grow parts from digital data. Much of what remains focuses on the latest systems and materials

developments, often resulting from vendor-issued promotional materials. What is missing is information that details the true experiences of rapid prototyping users. Without an accurate account of both the advantages and limitations, from a user's perspective, the knowledge gap impedes an increase in awareness and understanding.

Gathering information to develop an understanding is especially difficult for those who are new to the rapid prototyping industry. As an introduction to rapid prototyping, the discussion of the technology targets the majority of those in industry, those who have yet to apply it. Yet, this is not a light review of the technology. The detailed accounts and user insights offer a deep appreciation for the technology and the process. Even experienced rapid prototyping users will find valuable insight and information.

To fill the knowledge gap, this introduction to rapid prototyping details the process, individual technologies, applications, strengths, and limitations. It also offers a comparison of rapid prototyping technologies with processes like machining.

WHAT IS RAPID PROTOTYPING?

One benefit of a rapid prototype is that it improves communication. However, the technology is often a source of miscommunication and misunderstanding.

There are numerous terms for rapid prototyping, including: freeform fabrication, solid freeform fabrication, autofab, automated freeform fabrication, digital fabrication, 3D printing, laser prototyping, layer-based manufacturing, additive manufacturing, and solid imaging. The multitude of terms and definitions can confuse a discussion or description of rapid prototyping.

Equally confusing is that a simple term like 3D printing has multiple definitions. Some in the rapid prototyping

industry use the term 3D printing to characterize all varieties of rapid prototyping technology. Others apply the term to a specific class of rapid prototyping systems. With the great disparity in definitions and terms, it is critical that there is an agreement and understanding in any discussion of rapid prototyping. Without this agreement, miscommunication is likely.

This is Not a Book About Prototyping

Within the design and manufacturing communities, other factors contribute to the confusion. There is disagreement on the technologies that should be included under the umbrella of rapid prototyping. Many suppliers of technologies and materials for processes as varied as machining and molding promote their offerings as rapid prototyping. While each truly prototypes rapidly, they are subtractive or formative processes. To include them in the discussion that ensues would require an introduction to prototyping, a topic that is much too broad for a single book.

This is a Book on Rapid Prototyping

Instead, this is a book dedicated to rapid prototyping. This book is about additive processes that eliminate machining, tooling, molding, casting, and fabrication. The election to address only additive technologies is not an indication that other processes are not rapid. As will be illustrated, rapid prototyping may be a slower process or a weaker solution for a project. Combined with the extensive information and first-hand experience available for other, conventional processes, this detailed account of rapid prototyping promotes the ability to select the best technology and apply it wisely.

The technology decision is personal and unique. In some cases, rapid prototyping will be the best. However, as will be shown, in most situations the selection of the best tool

will not be obvious. With ample amounts of crossover, both rapid prototyping and the competitive technologies are likely to serve a user's needs. These conventional processes are often rapid prototyping solutions; however, they are not additive rapid prototyping solutions and, therefore, they will not be discussed.

DETAILED TECHNOLOGY DESCRIPTION

This introduction to rapid prototyping will cover, in detail, all aspects that are important for a clear understanding and appreciation of the technology. Chapter 2 begins with an overview of the technology, its applications, and benefits. In this overview, rapid prototyping is clearly defined.

While rapid prototyping can be a push button, one-hour process, much more goes into most prototypes. To develop an understanding and to build a foundation of information on which to build, Chapter 3 details the rapid prototyping process. Through this description, there will be a greater appreciation for what it takes to successfully build rapid prototypes and the information required for making good technology decisions.

For further clarification, classes of rapid prototyping are presented in Chapter 4. While the rapid prototyping industry lacks consensus, this proposed classification system helps to distinguish the differences between a $30,000 and an $800,000 system. Although the methodologies and output are similar, there is a great variance in operational demands, user control, and final results.

Chapter 5 discusses applications and benefits. As indicated, rapid prototyping is more than a prototyping tool. Its applications cover the full spectrum of design and engineering and extend to applications in manufacturing. Additionally, there are examples of applications outside of the confines of design and manufacturing. From these

examples, new ideas and unique, innovative solutions may come to mind.

Since some include machining in the rapid prototyping application set, and since machining can be as fast or faster, a detailed comparison of rapid prototyping and computer numerical control (CNC) machining is provided in Chapter 6. With this head-to-head comparison, it will be possible to determine when and how to apply each tool.

Using four leading technologies, Chapter 7 provides a head-to-head comparison of rapid prototyping systems. Containing information known only to rapid prototyping users, this comparison reveals key considerations of the technologies, exposes some little known truths, and eliminates common misperceptions.

For those who find that rapid prototyping could be valuable, the path through justification, evaluation, and implementation may be challenging. Chapters 8 and 9 are guides for the selection and implementation process.

Although the focus is on prototyping, an introduction to rapid prototyping would be incomplete without a discussion of rapid tooling and rapid manufacturing. These applications are intertwined with rapid prototyping, and it would be inappropriate to exclude them. In addition, many believe that these two applications may be the areas of significant growth in the coming years. Chapter 10 addresses both rapid tooling and rapid manufacturing.

To complete the introduction to rapid prototyping, Chapter 11 summarizes the key aspects of rapid prototyping and forecasts the role that the technology will play in the future. Whether or not the decision is to use rapid prototyping, one must keep abreast of the coming changes.

Appendices A through C offer supporting information. Appendix A provides user case studies that show the real-world benefits of rapid prototyping. Appendix B lists useful resources that may be helpful in the further evaluation of

the technology. And finally, a glossary of terms is provided in Appendix C.

SHADES OF GRAY

There is not an answer that is right for everyone. The benefits of rapid prototyping are always in question until the question is asked in the context of specific needs and goals. If rapid prototyping is a viable tool, the answer to the question of which technology is best will be unique, personal, and individual. Therefore, the information is not delivered with definitive statements. Instead, the technology is discussed in a way that allows the reader to develop his or her own answers.

This book has something for everyone. For those who believe in rapid prototyping, there is information that will support their convictions. For those who want to prove that rapid prototyping is an inappropriate solution, there is plenty of justification. And for those who simply want to determine the right answer, there is plenty of information to aid in the decision-making process. How can all of these desires be satisfied at once? It is simple. This journey through rapid prototyping offers no definitive statements, and in many cases, it is delivered in a way that invites more questions. The information offered carries an overriding principle that the answer to each question is ''it depends.''

The strengths and weaknesses, applications and benefits, and evaluation and implementation of rapid prototyping are unique to each part, product, program, and company. Therefore, the answer to every question will be ''it depends.'' The answers can only be determined when the information on rapid prototyping is combined with the specific and unique circumstances within each company and for each project.

A TOOL FOR CHANGE

Faced with economic challenges and global competition, the way business is done is changing. Organizations around the globe need to drive costs out of the process and product while enhancing quality and reducing time to market. Those who shoulder the burden of these requirements and initiatives find themselves with more work, fewer resources, and crushing deadlines. To cope or excel in this environment, the way business is done has to change.

Although this change will come in many forms and take years to develop, two key elements are collaboration and innovation. Design engineering and manufacturing engineering need to eliminate the barriers between the departments. Rather than ''throwing a design over the wall,'' design and manufacturing should communicate early in the process. This communication will produce a better product at less cost and in less time. To innovate, change is required, and this change demands that nothing is taken for granted and that no process is sacred. New methods, processes, and procedures are required in the highly competitive business environment.

Rapid prototyping may be the tool for change. To realize its full potential, rapid prototyping should be adopted by all functions within an organization. If implemented, it should not be designated as merely a design tool. Manufacturing needs to find ways to benefit from the technology, and it should demand access to this tool. This is also true for all other departments: operations, sales, marketing, and even executive management. When adopted throughout the organization, rapid prototyping can be a catalyst to powerful and lasting change.

INFORMED DECISIONS

The rapid prototyping industry has achieved much since its inception. There have been major advances since the 1987 introduction of stereolithography. Yet, there is room for growth and a need for further advancement.

Many of the obstacles that rapid prototyping faces are not unique. As with any new technology, there is a resistance to change and a reluctance to work through the challenges of a developing technology. However, there are other factors that are unique to this industry. Since rapid prototyping requires 3D digital definition of the part, its growth rate is the same as that of CAD solid modeling, an application that is far from being used by the majority of design professionals. Additionally, rapid prototyping has been burdened with a negative perception that the parts are ''brittle.'' While this was true many years ago, this is no longer an appropriate generalization. Yet, many use the belief that rapid prototypes are brittle to justify not evaluating or using the technology.

Since it continues to be a tool for the minority, rapid prototyping may not pose a competitive threat to those who do not use it. However, many companies that have implemented the technology have discovered powerful advantages in applications that range from product development to manufacturing to sales and marketing.

The decision is yours. This introduction to rapid prototyping offers no answers. Instead, it offers information to assist in making an informed decision.

REFERENCE

Wohlers, T. 2003. *Wohlers Report 2003: Rapid Prototyping and Tooling State of the Industry Annual Worldwide Progress Report*. Fort Collins, CO: Wohlers Associates, Inc.

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