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**MANUFACTURING
TECHNIQUES
FOR
PRODUCT DESIGN**

2nd Edition

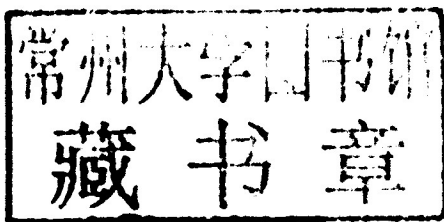
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Chris Lefteri

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Making It

Manufacturing Techniques
for Product Design



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For Jerome, our treasure



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Introduction

We are drawn to the unknown, to uncovering secrets and to unearthing the unseen nature of the modern world – from childhood TV shows that peer through the windows of factories looking at lines of chocolate biscuits and milk bottles being made, to cottage industries that reveal to tourists the production methods of indigenous craftsman, even down to DVD 'bonus features' that entertain us with how filmmakers cheat reality with special effects. Designers in particular are constantly looking for new ways to transform both old and new technologies and to apply them within the design arena.

The invention of machines that are used to turn out two thousand light bulbs per minute or ultra-fine flexible fibre optic cables has always amazed me and how they came into being. What kind of creative mind would have conceived the process that requires hot, sticky, molten glass to be suspended from a tower and dropped at a slow rate, stretching into tubes of glass less than 1mm thick to create an optical glass fibre; or that contorts steel wire into the iconic Gem paper clip at a rate of 300 per minute; or the process that makes glass marbles with those swirly patterns of colour, each with its own pattern? But these uniquely formed products are each specific to their own production process and are for another book. Instead this book presents those methods that are relevant to the production of any given object, in a nutshell those that are relevant to industrial design.

Since the publication of the highly successful first edition of *Making It* there

have been many innovations in the world of production, a selection of which has been added to this new updated edition. Some are highly specialized, such as electromagnetic forming, some are old methods re-evaluated, such as Industrial Origami®, and others combine two processes, such as Exjection®, a method of making that combines injection moulding and extrusion. There have also been some notable uses of established production methods, such as Marcel Wanders' Sparkling Chair, which upscales injection blow molding from the plastic bottle industry and applies it to the making of a piece of furniture.

There is a growing momentum for a more sustainable approach to design. In order to address the increasing importance of energy use, material scarcity and ethical production I have also added details that will give the reader an introduction to some of these complex areas and key points of consideration. In addition there is also a major new section on finishing techniques, as one of the most common ways is to innovate by colouring, painting, spraying, growing or adding functionality to a component. The chart on pages 10 to 13 provides an at-a-glance overview of major factors such as volumes of production and cost for each technique that will give the reader a straightforward comparison and quick reference guide to these key pieces of information.

As stated, the aim of this book is to explore the hidden side of objects within the context of industrial design. To peer into the world of machines and the often

creative and inspired ways that they have been assembled to morph liquids, solids, sheets, powders and hunks of metal into three-dimensional products. To examine these pieces of theatre in a way that has not been presented before in a book. To try and communicate what is an inherent playfulness that is evident in mass production. To encourage the abduction of some of these methods by designers to make better products and to exploit production as part of the creative process rather than as a means to an end.

My intention was to take all the information that exists in technical manuals, trade journals and websites for associations and federations in the engineering sectors and to encapsulate it in a guide for the designer that would be a relevant introduction to the world of the manufactured object. In one sense to celebrate all the relevant methods of mass- and batch production for the three-dimensional object at this particularly important crossroads in the evolution of objects. This is a time when old ideas of manufacturing are being re-evaluated by the design industry and new possibilities are surfacing, which have the potential to alter dramatically the way we make, choose and consume our products. It used to be the case that design was the slave to manufacturing, restricting creativity, moulding constraints and costs. In many cases this is still true but increasingly manufacturing is seen as a tool for designing new opportunities to bring new materials and ideas to new methods of production, and to experiment with preconceived volumes of production.

Some of the examples featured in this book reflect a stage of development where the new tools of designers and makers are not physical tools but factory set-ups. Take, for example, Malcolm Jordan's Curvy Composites, a degree-show design project that resulted in a completely new way of forming wood. I couldn't resist

also including some of the more offbeat processes that perhaps don't really fit into the realm of the mass-produced object but help point the way to a new direction, ideas that take a type of industrial production and combine it with a craft-like approach, projects that take small-scale, widely available machines and re-use them.

Before the Industrial Revolution the crafting of objects was often influenced by surrounding geography. Ceramics, for example, were designed and made in areas where there was an abundance of clay, such as Stoke-On-Trent in the north-west of England, the birthplace of Wedgwood and countless other ceramics factories. Places with large areas of woodland often had communities that specialized in furniture production. Skills and materials came from specific local resources. The global economy has had consequences for local resources and has often destroyed communities, but now technology is taking production back to the small-scale craft user and placing it in the hands of the consumer. Sometimes this is intentional and driven by new products and technology, at other times it is driven by people abducting machines and using them for something for which they were not intended. The adaptation of the humble inkjet printer for rapid prototyping is one such example.

The re-use of this type of product or technology is a vital part of evolution: experimenting, mixing things up and swapping them around, turning existing conventions on their head. Our insatiable appetite for making things races ahead at full speed. But if the old tools of craftsmanship were hand tools for shaping materials then the new tools of the craftsman are the machines. For under £100 you can buy an inkjet printer, take out the guts and start playing with the workings and use CAD-driven data to produce a whole range of new things. When people first started making 'things'

they picked a lump of wood, understood its properties to a certain degree and were able to chop it into a useable product. For some, the lump of wood has become the inkjet printer, a piece of technology that has been chopped up and generally messed about with to create a multitude of products.

Possibly one of the most unusual technologies of this kind is that which has been developed by various teams of scientists across the world using 'modified inkjet printers' to build up living tissue. Based on the long-held knowledge that when placed next to one another, cells will weld together, the tissue is built up using a thermo-reversible gel as a kind of scaffolding over each cell. A team from Medical University of South Carolina uses this gel as a way to support the cells as they are being distributed. This gel is interesting in itself, designed to change instantly from liquid to gel in response to a stimulus such as increase in temperature. This would allow tissue to be placed inside the body supported by the gel; the gel would then dissolve.

The core of this book, however, deals with mass-production techniques, some well established, others very new. In order for these tools to be used, they need to be understood in all their forms and to be presented in a manner that is relevant to design, stimulating ideas and allowing for new creative connections to be made, connections that could provoke the re-appropriation of a technology into a new area or industry. The structure and layout of this book are straightforward and allow for a casual toe-dipping into the world of the manufactured object, hopefully to inform and inspire a fresh look and a greater understanding of the backstage arena of the world of consumerism.

How to use this book

The book is divided into sections based on the shapes of components that can be produced with each process. It does not set out to answer all the questions you might ever need to know about these methods but does provide a clear and basic introduction, using a combination of text, illustrations and photographs of the products. The visual explanations provided in the diagrams serve to encapsulate the principles of the process and the steps that go into making a final component. They are not meant to be accurate drawings of the machines.

The text for each feature is broken down into two main forms to provide a summary of the particular process and a secondary list of the key points that relate to the process.

Pros and cons

These are bullet-pointed notes that summarize each production method to provide a quick guide to key features.

Volumes of production

This explains the range of unit volumes that different methods are capable of, from one-off rapid prototyping to single production runs in the hundreds or thousands.

Unit price vs capital investment

One of the main criteria for specifying a particular method of production is knowing the initial investment that is required. This can vary enormously from plastic forming methods, such as the various forms of injection moulding, which potentially can run into tens of thousands of pounds, to CAD-driven methods, which require no tooling and minimal set-up costs.

Speed

Speed is an important factor in understanding the scale of production and how many units can be produced over a period of time. If, for example, you want to make 10,000 glass bottles, then the automated glass blow moulding process, which can produce 5,000 pieces per hour, is not for you, as the set-up and tooling would prohibit such a short production time on the machines.

Surface

This briefly describes the type of surface finish that you can expect from a particular process. Again this can vary enormously and indicates whether a part would need a secondary process in order to arrive at a finished part.

Types/complexity of shape

This offers guidance on any restrictions that will affect the shape of the component and any design details to consider.

Scale

This gives an indication of the scale of the products that can be produced from the particular process. Sometimes this can offer some surprising facts, for example some metal spinners can spin metal sheets up to 3.5 metres in diameter.

Tolerances

The degree of accuracy that a process is capable of achieving is often determined by the material. Machine-cut metals or injection-moulded plastics, for example, are capable of highly controlled tolerances. Certain ceramic processes, on the other hand, are much less able to achieve precise finished dimensions. This section gives examples of this accuracy.

Relevant materials

This is a list of the types and range of materials that can be formed with the featured process.

Typical applications

A list of products and industries that typically utilize the method of production, the word 'typically' has to be emphasized as the list is not exhaustive but gives sufficient examples to help explain the process.

Similar methods

This provides a key to other processes featured in the book that might be looked at as an alternative form of production to the one featured.

Sustainability issues

A very brief overview of some of the key points that fall into the area of sustainability. This will allow the reader to make more informed decisions on areas such as energy use, toxic chemicals and material wastage.

Further information

This lists web resources to visit for further information. These include contributors to the book. Any relevant associations, where available, are also listed.

Comparing Processes

The chart that runs over the next few pages will enable you to compare different processes and evaluate which is best for your own product. Processes are listed according to chapter type and in the same order as they appear in the relevant chapter. See the chapter entry for further detail.

Key:	★= low ★★= mid ★★★= high	Cost of capital investment	Number of components produced per hour	Quality of surface finish
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1. Cut from Solid

Machining	★	★ / ★★	★★★
Computer Numerical Controlled (CNC) Cutting	★	★ / ★★	★★★
Electron-Beam Machining (EBM)	★★	★	★
Turning	★	★ / ★★	★★
Jigging and Jollying	★	★★ / ★★★	★★★
Plasma-Arc Cutting	★	★★ / ★★★	★★★ (edge surface finish)

2. Sheet

Chemical Milling	★	★★★	★★
Die Cutting	★★	★★	★★ (edge surface finish)
Water-Jet Cutting	★	★ / ★★	★★ (edge surface finish)
Wire Electrical Discharge Machining (EDM)	★	★ / ★★	★★
Laser Cutting	★	★ / ★★	★★ (wood) / ★★★ (metal)
Oxyacetylene Cutting	★	★★	★★
Sheet-Metal Forming	★★ / ★★★	★ / ★★	★
Slumping Glass	★★★	★	★★★
Electromagnetic Steel Forming	★★★	★★★	★★★
Metal Spinning	★★	★ / ★★	★
Metal Cutting	★★	★★★	★
Industrial Origami®	★ / ★★ / ★★★	★ / ★★ / ★★★	★★★
Thermoforming	★ / ★★ / ★★★	★ / ★★ / ★★★	★★ (depends on mould)
Explosive Forming	★★	★ / ★★ / ★★★	★★
Superforming Aluminium	★★★	★★	★★★
Free Internal Pressure-Formed Steel	★	★★	★★
Inflating Metal	★	★★	★★★
Pulp Paper	★★★	★	★
Bending Plywood	★★ / ★★★	★ / ★★ / ★★★	★ / ★★ / ★★★ (depends on wood)
Deep Three-Dimensional Forming in Plywood	★★★	★★★	★
Pressing Plywood	★★	★	★★★

Type of shape	Size	Degree of tolerance	Relevant materials
Solid complex	S, M, L	***	Wood, metal, plastic, glass, ceramics
Solid complex. Any shape that can be produced on CAD	S, M, L	***	Virtually any material
Solid complex. Any shape that can be produced on CAD	S, M	***	Virtually any material (high melting temperatures slow down process)
Symmetrical	S, M	*** (metal) ** (other)	Ceramic, wood, metal, plastic
Solid	S, M	*	Ceramic
Sheet	S, M, L	**	Electrically conductive metal
Sheet	S, M	***	Metal
Sheet	S, M	***	Plastic
Sheet	S, M, L	**	Glass, metal, plastic, ceramic, stone, marble
Sheet	S, M, L	***	Conductive metal
Sheet	S, M	***	Metal, wood, plastic, paper, ceramic, glass
Sheet	S, M, L	**	Ferrous metals, titanium
Sheet	S, M, L	**	Metal
Sheet	S, M, L	*	Glass
Sheet		***	Magnetic metals
Sheet	S, M, L	*	Metal
Sheet	S, M, L	***	Metal
Sheet / Complex	S, M, L	***	Metal, plastic, composites
Sheet	S, M, L	**	Thermoplastics
Complex	S, M, L	***	Metal
Sheet / Complex	S, M, L	**	Superelastic aluminium
Hollow	M, L	*	Metal
Sheet	S, M, L	***	Metal, plastic
Sheet	M, L	*	Paper
Sheet	M, L	*	Wood
Sheet	S, M	*	Wood veneer
Sheet	S, M	N/A	Wood veneer

Key:	★= low ★★= mid ★★★= high	Cost of capital investment	Number of components produced per hour	Quality of surface finish
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3. Continuous

Calendering	★★★	★★★	★★★
Blown Film	★★★	★★★	★★★
Exjection®	★★★	★★★	★★★
Extrusion	★	★	★★★
Pultrusion	★★	★	★★
Pulshaping™	★★	★★★	★★
Roll Forming	★★★	★★★	★★★
Rotary Swaging	★	★/ ★★★	★★★
Pre-Crimp Weaving	★	★/ ★★/ ★★★	★★
Veneer Cutting	N/A	N/A	★★

4. Thin & Hollow

Glass Blowing by Hand	★/ ★★/ ★★★	★/ ★★	★★★
Lampworking Glass Tube	★	★/ ★★/ ★★★	★★★
Glass Blow and Blow Moulding	★★★	★★/ ★★★	★★★
Glass Press and Blow Moulding	★★★	★★/ ★★★	★★★
Plastic Blow Moulding	★★★	★★★	★★★ (parting lines remain)
Injection Blow Moulding	★★★	★★★	★★★
Extrusion Blow Moulding	★★★	★	★★★
Dip Moulding	★	★★/ ★★★	★
Rotational Moulding	★★	★★/ ★★★	★★
Slip Casting	★/ ★★ (depends on number of components)	★/ ★★/ ★★★	★★
Hydroforming Metal	★★★	★★★	★/ ★★ (depends on material)
Backward Impact Extrusion	★	★/ ★★	★★
Moulding Paper Pulp	★★★	★★★	★
Contact Moulding	★★★	★	★★/ ★★★ (depends on method)
Vacuum Infusion Process (VIP)	★★	★	★★★
Autoclave Moulding	★★	★★	★/ ★★ (if gel is applied)
Filament Winding	★	★/ ★★/ ★★★	★★ (finishing required)
Centrifugal Casting	★/ ★★/ ★★★ (depends on mould material)	★/ ★★	★/ ★★ (depends on process)
Electroforming	★	★	★★★