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Hydroforming for advanced manufacturing

Edited by Muammer Koç

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Hydroforming for advanced manufacturing

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Preface

Throughout the last decade, increasing competition and environmental regulations has forced the transportation manufacturing industry towards producing low-mass vehicles to achieve fuel savings, reduced emissions and safe structures. In order to accomplish this goal in a cost-effective manner, manufacturers have to both develop or use new and lightweight materials, alloys or composites; and develop and improve new manufacturing techniques that can convert these materials into lightweight functional structures robustly, cost-effectively and with consistent quality. The hydroforming process, which has been long used to fabricate either intricate and small fittings for sanitary applications, or large but rather simple parts for aerospace applications, was a relatively new technology for the automotive industry in the early 1990s. It was taken as an new tool that could enable part consolidation, high strength-to-weight ratios, tight tolerances, better rigidity, less post-process operations, easy assembly, cost effective parts and tooling. With many other advantages and opportunities of design flexibility, there has been a continuously increasing interest in the hydroforming process particularly within the automotive and aircraft industries. As expected, the demand on the development of a knowledge base on this technology is also increasing so that mass production of new and more parts can become a reality.

As far as this author could survey and to his best knowledge, more than one thousand technical papers have been written and published on various aspects of this technology. Researchers, scientists, engineers from all over the world, both from academia and industry, researched the deformation mechanics, material behavior, tribology, tool design, equipment and system design, process control, etc. of this technique. Analytical and numerical models were developed and tested for a variety of parts of interest.

Yet, there is no textbook or handbook that serves as a single source of knowledge in this field of advanced manufacturing. One or two existing attempts were developed to the desired full extent but they do not suffice for students, engineers and researchers who are new to the topic.

This handbook on hydroforming was prepared with the aim of it becoming a main reference source of knowledge for decades to come. It is a product of a truly international and interdisciplinary collaborative work of many contributors. It presents all aspects of this technology comprehensively in a concise and direct manner. It comprises 16 chapters, and every chapter takes its topic from the very basics towards the latest and highest level of know-how. Chapters are organized in a similar manner to take the readers from fundamentals to the analysis of advanced and complex issues as well as to the latest trends in this field of research and development.

We hope that readers of all kinds of background, need and interest will find it useful and take it as a first step towards learning, researching, advancing and applying this technology into whatever their respective application would be.

I would like to acknowledge and thank all of my collaborating friends and authors for their contributions by sharing their knowledge and insight with us. Special thanks go to the publishing team members who relentlessly, patiently and with a great professionalism steered us towards completing all chapters in a timely manner.

Muammer Koç
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Contents

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Introduction and state of the art of hydroforming

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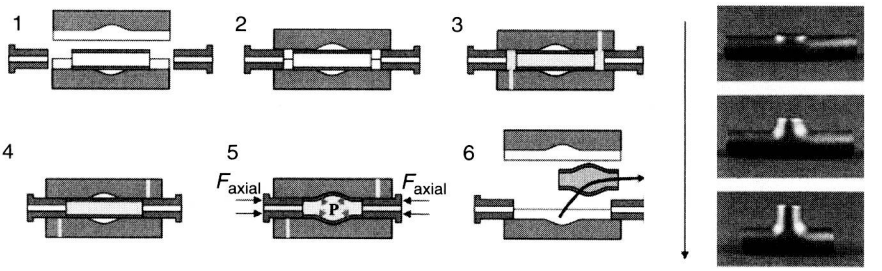
1.1 Introduction

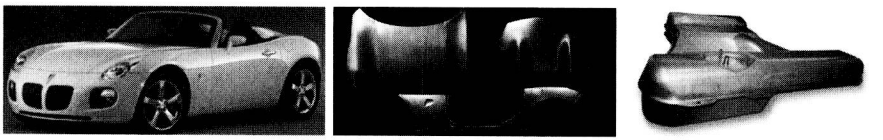
This chapter is intended to provide an introduction into the technology of hydroforming as a briefing for the upcoming chapters of this book. In it are summarized the fundamentals of hydroforming technology, its developmental background, hydoforming systems including equipment, tools and controls, as well as its role in the production of lightweight structures and vehicles. This chapter also provides introductory information on materials used in hydroforming and their formability issues in addition to information on hydroforming tribology, pre-forming issues such as effect of loading, path and process control. Computer simulation techniques and innovations in hydroforming are discussed towards the end of the chapter. Wherever possible, references to the existing published studies and to the corresponding chapters in this handbook are given to direct the readers to the right place for further reading and in-depth understanding.

1.1.1 Definition and examples of hydroforming

Hydroforming is a material-forming process that uses a pressurized fluid (liquid or gas) in place of hard tooling (punch, die, mold, inserts, etc.) either to plastically deform or to aid in deforming a given blank material (sheet or tube) into a desired shape as depicted in Fig. 1.1. With this technique, more complex shapes with increased strength and low cost can be manufactured as compared with stamping, forging or casting processes. The cost advantage usually stems from the fact that fabrication steps in hydroforming are significantly reduced, usually to a single step. In stamping, for example, multiple steps such as blanking, drawing, restriking, trimming, welding, etc. are needed to finalize a part whereas a sheet blank can be drawn into the final complex shape (as shown in Fig. 1.2 and 1.3 as examples) in a single step. Most of the time, additional post-processing steps such as hole piercing or trimming may also be incorporated in this step.

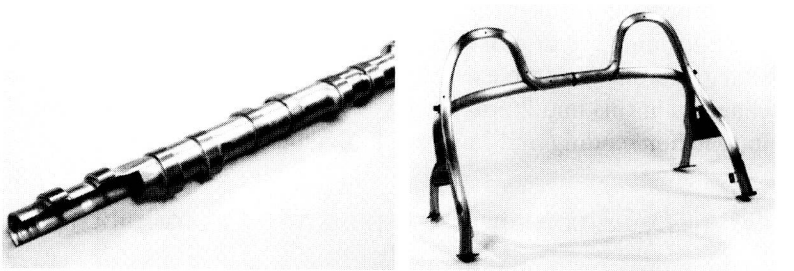


1.1 Steps in a typical hydroforming process shown on a small tubular part (courtesy of Siempelkamp Pressen Systems).



a b

1.2 Example hydroformed (sheet) parts: **a** 2007 GM Pontiac Solstice GXP has several hydroformed (warm) parts, **b** fuel tank comprising of two halves can be hydroformed in a single step.



a b

1.3 Example hydroformed (tubular) parts for various automotive applications: **a** hydroformed steel camshaft (BMW 3.0L DOHC I-6 Ward's 2005) offers 28 to 50% mass saving, **b** 2-piece roll bar for a convertible car (courtesy of Schuler Inc.).

In addition to various applications in the aerospace industry, such as panels, fuselage parts and casings and in the appliance industry, such as fittings, joints, knobs and handles, hydroforming has been increasingly used in the automotive industry since 1990s. Various parts for the automotive, appliance and plumbing industries are produced by hydroforming technology; they can be summarized as follows (Fig. 1.4).