Introduction

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Metal forming is a symbiosis of tradition and innovation driven by scientific and technological inventions. Comprehensive developments in materials, tooling and machinery lead permanently to new or improved metal forming processes and products. The driving motor in metal forming are the **technological innovations** which lead to new processes or process combinations resulting in novel or improved products. The enormous boost in innovations that occurred in the last decades was only possible by a concurrent development in **analysis methods and measurement techniques**, which act as the enabling tool for metal forming innovations by providing a physical insight to the processes. This is different than in other manufacturing technologies, for instance as in machining, since the effect of actuators in metal forming covers large parts of the workpiece volume based on complicated physical response functions.

Figure 1 shows the new process families that have been invented in the last 60 years. Most technological innovations in this period are related to sheet metal forming, except

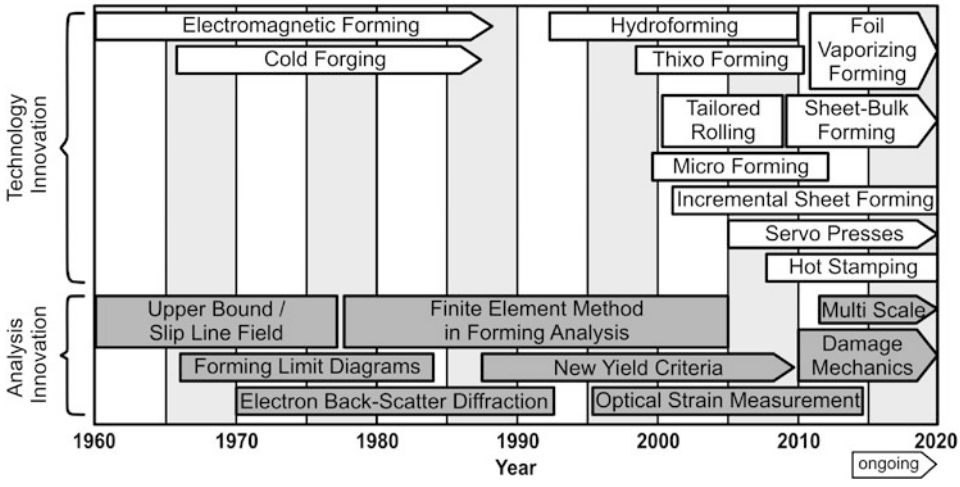

Fig. 1 60 years of inventions in metal forming – overview of the main active development period in selected areas

cold forging, tailored rolling, and parts of the micro forming technology. The analysis innovation can be located in two fields: analytical methods and measurements (see Fig. 1). Upper bound methods and slip line field methods are even today valuable tools for developing insight in complicated metal forming processes. Impressive developments in analyzing the microstructure enabled new and powerful computational methods, the so-called multi-scale methods. These trigger the transition of the phenomenological approach of plasticity to a physics-based approach today.

The basic drivers of these process innovations came in various streams of focused research and development, as shown in Fig. 2. The stream of near-net shape forming boosted the field of cold forging. The increasing product variance (especially in the automotive industry) initiated the flexible forming process development and inventions. Incremental sheet forming methods were basically developed in this era. The awareness of the anthropogenic greenhouse effect enforced energy savings in all branches of design and manufacturing, leading to environmentally benign forming processes. Today, these activities include most of the lightweight efforts, but also cover dry forming processes or low acoustic emission processes. A natural extension of the environmentally conscious design of products is the deterministic setting and utilization of product properties altered in forming processes. This recent development will be one of the main research trends in future decades. Developments in damage mechanics and multi-scale modelling will be the basis of this stream. Finally, it is believed that the precise setting of parameters, despite of several uncertainties in the material, process, environment etc., will be enabled by the closed-loop control of forming processes and forming process chains including the heat treatment processes. This last trend is just starting initiated by the collaborative work of various CIRP colleagues.

This book aims at demonstrating the enormous innovation affinity of metal forming by compiling the most important 60 inventions of the last decades. It must be emphasized that these inventions are not exhaustive in any way. Obviously, some of the brilliant ideas

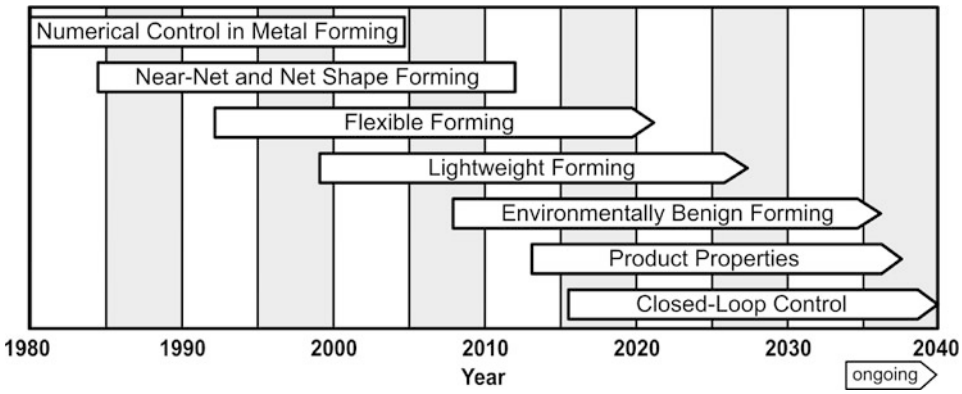

Fig. 2 Main trends in metal forming with a future projection

have been left unmentioned in this book. Nevertheless, we think that this work still can serve the aim mentioned before.

The book covers the 60 new ideas in 9 parts:

- Part 1: Material Characterization and Tribology (6 inventions)
- Part 2: Modelling (5 inventions)
- Part 3: Sheet Metal Forming (9 inventions)
- Part 4: Incremental Forming (7 inventions)
- Part 5: Shear Cutting (5 inventions)
- Part 6: Rolling (6 inventions)
- Part 7: Extrusion and Hot Forging (6 inventions)
- Part 8: Cold Forging (9 inventions)
- Part 9: Tube and Profile Forming (7 inventions)

Part 10 collects further developments covering 7 additional inventions and ideas.

The inventions in this book originate from 10 countries: Denmark, France, Germany, Italy, Japan, Poland, Portugal, Romania, United Kingdom, and the United States. It is noteworthy that several authors from many more countries are involved in these inventions, demonstrating that the forming innovation is internationally widespread.

The authors have confidence that the next decades will bring out many additional inventions and ideas that will improve the technology of metal forming even further and, hence, serve the wealth generation for the society in the same manner as they have in the past decades. The authors also hope that this book will stimulate young students, young researchers, and young engineers in the field of metal forming to recognize the huge opportunity for creativity of this vivid field of manufacturing engineering. At the same time, they hope that it is also recognized how metal forming technology goes hand in hand with analysis methods in mechanics, metal science, chemistry as well as measuring techniques. The terrific developments in mechatronic systems (including sensors and actuators), digital technology, and tailoring materials on nano-scale are wonderful opportunities for the future.

The authors also hope that this impressive collection of inventions in technology and science inspires national funding agencies and university administrations to recognize the huge added value of metal forming research for the society. Metal forming is obviously not an ancient technology that has exceeded its shelf-life for research. In fact, it is an ever-developing technology utilizing all available scientific knowledge and methodologies. Metal forming is an enabling technology without which it would be not possible to realize many of the innovations in biotechnology (e. g. implants, stens), in clean energy generation and transport (e. g. wind mills, super-conductors), space missions (e. g. boosters, structures), and many more. Metal forming could not enable all these technologies without evolving itself as presented in this book.

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