Manufacturing supported by Process Simulation

Challenges facing the manufacturing industry

The manufacturing industry is facing short- and midterm economical challenges, which arise from ever changing economic boundary conditions as well as underlying global and long-term megatrends. These megatrends will shape the future of our and other industries. We will present some development trends in the field of metal forming to cope with these challenges.

Simufact, as an international software house, is developing metal forming simulation software to empower the industry to comply with their development requirements, since process simulation is an early and important step in the life-cycle of a part. Simufact is providing numerical process and process chain simulation tools to empower the metal forming industry to be able to meet the challenges arising from the short-term and long-term challenges.

Global megatrends

The industrialisation of the so-called "Developed" countries and the extraordinary fast economic development of the "Emerging" countries, like Brazil resulted in a living-standard and live expectancy which is now the highest in history.

There are a number of global megatrends, which we believe will be valid for the long-term future and will have a strong impact on the economic development.

Geo-political and economic changes

The first megatrend is the extraordinary fast economic development of the "emerging" economies, soon surpassing the "developed" markets in several economic categories and thus shifting the economic and political weight.

Sustainability

Two parameters can be used to describe the well-being of a nation and the country's resource demand :

Ecological Footprint data tells us that an Ecological Footprint of less than 1.8 global hectares per person makes a country’s resource demands globally replicable.
The United Nations' **Human Development Index** (HDI)—which measures a country’s average achievements in the areas of health, knowledge, and standard of living—tells us that an HDI higher than 0.8 is considered "high human development."
It has been shown that none of the countries with a desirable development index indicating "high development" has an ecological footprint, which is considered sustainable.

Population growth

The world is facing a population growth, which is expected to continue in the next decades. This population growth drives a rising demand for energy consumption and raw materials. The sharp rise in steel and alloying metal prices our industry is experiencing is a good indicator for the short till midterm availability of these resources.

Evolution of mobility

The use of mobility will increase dramatically in the future. Therefore new concepts for mobility are required. The most noticeable changes for the consumer will be with respect to the power train. The vehicles may be sub-divided into:

1. Vehicles with internal combustion engine (ICE)
2. Parallel hybrid electric vehicles (HEV)
3. Plug-in-hybrid electric vehicles (PHEV) (range extender concept)
4. Fuel cell electric vehicles (FCEV)
5. Battery electric vehicles (BEV)

All these various types have different levels of impact on OEMs and on their suppliers, in particular the forging industry.

Hybrid concepts generally involve a more lightweight design, while pure electric vehicles will no longer have a large proportion of the forged components used today in the engine and power train. This will cause companies who primarily supply parts in these areas to think at additional options and challenges.

Technological changes

In the last decades the world has experienced a never-before-seen technological development. Only two examples are presented here:

- Knowledge explosion
- Growth of computing power represented by Moore's Law

We are convinced that these technological changes provide the key to solve the challenges to the manufacturing industry caused by the previously shown megatrends.

Lessons from the megatrends for the manufacturing industry

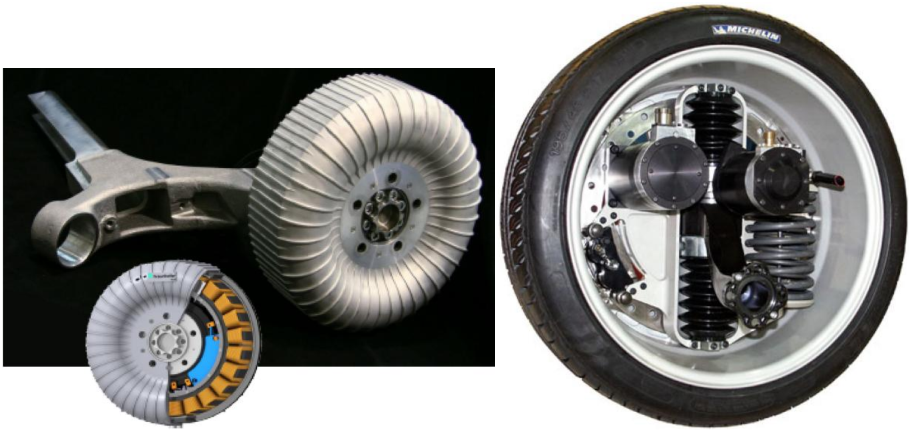
Which lessons can be drawn from the megatrends described above for the manufacturing industry?

1. There is a **growing market** for sophisticated, high quality & inexpensive products.
2. **Natural resources are limited**.
3. We do have an **alternative: increasing resource productivity**:
    - The ecological footprint of our products must be reduced as much as possible.
    - To achieve this, the principal task for engineers, designers, architects and scientists is to create products and systems with the highest possible resource productivity, not only during the manufacturing process, but for the entire product life cycle..
4. Increasing **resource productivity is economically beneficial**

Examples for products with high resource productivity

Examples of high resource productivity are products, which are designed to yield different types of utilities with an only slightly increased ecological footprint, such as the famous Swiss army knife and Smartphone.

This concept applied to the metal forming industry is nicely represented by the product examples like a torsion beam axle for electric driven cars, and the “Active Wheel” from Michelin. This reduces the number of metal formed parts to an large extent. Designing these products and laying-out the optimal manufacturing process chain are challenging, "using brain power instead of material".



Left: torsion beam axle with electric engine ; right: Active Wheel from Michelin

Numerical simulation is the key factor to develop resource efficient products and manufacturing processes

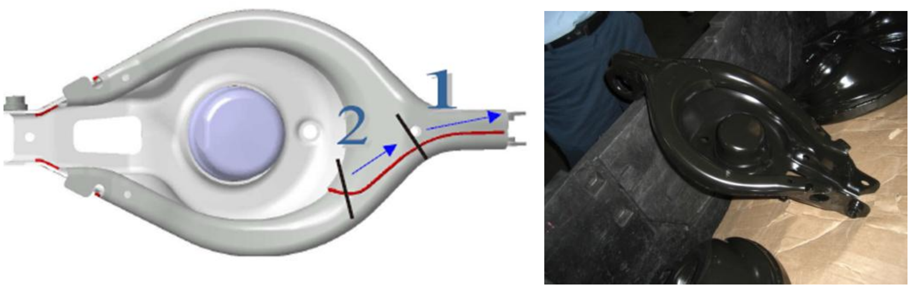
The German authorities have recognised that innovative concepts for energy and material effective manufacturing processes as a key factor to ensure high competitiveness, :

- "To achieve this, research is required to develop planning and evaluating systems, which allow for a fast and efficient analysis, evaluation and optimisation of the resource efficiency of individual processes and process chains.
- Furthermore, research is required to evolve the manufacturing processes, to manufacture products by the most effective means. Properties resulting from the manufacturing process should be targeted to improve the final product properties allowing energy and resource efficient use.
- A successful implementation of process changes requires a precise analysis of the initial process, the targets and the manufacturing conditions. Also, a very precise coordination of tools, manufacturing parameters and process conditions is essential."

These statements ensure us that numerical simulation tools like the Simufact products Simufact.forming, Simufact.welding, Simufact.premap and our future products are and will be an indispensable tool. Numerical simulations will help companies to develop and increase the needed knowledge, to look deeper into each process step and into the behavior of the material, to understand the dependencies and to develop new innovations. The world of manufacturing will get more and more complex.

Example of a process chain simulation: Forming of an automotive part with subsequent thermal joining

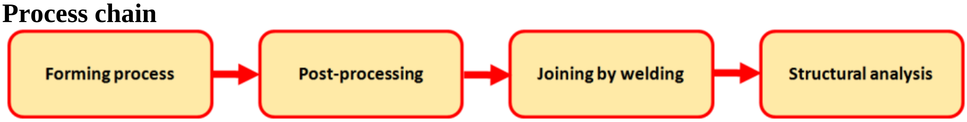
A large number of parts are joined mechanically or thermally after being formed. A holistic approach to the complete manufacturing process design allows maintaining narrower tolerances and will result in increased process stability and better product properties.



Welded assembly of sheet metal formed parts in the automotive industry

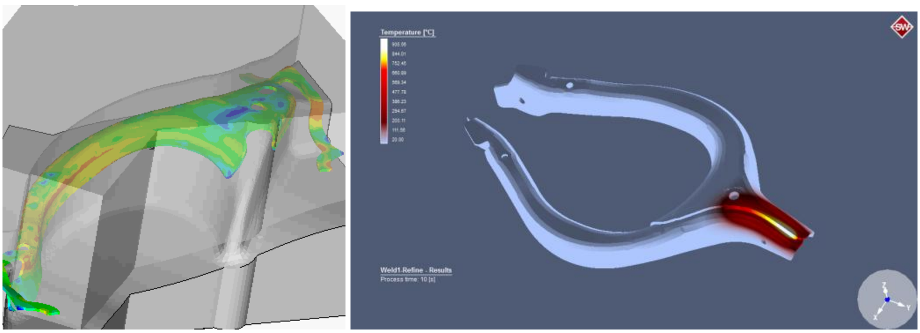
In our example, the metal forming simulation of the parts to be joined is carried out with Simufact.forming. Following that, the components are welded in Simufact.welding. The example shown, originates from a project at Mississippi State University, carried out in cooperation with Prof. Keiichi Motoyama. The manufacturing process chain consists of the following steps.

Process chain



Schematic representation of a process chain, including forming and welding

The metal stamping process is simulated first. The geometry of the initial blank is given by its CAD-geometry with a constant sheet thickness. After the forming step, including the spring-back, the part is trimmed during a next simulation step to its final geometry, including all required cut-outs. The components are now available in their final geometry with simulated sheet thickness distribution and all other properties, e.g. strain hardening and residual stresses to name the most important. Next, the geometries are imported in Simufact.welding where the clamps of the fixture and all relevant welding process properties are assigned. Following this, the simulation of the welding process is carried out. Following the welding simulation, the assembly is cooled and the clamps released according to their timing sequence.



Forming process of a sheet component followed by Welding

Heat treatment

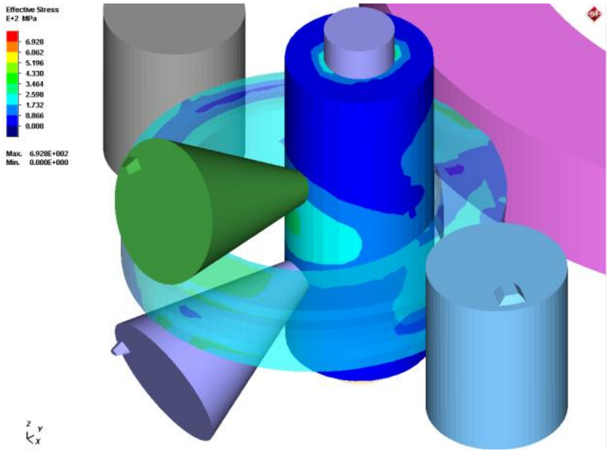
Depending on the real process chain, the welding simulation can be followed by a heat treatment simulation in Simufact.forming.

Structural analysis

On the final product, a structural analysis can be carried out with either Simufact.forming, or with other structural finite element software, while taking into consideration the properties resulting from the manufacturing history.

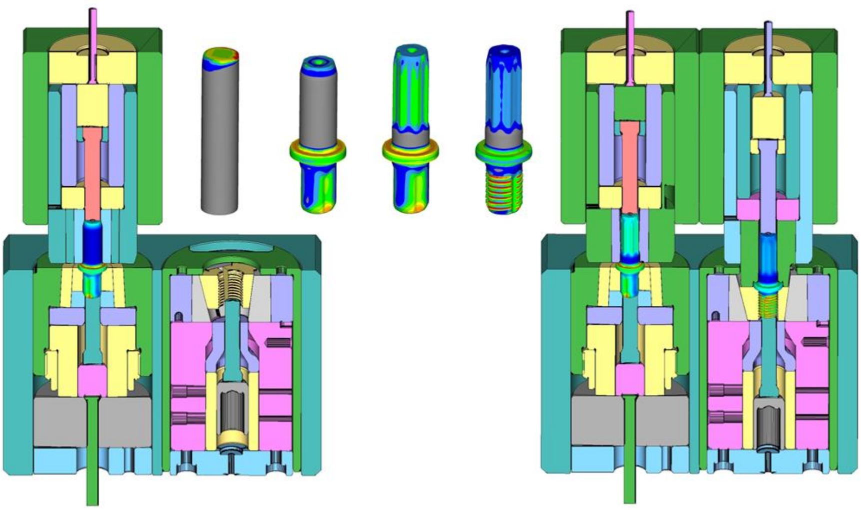
Consideration of tools and machines

Increasingly the coupling of tools and the work pieces are intensively studied. For example, during ring rolling the mandrel can be simulated as an elastic heat conducting body.



Simulated effective stress distribution in the mandrel

Another example is the complex tool assembly for a cold forming process carried out in a two die three stroke press. A detailed simulation model was used to develop a brand new manufacturing process, including segmented dies.



Simulation model of a complex tool assembly of a tool concept for thread embossing

This article contains excerpts from a keynote lecture presented at the SENAFOR 2011, by Dr-Ing. Hendrik Schafstall, Chief Technology Officer of Simufact Engineering GmbH. For a copy of the full lecture, including references for the data used in this article, see www.simufact-americas.com/simulation