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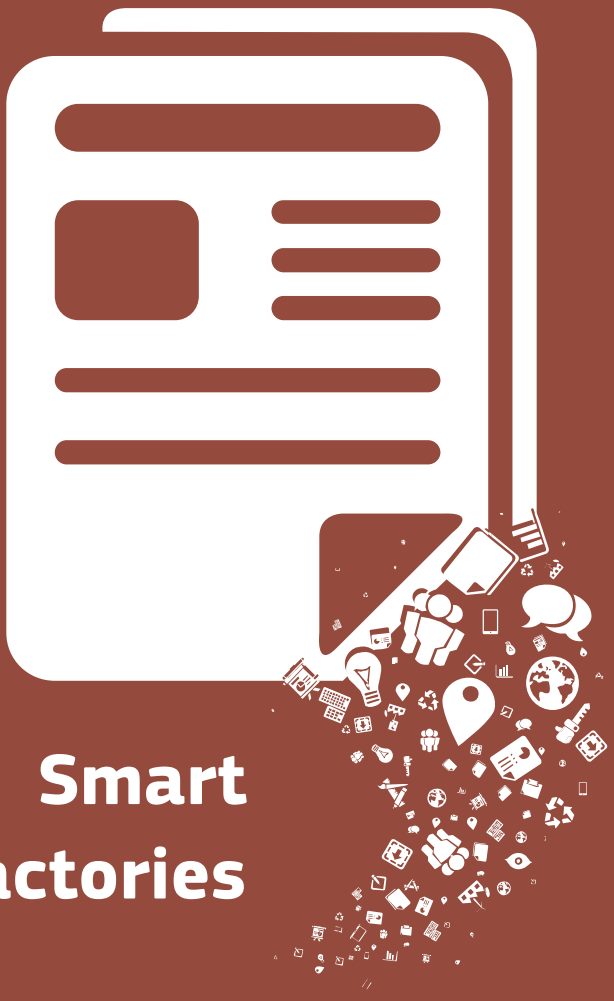

Smart Factories

Next generation forging

Case study 28

Enterprise and Industry

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Smart Factories

Next generation forging

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1. Executive summary

Forging has traditionally been regarded as a manufacturing process for shaping metal-based shapes by using localised compressive force. Its industry plays an important role in the European manufacturing industry and consists mainly of small and medium-sized enterprises (SMEs).[1] The industry can be broken down into two significant sub-industries: the castings industry and the forging industry. Moreover, European companies provide leading edge forging technology all over the world, evidenced by the company cases included in this case study.

It is argued that the forging industry needs to become more energy efficient and environmentally friendly. Next generation forging technologies are developed to help companies reduce their energy dependency, improve their environmental footprint, and gain a competitive edge in the forging industry. This is especially the case for companies in the European forging industry, as these companies particularly face strong competitive pressure in traditional high-volume segments from regions where production is less costly, such as Asia.Next generation forging technologies address a wide range of challenges**,** including a higher complexity of castings, more stringent requirements regarding eco-efficiency, affordability, the quality of products and delivery conditions, and a lack of specialisation and skills in production facilities.

However, next generation forging technologies not only address these challenges, they also provide significant benefits for end-users, such as lower material consumption, increased flexibility of production, a reduction in overall production costs, and improved materials and material properties. There are various factors that drive the uptake of the trend of next generation forging, which include environmental regulation, a need for increasingly more efficient and flexible manufacturing, and a strong and established customer base.

Some factors negatively impact the uptake of the trend. A conservative approach towards new technology from the traditional industry base limits their appetite for novel solutions provided by innovative forging companies. Also, a risk exists for European forging markets to lose part of their local markets as manufacturers relocate to other parts of the world, which also could result in a possible detachment of forging-focused European research centres and research departments from some of their customers.

Companies in Europe's forging industry face challenges in access to materials and energy at competitive prices at the global level. Moreover, the increasingly more complex technology of forging companies requires their employees to provide an increasingly specific set of high-level skills to engineer and to operate forging equipment and machinery. Companies face challenges in attracting this talent, and some overcome this by developing and implementing specialised apprenticeship programmes to train incumbent workers.

Successful next-generation forging companies display a strong market-based approach, specifically addressing the complex needs of their customers by actively engaging with them. In order to maintain or gain a competitive edge, these companies also strongly focus on excellence and innovation in their day-to-day business.

A set of policy recommendations can be drafted to engage and encourage the proliferation of next-generation forging technologies. Firstly, the (potential) skills gap in AMT should be addressed by stimulating companies to (jointly) develop apprenticeship programmes. Secondly, an environment of multi-disciplinarily should be promoted, especially between software engineering and manufacturing. Thirdly, the development of alternative materials for forging and resource efficient forging solutions should be stimulated.

Moreover, eco-efficiency in the manufacturing industry could be promoted to facilitate market uptake of next generation forging technologies. Finally, international collaboration between European forging SMEs and forging and manufacturing companies in regions outside of Europe should be stimulated to ensure European SMEs stay connected to their customer base.

2. Next Generation Forging

The forging industry constitutes a **key link between critical manufacturing segments**, i.e. metal suppliers (both ferrous and nonferrous) and end-user industries. Although the art of forging is over 6,000 years old, significant improvements were made from the 19th and 20th century onwards. [2] Nowadays, deploying leading-edge technology is crucial for forging companies to gain an advantage over their competitors. This has required continuous investments, research and innovation, evidenced by the fact that between 2005 and 2010 alone, 52 new open-die forges were built, accounting for an investment of more than 1,000M EUR.[3]

The forging industry in Europe faces a number of challenges and needs to adapt rapidly. With increasingly more competitive pressure on European producers in more traditional markets, such as mass product and commodities markets, European forging companies are moving more towards highly advanced forging technologies to gain a competitive edge. Whereas manufacturers in emerging countries typically have more favourable cost structures, European forging companies have a strong base in research and development. As a result, more and more European forging companies focus on developing innovative solutions instead of on mass-production, often tailoring their offerings to specific market segments or end-users.

The forging industry in Europe faces increasingly more competitive pressure from other regions, especially in mass product and commodities markets, and as a result focus on developing innovative solutions.

According to the Forging Industry Association, by 2020 forging needs to be the cost-effective, preferred process by which metal components of superior quality, integrity, and performance are produced for critical and demanding applications. This requires the development of more efficient forging technologies in the near future. The Forging Industry Association believes further technological progress in the industry needs to be achieved in order to meet industry's own goals by the year 2020.[4]

With growing concerns for the environment, rising fuel costs and depletion of natural resources, it is widely accepted that **the forging industry of the future needs to be energy efficient and preserve the environment.** Consequently, the need for environmentally acceptable, functionally effective, and affordable technologies that integrate pollution prevention into the entire metal forging processing system design will increase significantly.[5]

Next generation forging technology provides a solution for these challenges by drawing on lighter, stronger, and higher-quality alloys, rapid prototyping technology, and advanced computer simulation software. The higher-quality alloys enable forgings to compete on the market with otherwise superior materials.

Next generation forging technology draws on several elements, such as lighter, stronger, and higher-quality alloys; rapid prototyping technology; and computer simulation software.

Rapid prototyping technology increases the speed of production and adds flexibility for end-users, which increases the competitive position of companies employing the technology. Moreover, advanced computer simulation software is used to simulate heat-treatment, machine distortion and design optimisation, enabling companies to predict the microstructure and mechanical properties of forged products before they are produced.[6]

Next generation forging technologies provide numerous benefits to end-users as well. These benefits include[7]:

- **Lower material consumption:** With advanced forging technology, not only can efficiency be increased with respect to the amount of material required, but also more efficient prototyping can be achieved through the help of simulation software and rapid prototyping technology.

- **Increased flexibility:** Next generation forging technologies allow producers a greater degree of flexibility in their production processes, such as greater flexibility in material use, greater flexibility in adjustments during production, quicker ramp-up times and faster prototyping.

- **Reduction in environmental impact:** Traditional forging processes are highly energy intensive. Various initiatives are developing more energy efficient forging technologies to drive down the environmental impact, such as the REForCh project funded by Framework Programme 7.[8]

- **Increased efficiency of forging processes:** With the advent of advanced simulation software, forging processes can be better optimised without the need of testing every single parameter, which greatly increases the efficiency of forging processes.

- **Reduction in overall production costs:** Due to a combination of cost factors, including lower material consumption (i.e. better material utilisation) and improved efficiency of the forging process, overall production costs can significantly be reduced for forging companies.
- **Improved materials and/or material properties:** With the development of alternative materials or hybrid materials, properties can be greatly enhanced, which benefits the forging process, the production costs, the flexibility towards end-users, and the overall quality of the product.

3. Socio-Economic Relevance

Next generation forging technology has a tremendous impact on the traditional manufacturing industry in Europe. With a need to innovate in the forging industry to keep up with competing regions, next generation forging technologies are pivotal for European forging companies to gain and keep a competitive edge.

3.1. The market size and potential of the trend

Although the forging industry is generally considered to play an important role in the (European) manufacturing industry, data on the industrial demand for castings and forgings is limited. This makes it difficult to interpret the demand for next generation forging technology. Furthermore**, the European foundry and forge industries are much differentiated** both in terms of size of the companies and the types of products produced as well as technologies employed.[9]

Nevertheless, the industry can roughly be broken down into companies focusing on castings and companies focusing on forgings. These will be discussed separately below.

The castings industry is well established in the European economy. The European foundry industry for ferrous castings is the second largest in the world, where China is the dominant market leader in sheer production volume. **For non-ferrous castings, however, the European industry is estimated to be the largest in the world by production volume**.[10]

A major part of the total production of castings consists of ferrous-metal castings. In 2008, this equalled 80% of total castings production. Within ferrous-metal castings, iron castings account for more than half of the ferrous-metal production, of which nodular iron is the most important source. Production volume of nodular iron castings grew 4.7% per year between 2004 and 2008. This can mostly be explained by the increasing use of nodular iron in sectors that require high strength and heat conductibility, such as the automotive market.[11]

On the demand side, the automotive industry is the most important market segment. It accounts for 50% of all castings, followed by the engineering industry (30%), the construction industry (10%), and other industries such as the aeronautics and electronics industry (10%). While iron castings are mostly used in the automotive industry, steels castings are especially used in the engineering and valve making industries.[12]

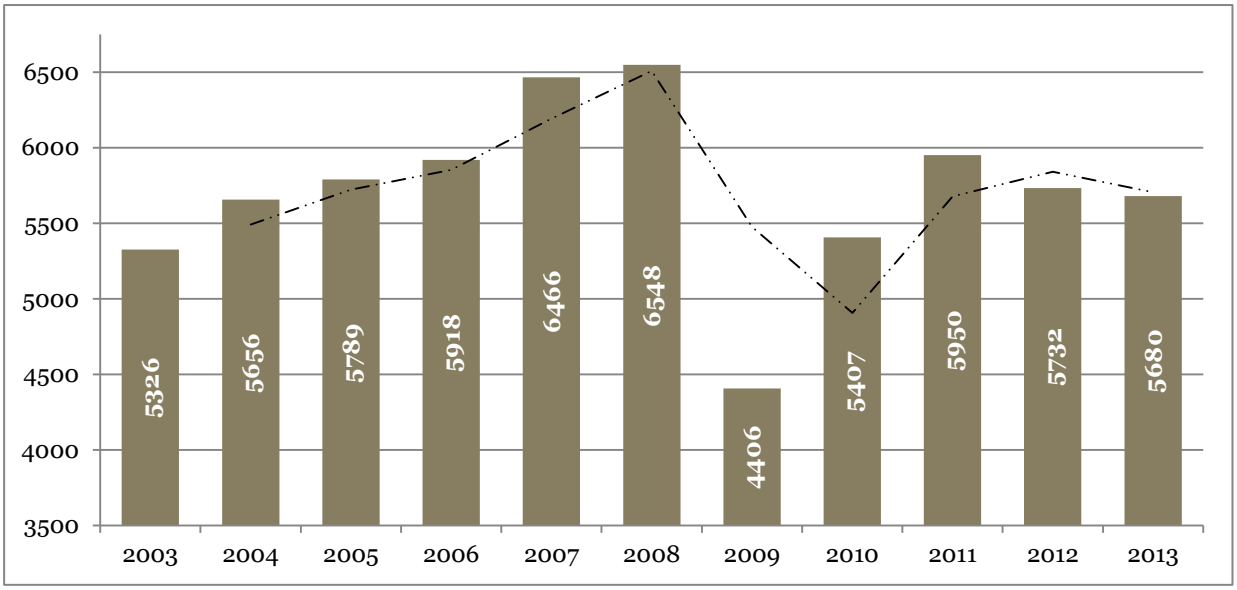
The automotive industry is the most important market segment of the castings industry, accounting for 50% of all castings, followed by the engineering industry (30%) and the construction insustry (10%)

Figure 1 on page 5 shows the trend in production volume of the European forging market. The European production market collapsed in 2009 and has been recovering to a pre-crisis point in 2010 and 2011. By 2012, the market experienced a decline again, mostly attributed to a decline in sales of passenger cars and commercial vehicles. Production volumes were estimated to fall even slightly more in 2013.[13]

However, **there is significant growth potential in volume,** particularly owing to developments in the automotive sector. With the general platform strategy of the automotive industry, higher production volumes for forging companies are expected.[14] Automotive companies seek economies of scale in developing cars by sharing their so-called platforms, i.e. the architecture that is at the core of vehicle engineering. Most of these companies will as a result focus on larger volume production of parts, as many configurations are being standardised.[15] With a strong presence in the European automotive industry, the European forging industry is likely to benefit. Furthermore, trends of downsizing engines, and of increasing demand for Diesel powered cars and for four-wheel driven SUVs, further increase demand for the forging industry.[16]

Despite growth potential in volume, revenues for the forging industry are put under pressure by the increasing number of system suppliers. EUROFORGE argues that these system suppliers tend to make the European forging industry tier two or even tier three suppliers. The marginal profits are therefore decreasing and narrowing down costs has become a major priority for the forging industry.[17]

Figure 1: Total production of forgings of EUROFORGE member countries (2003 – 2013)



Source: PwC adaption of EUROFORGE data (www.euroforge.com)

The main cost drivers of the European forging industry comprise of materials, personnel and energy costs. Wage costs are reasonably stable, and account for 15-40% of the total production costs (depending on the process type and order size). Energy costs, on the contrary, have been increasing rapidly in the last 10 years. In that period, electricity prices have increased by 95% and natural gas even by 100%.[18]

Companies in the European forging industry try to combat these high energy costs by focusing on reduction of energy expenditures (Table 1). This trend is strengthened by European legislation on eco-efficiency, which in addition to energy efficiency, provides companies an incentive to emit less CO_2.[19]

Table 1: Overview of the company cases referred to in this case study

Company	Location	Business innovation	Signals of success
Simufact Engineering	DE	Simufact Engineering GmbH develops software for the optimisation and design of manufacturing processes with the help of process simulation.	- Simufact Engineering is regarded as one of the key players in modelling software for the forging industry. - Successful acquisition of a key industry player in the field in 2007 and display of continuous growth. - Provides services to leading customers in the field, such as Robert Bosch GmbH, the Schaeffler-Group, Airbus Deutschland GmbH and key automotive industry players, such as Audi AG, BMW AG, Porsche AG and Volkswagen AG.
voestalpine	NL	Voestalpine Polynorm Metals Group is specialised in the development and production of products and components for the automotive industry and industrial applications markets, like the construction industry and renewable energy markets. Various leading edge technologies are used, such as injection moulding and compression moulding.	- With over 1.700 employees and 4 production and engineering centres, the voestalpine Polynorm Metals Group is a global player with a local presence. - The voestalpine Groep is an organisation with well over 40.000 employees, 360 production companies and is active in more than 60 countries.

Schuler Group	DE	Schuler Group is one of the technological leaders in the field of metal forming. An example of their innovative power can be found in the ServoDirect Technology. This technology has led to significant increases in output of blanking and forming presses. Another example is their Crossbar Feeder, which allows users to transport and position parts more flexible in press lines.	- Numerous patent applications on leading-edge technology every year. - Schuler Group realised 1186 million EUR in sales in fiscal year 2012/2013 and employs over 5,500 people.
Sheffield Forgemasters International Ltd	UK	SFIL specialises in a broad range of heavy steel forgings and steel castings as well as stocking steel ingot and bar.	- Sheffield Forgemasters International Ltd (SFIL) is the largest independently owned Forgemaster company and is one of the biggest private sector employers in South Yorkshire. - Despite a steady decline in steel manufacture in the UK over the past few decades, SFIL has continued to grow and is now a world leader in heavy steel castings and steel forgings. - Award-winning apprenticeship programme.
AURRENAK S. Coop	ES	AURRENAK was established more than 35 years ago and focuses on the design and manufacture of mouldings for the iron and aluminium casting industry. Aurrenak is involved in a number of cooperation agreements with other manufacturing companies and has participated in a number of national and regional research projects in the past years, most of them related to high precision casting tools.	- AURRENAK has more than 30 years of experience in the industry. In 2010, the company employed 90 people and had an annual turnover of 13 million EUR. - AURRENAK has developed solutions for leading industry players particularly in the automotive sector.

3.2. Next generation forging technologies address a wide range of challenges

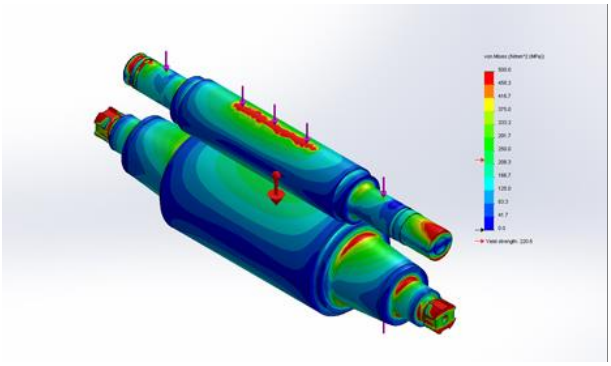
Problem 1 – As castings become more complex and are used in larger, more complex and more demanding processes, large size castings of high quality are demanded by customers.

Innovative solution 1 – **Sheffield Forgemasters International** Ltd. manufactures the world's largest castings. Through continuous improvements and developments, Sheffield Forgemasters has developed solutions to satisfy the increasing demands for larger heavier castings for forging presses and rolling mill markets.[20]

The impact of the technology is clearly demonstrated in one of the case studies featured on Sheffield Forgemasters. In 2009, Sheffield Forgemasters was approached by a company that had to stop production at an oil platform as cracks had materialised in the subsea structure of the oil storage tank. Previous efforts to repair the crack had failed.

Sheffield Forgemasters' expertise in large castings, particularly in the oil and gas industry, was key for providing a solution. Not only did they manage to repair the crack, but the large repair casting that was forged with their innovative technology was awarded the Cast Metals Federation (CMF) Cast Component of the Year Award 2012.[21]

Example of Sheffield Forgemasters' analysis of a forging tool



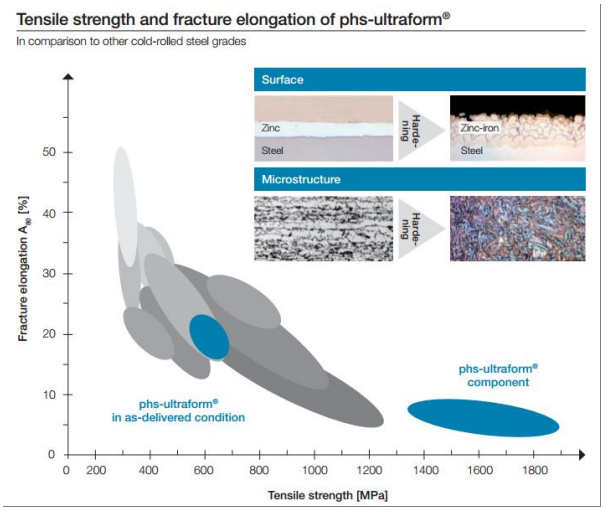
Source: Sheffield Forgemasters

Problem 2 – Next Generation Forging technology needs to be environmentally friendly, resource efficient and functionally affordable, taking into account a need for new lighter-weight, higher-strength, and higher-quality alloys.

Innovative solution 2 – **Voestalpine Plastics Solutions** focuses on the development of hybrid solutions, particularly combining the design freedom of plastics and the strength of steel. These are simply referred to as Plastic Metal Hybrids and form a key example of next generation alloys that reduce the environmental footprint of the industry while meeting increasingly higher customer standards. Innovative materials include SMC (Sheet Moulding Compound), D-LFT (Direct Long Fibre Thermoplastics), GMT (Glass Mat Reinforced Thermoplastics, and phs-ultraform®.

The benefits are best illustrated by considering one of these materials in more detail. Phs-ultraform® is a light-weight material developed and patented by voestalpine. The material is extremely strong (up to 1500 MPa), has a high level of corrosion resistance, causes minimal tool wear (even with high unit numbers), can be used to produce both complex parts and large components, and can be tweaked to the desired properties due to a wide variety of different material and thickness combinations.[22]

Benefits of voestalpine's phs-ultraform® technology compared to conventional cold-rolled steel grades



Source: voestalpine

Problem 3 – There is an increasing need to focus on complex modelling and simulation software to further increase production efficiency of manufacturing facilities. This, in turn, requires specialisation and skills not often available in all production facilities.

Innovative solution 3 – **Simufact Engineering** developed specific simulation software for forging, Simfact.forming. Simufact.forming is a simulation tool that has been developed especially for the forming industry. It has been developed to support in all forming applications, independent from process temperature, machine used or material processed. Examples of forging elements that can be simulated include closed die forging or extrusion, drawing, upsetting, bending or free forging, flat rolling, profile rolling or tumbling – cold, hot or semi-hot, mechanical press, hammer or screw press, rolling machine or orbital forging.

With Simufact.forming, companies have access to an integrated simulation environment for the optimisation of all forming processes. As such, it provides a valuable tool for simulation the efficiency of (changes) in the forging process without the need to build prototypes. Moreover, the depth of the simulation is increased thanks to the advanced modelling software, which allows companies to have a more complete and accurate simulation of the forging process.

However, the complex modelling software may also be more difficult to use or understand for companies. Therefore, Simufact Engineering also offers an extensive range of consultancy services that help implement the software with the client, based on their clients' needs.

Simulation elements of simufact.forming software

Source: Simufact

Problem 4 – Nowadays shaped parts and fasteners are almost exclusively produced by forging processes, which are traditionally suitable for high volume standardised products. Customers, however, require increased product quality, small batch sizes, complex parts geometries and just-in-time delivery conditions. This poses significant challenges for the automation systems in the forging industry.

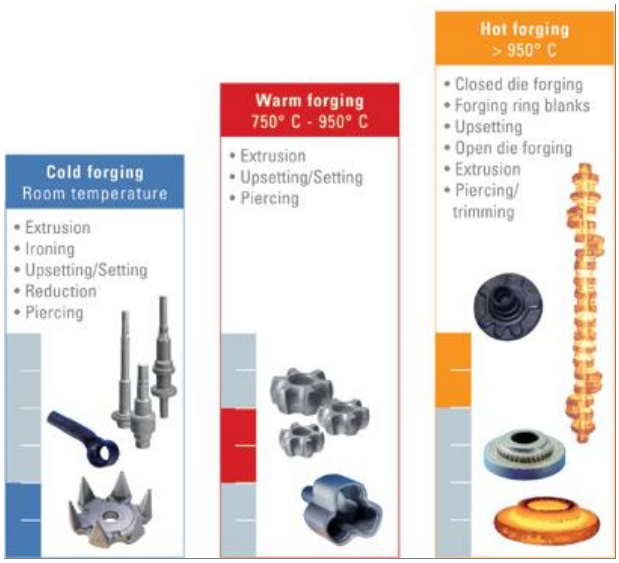
Innovative solution 4 – Schuler Group is one of the leading suppliers of cold, warm and hot forging systems in the world. Schuler aims to develop innovative forging solutions, underlined by their claim that they will provide Europe's most modern forging line to an automotive supplier in Turkey by early 2015.[23]

To tackle the challenge described in the problem statement above, Schuler has developed a number of forging technologies that can be applied. One example concerns the FormMaster multi-station presses. These presses have been designed in dialogue with operators, production and

maintenance specialists, and toolmakers and designers. Moreover, the FormMaster multi-station can be combined with Schuler's Servodirect technology, which further increases the efficiency of the process.

Aside from the FormMaster technology, Schuler has developed a number of other forging techniques in all ranges of cold, warm and hot forging processes. For instance, their eccentric presses with Servodirect technology offer both a high component quality with complex parts and a high level of energy efficiency compared to conventional presses.

Examples of Schuler's cold, warm and hot forging systems



Source: Schuler Group

Problem 5 – Customers demand high precision forging solutions to minimise the occurrence of errors during manufacturing.

Innovative solution 5 – AURRENAK is an SME with more than 30 years of experience in the forging industry. They specialise in castings and tooling for the automotive sector. They employ a wide range of forging activities, including the design and manufacture of elements for tooling manufacture, verification and assembly.

Over the years, AURRENAK has specialised in the development of high precision casting tools. These casting tools reduce the number of errors that occur during the manufacture of castings. AURRENAK offers high-pressure die casting solutions, iron sand casting solutions, and gravity & low pressure casting solutions. Moreover, they have engaged in various collaborative research projects in this field, including the innovative REForCh project funded by the European Commission through the Seventh Framework Programme.[24]

The technology developed for the REForCh project exemplifies the innovative power of AURRENAK. Within a consortium of 3 SMEs and 3 research institutions, they are developing a resource efficient forging process chain for complicated high duty parts. By applying flash reduced forging to the forming of high duty parts, high dimensional accuracy and high quality parts can be forged with less energy and material consumption.

The forming stages of a crank shaft produced with flashed reduced forging

Source: http://www.reforch.eu/

3.3. The (socio)-economic effects of the trend

The European foundry and forging industry is dominated by small and medium-sized enterprises (SMEs), which make up 80% of the companies in the industry. Illustratively, the average number of employees per company was about 118 per forge in 2008.[25]

An important consequence of the technological progress in the forging industry is an increasing demand for higher skilled jobs and for medium-skilled jobs with a specific technological focus. Market research suggests that the number of unskilled workers in the forging industries have gone down in virtually all countries of the European Union in the past decade.[26]

This is also reflected in the average output per worker in the forging industry. Between 2005 and 2008, the average volume output per worker increased from approximately 75 tonnes to about 95 tonnes. It has been argued that the explanation for this rise in output is mostly found in the strong investments in innovative technologies. These technologies required a higher level of skill to operate, which in turn required European companies to increase the share of medium to high skilled labour. This trend is expected to continue, though at a somewhat lower rate.[27]

The European forging industry also plays a role as an enabling industry for other industries. Forged components make possible designs that can accommodate the highest loads and stresses. Recent advances in forging technology have significantly increased the ranges of properties available in forgings.[28]

3.4. Client perspectives and challenges related to the uptake of the trend

Next generation forging technology capitalises on underlying trends, such as a need for more efficient forging processes, the availability of advanced simulation software, and a need

for more research efficient and sustainable production methods.

Major factors that drive the uptake of the trend include:

- **Environmental regulation**: With a clear need for less environmental impact of production facilities, regulation can stimulate the uptake of alternative technologies that are more resource efficient and environmentally friendly. For instance, specific regulation on carbon emissions or restriction of Substances of Very High Concern under the REACH legislation forces producers to switch to alternatives. As this touches some of the key benefits of next generation forging technology, current environmental regulations help the uptake of advanced forging technologies that address environmental concerns.

- **A need for increasingly more efficient and flexible manufacturing:** Most of the next generation forging technologies help make forging processes more efficient and flexible, e.g. through the provision of more accurate simulation software and more adaptable forging techniques. Next generation forging technologies thus capitalise on this market need, which drives growth in this market segment.

- **Broad application area of the technology, providing a strong and established customer base:** The broad application area of the technology results in potential efficiencies in production, potential cost-efficiencies for producers as well as end-users, and lead to higher quality products.

Major challenges that may negatively impact the uptake of the trend include the following aspects:

- The manufacturing industry is often characterised as having **a rather traditional approach towards technology**. In practice this means that manufacturing companies may require extensive convincing to employ new technology. Especially for smaller companies that develope innovative forging technologies, convincing industry giants can be challenging and hinder a quick market uptake.

- With part of the manufacturing industry shifting towards other regions, such as Asia, **European forging technology companies risk losing part of their local markets** and need to increasingly employ their businesses on a more global scale. Companies that supply forging technology to such manufacturing companies need to be willing and able to work outside of their local region. An important aspect of that is to understand cultures and markets in other regions of the world. Setting up subsidiaries in other regions or working with local partners may help in opening up opportunities in other regions.

- Furthermore, the trend of part of the industry shifting towards other regions also potentially detaches European research centres and research departments from some of their end-customers. This can make it more challenging for European forging companies to develop technologies that fit their customers' needs as they are often physically too far removed from their customers to fully understand the desired end-user solution. Working with local partners, opening up subsidiaries, and working on-site in other regions for short periods of time can help overcome this challenge.

4. Drivers and obstacles

This section addresses the drivers and obstacles for the successful uptake and proliferation of next-generation forging technologies in the European manufacturing industry. Two of the main obstacles identified in the industry relate to supply risk (i.e. access to materials and energy at competitive prices) and a risk of shortages in skills. Furthermore, successful companies tend to be driven by a market based approach, actively catering to the increasingly more complex needs of customers. These companies also strive for excellence with continuous innovation in order to stay globally competitive. The drivers and obstacles are discussed in more detail below.

4.1. Shortages in skills and competence deficits in Advanced Manufacturing Technologies

Most companies **struggle to find highly skilled and specialised employees, especially highly skilled engineers.** This challenge is typical for European companies that require human resources with specialised technical skills. An up-side for the large size of the companies included in this case study is that they can leverage their size to more easily compete for talent.

Nevertheless, talent shortages are still reported. This challenge is mostly addressed through engaging in collaborative research, attracting PhD-students, offering internships and giving company presentations to incumbent graduates. Collaborative research allowed the companies to undertake projects by sharing resources, i.e. sharing part of the workload of the project among resources from multiple companies. Interns and PhD-students in many cases not only brought companies valuable resources, but also offered companies a way to show the students what the work was like. Through both internships and PhD-scholarships, they have managed to attract and retain talent in their companies. Moreover, company presentations helped to promote the company under potential employees.

Most companies struggle finding highly skilled and specialised employees. To overcome this challenge, Sheffield Forgemasters developed an award-winning apprenticeship programme.

Additionally, a highly relevant trend emerges of **increasingly more shortages for medium-skilled technicians and engineers** (i.e. upper- or post-secondary trained employees). In Europe, highly skilled graduates are slowly crowding out medium-skilled graduates over time. This trend is expected to continue in the coming years. [29] In contrast to traditional forging technology, advanced forging facilities require technicians with a set of specifically trained skills to be able to operate the relevant machinery and equipment. This typically requires technicians that completed (lower) tertiary education, either in-house or at a learning institution, which are becoming more scarcely available.

To address this type of skills challenge, **Sheffield Forgemasters International Ltd. developed an apprenticeship programme.** Applicants (typically aged between 16 and 24 years old) are trained the "Forgemasters way". The programme, supported in part by government funding, is highly acclaimed and provides Sheffield Forgemasters International Ltd. a competitive advantage over their competitors. [30] Sheffield Forgemasters' apprenticeship programme shows that forging companies that face this skills challenge could consider setting up (joint) apprenticeship programmes to overcome this.

4.2. Complexity of simulation software is both a driver and a barrier to growth

While more sophisticated simulation software is a key driver for the trend, it also brings about challenges in developing, using and improving the software. This **requires a high degree of technical skills, typically scarcely available to the companies.**

On the up-side of simulation software, it can be noted that companies providing such software cater to a very specific need of end-users. Simulation software allows, for instance, simulating the functionality and design of castings before they are tested on a production run. This saves customers both time and money and allows for rapid changes to the design to further optimise the forging process. In such cases, more complexity goes hand in hand with advantages such as more accurate results and more parameters to tweak. This makes it more interesting for production companies as well, stimulating the up-take of the innovation.

Companies face challenges in having access to materials and energy at globally competitive prices and deal with the challenge by focusing on developing leading edge and energy efficient technologies.

However, this complexity also brings about a challenge that is highly related to the skills challenge described in 4.1. **The more complex simulation software becomes, the more difficult it becomes to develop, employ and adjust it.** This requires highly skilled professionals that can work with highly complex simulation software.

Forging companies that provide advanced simulation software also need to incorporate the needs of their customers, which vary on a case-by-case basis. Apart from the fact that this demands high technical skills, a set of soft skills is also crucial to understand the customers' needs. Moreover, soft skills are needed to provide consultancy services that rely on the possibilities of the simulation software. Such consultancy services typically focus on optimising forging processes at companies by providing extensive recommendations for improvement, based on the outcome of simulation exercises.

Simufact Engineering can be taken as a key example of a company that leverages this combination of hard and soft skills. While they currently develop and provide leading-edge modelling software in this field, they started out as a consulting company more than thirteen years ago. Back then the company used powerful existing modelling software from the United States (MSC.Software), but continuously improved and enhanced this software. Driven by high success on the German market, the company ended up acquiring the complete manufacturing modelling department from MSC.Software in 2007. This has provided them with a good balance in technical competencies and business skills, which primed the company for explosive growth.[31]

4.3. Access to globally competitive prices for materials and energy

Forging is highly energy intensive and is dependent on raw materials. In order for the EU forging industry to be competitive, producers need access to energy and materials at competitive prices.

Compared to other regions, Europe has faced serious challenges in gaining access to materials at competitive prices. Reason for this is the strong competition of some of Europe's largest trading partners, particularly China. **Specific examples include challenges in access to scrap metal, which have forced European producers to switch from scrap material to ores and concentrates**. In more critical cases, such substitution was not possible and has resulted in lower production. It is expected that aluminium and copper casters in the forging industry will be affected by this trend in the coming decade.[32]

Access to energy at competitive prices is also a challenge in Europe. Although intra-EU differences can already amount to significant differences in prices of gas and electricity, the difference between Europe and other world regions is even greater. This puts forging companies in Europe at a considerable disadvantage, especially in the more traditional mass product and commodities markets.

Companies in Europe find different ways of dealing with this challenge. **The companies analysed in this case study predominantly focus on developing and employing leading-edge technologies to gain a competitive advantage over their direct competitors.** Instead of competing merely on price, these companies typically develop high-tech solutions that provide their customers with benefits such as improved resource efficiency, more flexibility, and forgings from stronger and lighter materials. By developing technologies that are more resource efficient than their competitors, some of the impact of comparably high material and energy costs are compensated.

Voestalpine provides a prime example of how companies can deal with this challenge. By focusing on their innovative power, they have been able to develop hybrid materials for their forgings that are more resource efficient, more flexible and stronger than their non-hybrid counterparts.

Furthermore, **Simufact Engineering** can help make forging processes more efficient with their specialised forging simulation software. In a way, their technology can be seen as a key element for companies to overcome some of the challenges described in this section, which in turn stimulates the uptake of Simufact Engineering's simulation software.

4.4. A market driven approach that goes beyond the traditional boundaries of forging

Another common denominator across the companies is that **each of them has a strong market focus**. Not only are they actively pursuing market opportunities, but they are also very focused on specific customers' needs.

Moreover, to better serve their customers, the analysed companies tend to go beyond the traditional boundaries of the forging industry. In parallel with their core forging activities, these successful companies offer their clients a wide range of support and consultancy services. This observation is in line with the general trend in forging companies of the future. Customers expect increasingly more flexibility from manufacturers and a better fit with their requirements. This requires manufacturers to offer a more differentiated approach to their customers. Next generation forging technology enables manufacturers to offer a higher degree of flexibility.

Through continuous expansion for their Research & Development department, voestalpine aims to position itself as an international technology leader.

An example of this is Schuler's Crossbar Feeder technology, which allows users to transport and position parts more flexible in press lines. Another one can be found in Simufact Engineering's simulation software, which reduces costs and time by providing high precision simulation outputs.

The companies' ability to adapt to the needs of their customers, and to provide support well beyond the traditional boundaries of forging, gives them a strong competitive edge and is a key driver for their success.

4.5. Continuous innovation is key to keep a competitive edge

The companies in this case study **share a focus on their innovative power.** This focus on innovation is needed to overcome some of the key challenges described in this report, including competitive pressure in markets for mass products and access to materials and energy at competitive prices. This focus is also communicated publicly, e.g. with the Schuler Group underlining their ability to innovate through numerous case studies published on their website together with references to patent applications of leading-edge technologies. Furthermore, Sheffield Forgemasters International Ltd. identified R&D as "fundamental to the strategy of the business".[33]

Voestalpine also thanks its competitive edge to their strong focus on innovation. The company has a clear strategic objective to *"achieve the most modern technologies and the best qualities"*, claiming that it is their guarantee for success and survival.[34] With increasing international pressure in more traditional markets, such as the mass products and commodities markets, CEO Wolfgang Eder argues that the company needs to focus on other niches.[35] Their focus on innovative power ensures voestalpine to stay internationally competitive. In fact, voestalpine plans on continuous expansion for their research and development department to position itself as an international technology leader.

4.6. Accessing markets outside of Europe can be challenging but it is increasingly important

One of the threats that European forging companies face is that part of their customer base is moving to regions outside of Europe. With particularly the high volume forging facilities moving from Europe towards Asia, European SMEs in the forging industry run a risk of becoming disconnected from part of their customer base. Without a direct customer base in the near vicinity, it makes it more difficult for these forging companies to develop relevant solutions for their market. Moreover, the distance between the companies and their customer base as well as the cultural differences that may arise can make commercialisation of innovation a difficult process.

In addition to gaining a presence outside of Europe and staying connected to the customer base, **new business opportunities exist outside of Europe for European forging companies.** Although particularly Asian manufacturing industries are often considered as having outdated technology in place, market reports suggest a shift towards more advanced technologies being developed and employed in the region.[36] European forging companies developing next generation forging technologies could capitalise on this market trend once connected to established players in regions outside of Europe.

However, forging companies, particularly SMEs, find it difficult to access these non-European markets. Reasons for this were reported to be cultural differences, a lack of a local presence, and the absence of a network in target countries. This makes it difficult to engage with potential customers. To overcome this challenge, **AURRENAK signed a partnership agreement in 2009** with Ningbo Heli Mould Technology Sharehold Co. Ltd, a large Chinese foundry.[37] The aim of the partnership is to undertake joint projects under the name of "European technology and Chinese manufacturing". For AURRENAK, the key reason for engaging in a partnership with a Chinese foundry was to secure its position in the Chinese market. Their Chinese partner in turn benefits from the technology jointly developed with AURRENAK.

AURRENAK signed a partnership agreement in 2009 with a large Chinese foundry to undertake joint projects and secure its position in the Chinese market.

4.7. Access to finance is a potential barrier for up-scaling

Admittedly, none of the companies included in this case study has faced serious constraints in attracting capital. Of course, attracting capital on the right terms and at the right moment is a challenging business element. However, the sheer size of the companies included in this case study enables them to overcome most of these concerns.

Nevertheless, it was indicated that access to finance may be a particular concern for SMEs. The highly competitive market requires highly innovative solutions, which puts considerable pressure on R&D activities. However, the critical moments for funding are when companies want to up-scale their technology. Manufacturing facilities are expensive, and so is the testing of new forging technologies. **Further up-scaling new forging technologies requires considerable capital investments, which in practice are out of reach for SMEs.**

However, it should be mentioned that **SMEs often have opportunities to work together with large companies** to jointly develop such solutions. For instance, the Seventh Framework Programme – an EU funding programme – has supported various projects in this field, such as REForCh.[38]

5. Policy recommendations

Following the drivers and barriers identified in this case study, a number of policy recommendations have been drafted. These include addressing the skills gap in advanced manufacturing technologies, promoting an environment of multidisciplinary, stimulating the development of alternative materials for forging and resource efficient forging solutions, promoting eco-efficiency in the manufacturing industry, and stimulating international collaboration between European forging SMEs and manufacturing companies in other regions of the world. These recommendations are explained in more detail below.

5.1. Address the skills gap in AMT by stimulating companies to (jointly) develop apprenticeship programmes

Companies face challenges in attracting people with the right skills to do the job. The companies in this report illustrate interesting ideas that can be further explored at the EU level.

Of particular interest are **apprenticeship programmes developed by companies**. Learning on-the-job is a key element for obtaining the right set of skills required to successfully execute a job task. Moreover, it helps students to familiarise themselves with their actual future working environment and introduces them to real-world cases and challenges they can choose to work on after they finish their studies. Apprenticeship programmes also offer students a certain degree of job security, as they are to a large extent ensured of a job after they finish their apprenticeship programme.

For companies, apprenticeship programmes also have clear benefits. Not only do they help them to attract talent, it also helps them to train new hires on the specifics necessary to operate their increasingly more complex equipment and machinery. Also, this helps ensuring a good match between skills demand (i.e. the company) and skills supply (i.e. the talent pool). **Stimulating companies to set up similar programmes may therefore help at the EU level to alleviate some of the skills challenges.**

Some companies may, however, lack the resources to set up such programmes. Moreover, for particularly small companies, the costs of such an apprenticeship programme may outweigh the costs. As a solution, it could be beneficial to stimulate companies to jointly set-up apprenticeship programmes. While some specifics may need to be trained at the company level, such as working with proprietary technology or processes, more generalised modules may be set-up jointly in order to share the costs.

Furthermore, **the development of EU-wide targeted skills programmes that focus on specific technology areas** may improve the availability of qualified human capital needed to drive the (further) development of forging technologies of the future.

5.2. Promote an environment of multidisciplinary, especially between software engineering and manufacturing

Simulation software in the forging industry of the future requires professionals that **understand the manufacturing processes as well as are skilled in developing and using advanced simulation software.** This requires a certain degree of multidisciplinary, both of individual workers and of teams.

Currently, students are typically trained in either manufacturing or software engineering. In order for them to jointly address these topics, it would be highly beneficial if these students interact. Also, a focus on multidisciplinary would allow skilled professionals to learn from each other, further increasing their ability to react to the increasingly more complex customer demands.

It is therefore recommended to **promote an environment of multidisciplinarity, particularly of manufacturing engineers and ICT professionals.** Together, these two groups of highly skilled workers are more likely to address the complexity of modelling software while keeping in mind the increasingly challenging end-user requirements. Furthermore, in specific apprenticeship programmes both the required software engineering skills and the required manufacturing skills could be trained. This would help to provide future workers with the right set of skills for developing and employing particularly complex forging simulation software.

5.3. Stimulate the development of alternative materials for forging and resource efficient forging solutions

Materials and energy are a key input for the forging industry, as is true for the manufacturing industry in general. This case study describes that **European forging and manufacturing companies face particular challenges in accessing these inputs at competitive prices compared to their global competitors**. While companies would benefit from gaining better access to materials and energy at globally competitive prices, another solution would be to become less dependent on these two.

European funding efforts for research in the forging industry could be focused on alternative materials forging and resource efficient forging solutions. This may incentivise existing companies to develop cleaner forging technologies, it may provide SMEs a platform to demonstrate new solutions that have been developed, and it may reduce the dependency on traditional markets for energy and materials.

Efforts in this respect have already started in Europe and could be further explored within the existing European funding schemes. One example is the REForCh project that was funded by the European Commission through the Seventh Framework Programme. This project aims to develop a new resource efficient forging process chain based on flash reduced forging. It is not only expected to result in a more resource efficient forging process, but it also brings together both SMEs and large industry players in order to boost the commercialisation of the innovation. Within the Horizon 2020 programme, these type of projects could also be considered in specific calls.

5.4. Promote eco-efficiency in the manufacturing industry

Whereas developing resource efficient forging solutions ensures that the technology becomes available, **it is crucial for the survival rate of companies developing this technology that it is adopted by the market.** One of the challenges identified in this case study relates to a traditional stance towards technology in the manufacturing industry. Due to the complexity and volumes of production, established industry players have a tendency to rely on proven methods. This makes it particularly difficult for SMEs to get partners convinced of the benefits of their proprietary technology, which in turn hinders the uptake of new forging technology developed by these companies.

One way to stimulate market uptake is to stimulate eco-efficiency in the manufacturing industry. Manufacturing companies may be incentivised to adopt resource efficient forging processes by e.g. promoting standards or setting clear goals for energy reduction. This not only increases the attractiveness of next generation forging technologies, but also decreases the dependency of the manufacturing industry on resources and materials. The Forging Industry Association already underlined the need for the forging industry to develop advanced technologies for energy and resource efficiency.[39] Policy makers in Europe can leverage on this consensus within the forging industry by setting clear goals together with the European manufacturing industry.

5.5. Stimulate international collaboration between European forging SMEs and companies in other regions

To overcome the challenges European forging SMEs face in accessing markets outside Europe, **international collaboration between European forging SMEs and established industry players or other SMEs from regions outside of Europe could be stimulated.** This creates an international presence of European forging SMEs, helps these SMEs to connect to markets outside of Europe and helps them to deal with cultural differences that may arise. Such collaboration could be stimulated through joint research projects that involve both European forging companies and forging or manufacturing companies that are active in regions outside of Europe.

To facilitate international collaboration, European policy makers can set up international matchmaking events that bring together these companies. Through matchmaking events, common projects could be identified that involve both innovative European forging companies and internationally established companies with a presence outside Europe. Furthermore, European funding programmes could be further explored to fund the collaborative research undertaken within the common projects.

6. Appendix

6.1. Interviews

Company	Interviewee	Position
Simufact Engineering	Dr Hendrik Schafstall	Managing director & partner
voestalpine	Dr Wolfgang Eder	CEO
Schuler Group	Simon Scherrenbacher	Corporate Communications
Sheffield Forgemasters International Ltd.	Dr Graham Honeyman	Chief Executive of SFIL
AURRENAK S. Coop	Mr. Borja Lizari	Managing director

6.2. Websites

Simufact Engineering	www.simufact.de
voestalpine	www.voestalpine.com
Schuler Group	www.schulergroup.com
Sheffield Forgemasters International Ltd.	www.sheffieldforgemasters.com
AURRENAK S. Coop	www.aurrenak.com

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