Hydroforming in high-volume Production

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1 Abstract

Hydroforming has always been a method which is not only used for smaller batch sizes but especially for mass quantities with more than 250,000 units. For high volume production, in comparison to medium-sized series, the focus is moving from questions of feasibility and tooling costs to cost-optimal solutions with high automation capability, process stability and short cycle times. Since many years Salzgitter Hydroforming (SZHF) is producing both components for heating technology and exhaust applications in sometimes complex multistage hydroforming processes, as well as chassis and body components with standardized process chains.

In the following report tooling and automation concepts for chassis parts both with high flexibility for variable manufacturing processes of exhaust gas components as well as highly specialized large-scale solutions will be presented. The new production line of the site Brumby is highlighted: Around the core unit of the 50,000 kN hydroforming press all preform operations starting from the tube magazine with weld positioning, three CNC mandrel bending machines and preforming press via a buffer with the two cutting lasers and subsequent run washer system through to automated packaging are fully interlinked and fully automated. It is reported on the experience of the first year of production of the plant.

2 A Serial Production Hydroformer in changing European Market

Even in Europe the automotive production is slightly increasing in the last few years. The increase of the hydroforming market was stronger than the growth of the automotive production with the exception of 2015 (Fig. 1), where the new hydroforming business fell back to the still high level of 2012/13.
Figure 1: Overview of automotive production of hydroformed parts in Europe

Figure 2 shows the development of the hydroforming presses in Europe. Since 2004, no evident trend is given. Moreover, similar to the order rate, stagnation takes place. Significant productivity gains are reached by major retrofits of presses.

Figure 2: Number of Hydroforming Presses in Europe
3 Boundary Conditions at series production of hydroformed parts

Typical products for hydroforming are exhaust and body & chassis parts. Dividing the first from the latter two, Figure 3 sums up the development of the amount of parts clustered in groups. Here a trend to medium sized orders is noticeable for exhaust components. For Chassis components no significant trend is seen.

![Figure 3: Distribution of small, medium and high volume products 2013 & 2015 in Market segments Exhaust and Chassis & Car body](image)

3.1 Chassis Components

The quantities in chassis and body ranges significantly higher than the exhaust components. Volumes of 150000-500000 parts are common and of cause batch sizes are significantly higher. Automation concepts are much easier because of standardized process chains for most chassis components, Figure 4:

![Figure 4: Process chain for hydroformed chassis components](image)
3.2 Exhaust Components

Most Automotive platforms have only one or two different chassis but can have a plurality of different exhaust systems, depending on engine and country-specific requirements. This results in annual quantities of 5,000 to 100,000 parts per year, at usual batch sizes from 250 - 6,000 parts. As can be seen in figure 5, the complex parts have several working steps to be followed separately. Typically different components need differing process chains, so a standardized automation concept for a vast number of components.

![Process chain for hydroformed exhaust components](image)

Figure 5: Process chain for hydroformed exhaust components

4 Challenges for Manufacturers

4.1 Evaluation of different production concepts

Based on the market requirements, Salzgitter Hydroforming has adapted its manufacturing processes. For a 2nd Tier supplier a high degree of flexibility is of special importance with regard to the varying customer requirements (product-specific flexibility) and with respect to the fluctuating volume (capacity-related flexibility). So in the facilities of Salzgitter Hydroforming all three most used manufacturing processes, and if necessary combinations, are used:

- Workshop manufacturing
- Line chained manufacturing
- Island Manufacturing
Already in the product offer phase it is essential to choose proper manufacturing processes, as this is the basis for important cost factors of the component. This takes place with the respective advantages and disadvantages taking each procedure into account.

The following Table 1 summarizes the previously mentioned fact.

<table>
<thead>
<tr>
<th>Production Concepts</th>
<th>Advantages</th>
<th>Disadvantages</th>
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<tbody>
<tr>
<td>Workshop manufacturing</td>
<td>High flexibility</td>
<td>High stocks</td>
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<td></td>
<td>High efficiency</td>
<td>High throughput times</td>
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<td></td>
<td>Less sensitive</td>
<td>High planning effort</td>
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<tr>
<td>Chained line manufacturing</td>
<td>Low stocks</td>
<td>Limited flexibility</td>
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<td></td>
<td>Short throughput times</td>
<td>High investments</td>
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<td>Island manufacturing</td>
<td>Good QA-loop</td>
<td>High empty / setup costs</td>
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<tr>
<td></td>
<td>High flexibility</td>
<td>Reduced efficiency</td>
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<tr>
<td></td>
<td>Good division of labor</td>
<td>Highly skilled personnel</td>
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<tr>
<td></td>
<td>Good QA-loop</td>
<td>High implementation costs</td>
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Table 1: Advantages and Disadvantages of different production concepts

Under the conflict of objectives of minimizing lead times and the highest possible capacity utilization, especially the production volume plays an important role in deciding on the method of manufacturing.

### 4.1.1 Exhaust Components – Workshop and Cell Production

To produce lower quantities of many similar derivatives with complex task schedules at optimal costs, a high degree of flexibility is required. This offers the workshop production, in which a group of functionally identical or functionally similar machines are spatially combined by the vicarious principle. At the Crimmitschau site, where the exhaust gas components are concentrated, there is such a concentration of similar work activities, such as in the bending center, the press hall or the finishing center. For utilization of cost potentials a number of machines is automated to allow e.g. a multi-machine operation.

The workshop production gets combined with a cell production, a form of group production. The method is used in the finish area, in which a group of workers and/or
machines manufactures products through several different process steps. A prerequisite is that all required resources in the manufacturing cell are ready for usage, regardless of the capacity utilization rate.

### 4.1.2 Chassis Components – Line Production

The quantities for chassis and body components range significantly higher than for the exhaust components. Volumes of 150000-500000 parts are common with corresponding higher batch sizes. For the production of high volumes of products with a low amount of working steps, a faster production cycle with low work-in-process is important. This option provides the production line with a complete series of operations. In this type of production, the spatial arrangement of resources and jobs to the production process takes place. The production process determines the order of the production facilities. At the Brumby (Germany) site three production lines are in operation based on this concept. These are linked together with automated handling technology and have intermediate buffer to absorb disturbances in the workplace, which in turn leads to reduction of production standstills.

Thus the line production has clear advantages in a high-volume component spectrum. But here there is the conflict of a high production output and demand of more flexibility and a reasonable investment level. The latter is of increasing importance for many of the medium-sized manufacturers of hydroformed components. The financial crisis showed limits for smaller companies requiring funding for production lines. In demand are new approaches that lead to a significant reduction of investment resources, while maintaining the same or even improving production yield. One way is the specific use of retrofitted machines. From the boom phase of hydroforming technology in the late 90s, there are a number of bending machines and hydroforming presses, which are released due to run out productions or strategic reorientations. These systems comply in the mechanical and hydraulic state still with the present state of the art. With a specific modernization of electric and electronic components as part of a major overhaul, the machines can be re-upgraded so that they are entirely equivalent in performance to new systems. A further use of the plants for 10-15 years can be planned. Compared with the procurement of a new plant, there are significant savings possible.
4.1.3 Practical Example

For product manufacturing with limited flexibility there are also concepts in order to circumvent high investment costs. Automations at SZHF are designed in a way that offers additional opportunities to infeed and outfeed parts in the individual processing steps. This allows great flexibility in the production run, to cover a high variety of components. In addition, under these conditions, production cells can be switched on or be deselected, which is particularly positive in case of incidents. Our new production line at the site Brumby meets these requirements considering high flexibility and high production performance at the same time, (Figure 6).

Main plants are a preforming-press with 2,000 kN and a 50,000 kN hydroforming-press, which were originally established in the late 90's in Italy by a well-known 1st tier supplier. After production ran out, we took over the plant technology and built it up in Brumby. The hydroforming press received a modernization of water hydraulics and was equipped with a completely new control. Unlike the original use of the presses, where they were operated as "stand-alone units" they are now integrated into an automated line including three CNC bending machines. Only one bending machine was newly procured. The other two are already 20 and 10 years old and were just completely retrofitted with the analog performance characteristics of the new plant. The forming line is built up in three cells:

1. Material feeding, positioning, bending
2. Oiling, preforming
3. Hydroforming, component geometry control, material buffering,

which can be operated both as an automated line, as well as single cells. This is gained by a separation of the control-devices of the cells and the possibility to put in or put out semi-finished products of each cell.
Figure 6: Fully automated forming and finishing line

To ensure trouble-free automatic line operations, a buffer for 20 components is located between the first two cells. Failures in the bending area can be compensated through this buffer. Moreover, since the capacity of the bending machines exceeds that of the remaining line, the buffer can be filled time neutral again after a stoppage (see Fig. 7). Between the different cells there are possibilities for component control via SPC access. The described line concept achieved that no manual component handling is required, and the operator only has monitoring tasks from material entry to output.

Figure 7: Bending Center with conveyor buffer
Compared with the first automatic route, which was put into operation in Brumby 2001, the workforce has been halved, while increasing the output by over 30%. In contrast to the first line, where the component removal is still done by hand, this is now done through a discharge system, which transfers each component accurately to special containers. This is necessary, because another automated production line for further processing and finishing is following. This finishing line is therefore divided into three cells, working analogue to the forming line in chain or alone:

1. Material feeding, laser cutting (Figure 8)
2. Washing
3. Package

Key pieces of the line are two twin-cabin-laser-systems and a water-based spray washer. A special feature of the configuration of the line was the automation of the twin-cabin-laser-systems on which there was no significant experience. With the installation of 6 axis handling robots it has successfully been integrated. A further challenge was the limited space that would allow the component removal from the laser cell only with an overhead conveyor.

Figure 8: Laser Cutting in line and Washing line

This overhead conveyor (as seen in Figure 8) is designed in a way that allows to stop or remove the individual hangers at will, regardless of the continuously circulating conveyor chain ("Power & Free system"). Each hanger consists of a trolley and a universal frame on which the entire range of parts can be used both manually and automatically. Addressing the hangers takes place via an RFID chip, which is rewritten in each cycle.
according to the provided sequence. The standard version of the processed components is passed from the laser to the conveyor and then driven through the 20 m long cleaning plant where they get washed, rinsed and dried.

Automatic packing of the parts takes place at one of four output stations. In pure automatic mode there is only monitoring personnel necessary. The entire system can be operated by two people. In the mixed mode of the washing system (automatic, manual assembly) two further operators are provided for input and output.

By harmonization of the cycle times of the forming and the finish line, the components can be produced continuously and with minimal lead time. Intermediate stocks and so-called unready products do not occur, which simplifies manufacturing planning massively.

This production concept enables Salzgitter Hydroforming to offer each customer the optimal solution for each product and production volume.