

Investigation of the Electrohydraulic Forming Process with respect to the Design of Sharp Edged Contours^{*}

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Abstract

The overcoming of design constraints with respect to forming of sharply contoured sheet metal workpieces made of high strength steel or other materials which are difficult to form is an important aspect in sheet metal part production. One interesting solution to extend existing forming limits can be the use of electrohydraulic forming as single forming operation or in combination with quasi-static hydroforming. Apart from promising results regarding the feasible part geometries this process allows a quite efficient production due to its potential to reduce equipment expenses.

Current research work at the Chair of Forming and Machining Technology (LUF) at Paderborn University deals with a comparison of investigations on both processes, quasi-static and high speed hydroforming. Recent results show an adequate comparison of achievable edge radii using an oblong die geometry and sheet metal made of thin stainless steel. It can be seen that when using electrohydraulic forming an increase of discharge energy leads to smaller radii than achievable by quasi-static hydroforming.

An additional potential can be seen in the process characteristic itself because the very short pressure pulse allows a significant reduction of locking forces using only the inertia of the tooling mass.

Keywords

Hydroforming, near net-shaped contouring/radius, high-speed hydroforming

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1 Motivation

Requirements regarding the part design and the necessity of an economic realization lead to high demands on multifunctional parts with very complex geometries. Especially the demands regarding surface quality, producibility of sharp contours, and accuracy are difficult to meet by conventional forming processes like deep drawing. This becomes a serious problem when using high strength materials. A promising solution could be the use of special processes like (conventional) quasi-static hydroforming, high speed forming, or a combination of both. Conventional hydroforming allows the production of complex workpieces with favourable properties even when high strength materials are used [1]. Unfortunately, there is a high working media pressure necessary for the forming of sharp contour elements which increases with material thickness and strength. Consequently, very high expenses regarding the machine and tools are necessary [1]. On the other hand, high speed forming processes allow the manufacturing of complex geometries even when high strength materials are used because of a better use of the material formability or the special process characteristics [2]. But high speed processes have some constraints e.g. regarding the production of large scale components (electrohydraulic forming), security (explosive forming), or the material (electromagnetic forming) [3-8]. So a promising solution could be the combination of quasi-static and high speed forming processes. That is why comparative research work regarding a combination of conventional and high speed hydroforming processes is performed at the LUF at Paderborn University. The basis of this research work is a detailed analysis of the properties of the single processes.

2 Experimental setups

2.1 Hydroforming

Conventional quasi-static hydroforming was used as reference process for the comparison of conventional and high speed hydroforming processes. Therefore, a tool setup consisting of a die, intermediate plate, and pressure intensifier ($p_{\max} < 400$ MPa) was used (**Figure 1**). The tool was mounted inside of 8000 kN hydraulic press for applying the necessary locking force.

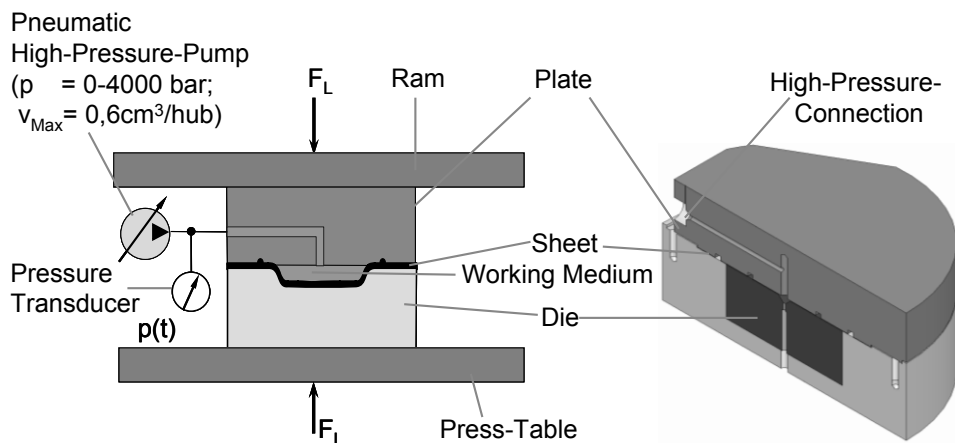


Figure 1: Experimental Setup for the hydroforming of thin sheet metals

2.2 High-Speed-Hydroforming Setups

After a detailed analysis and valuation of principles for the generation of short pressure pulses for the deformation of sheet metal parts four promising methods were selected.

These methods were subject of intensive research work regarding course and result of the forming process, feasibility, achievable part properties, and expenses. Therefore, two different electrohydraulic experimental setups, one electromechanical and one pneumomechanical, have been realized (**Figure 2**).

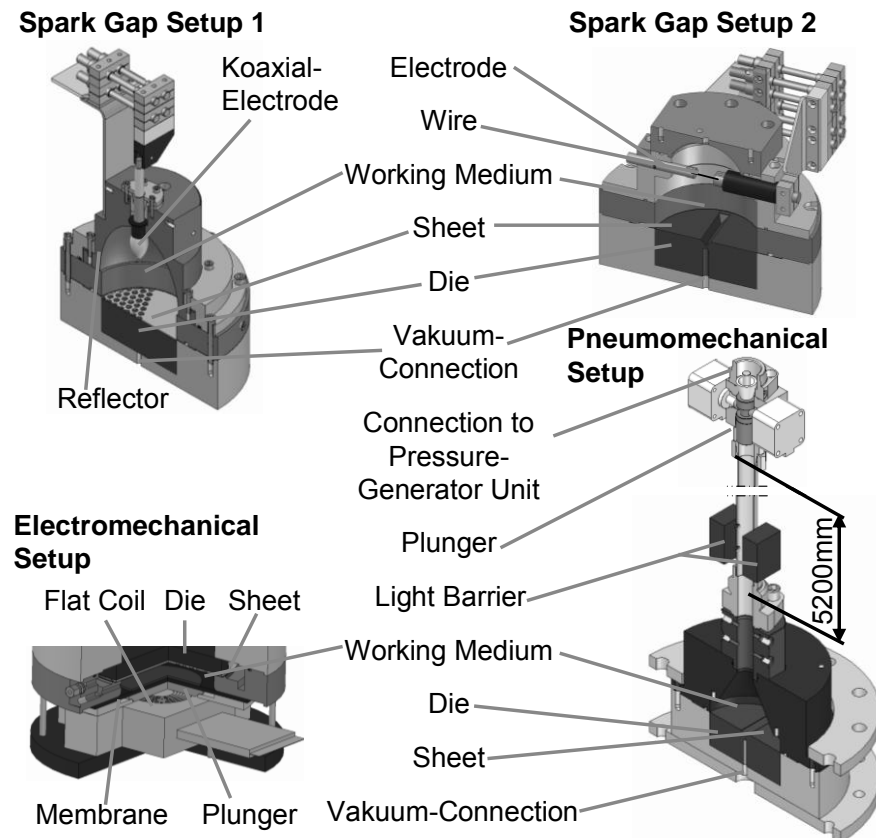


Figure 2: Assortment of experimental setups for the generation of pressure pulses in a working medium

The electrohydraulic setups consist first of all of a capacitor, a switch, and an underwater spark gap which was mounted inside of a closed container or tool. The maximal charging energy was 5.6 kJ. The difference between the two setups is the use of a thin wire for easier ignition in the second setup (**Figure 3**) and the use of a reflector for focussing the shockwave in the first setup.

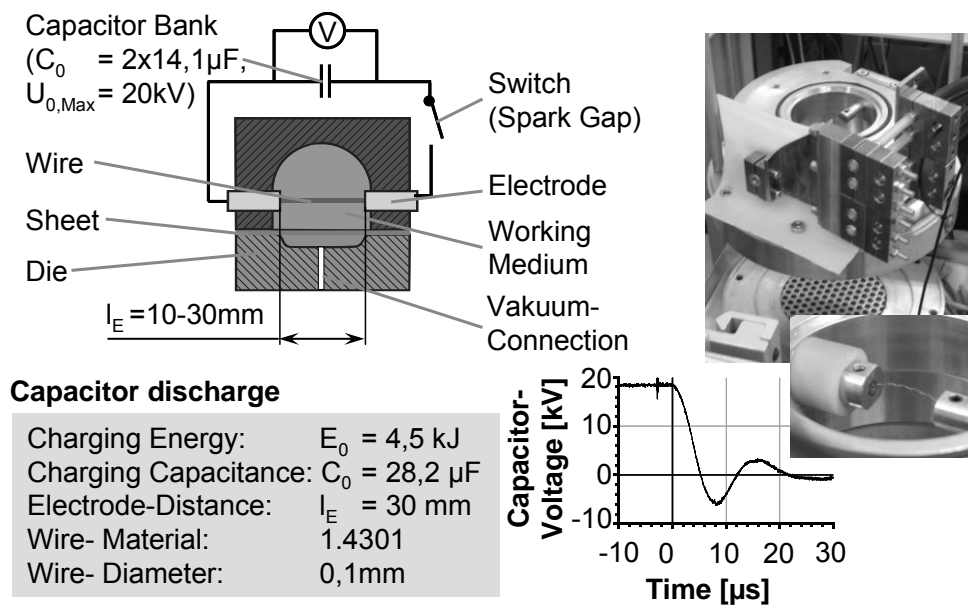


Figure 3: Basic process cycle of the electrohydraulic forming process

The electromechanical setup uses a flat coil (connected with a high current switch and a capacitor) to accelerate a plunger (**Figure 4**). The plunger movement causes a pressure pulse suitable for the desired forming operation. The maximal charging energy in this setup was 1.5 kJ.

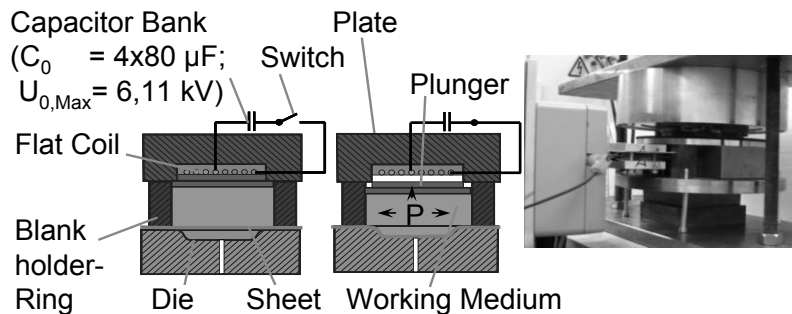


Figure 4: Experimental setup with an electromechanical generated pressure pulse

The fourth experimental setup which has already been investigated is a pneumomechanical setup where the pressure pulse is generated by the impact of a pneumatically accelerated plunger into a working media reservoir (**Figure 5**) [9], [10]. The experiments were conducted on the setup shown in **Figure 5** which had an acceleration tube made of steel with a length of 5200 mm, an outer diameter of 38 mm, and an inner diameter of 33 mm. The maximum energy that can be achieved with this setup is currently limited to 1.4 kJ.

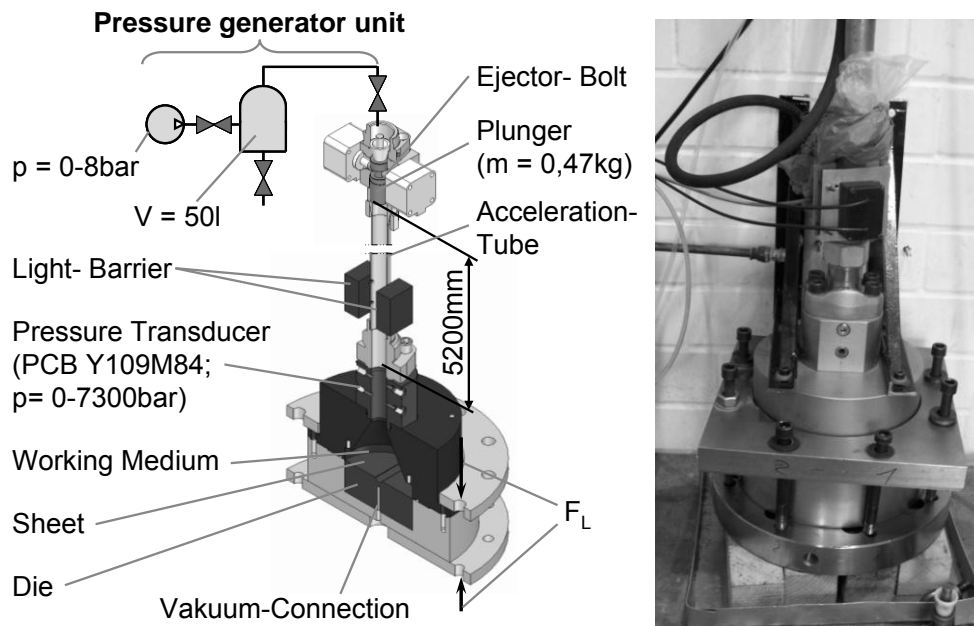


Figure 5: Pneumomechanical setup

3 Technological Research Work

Focus of the technological research work concerning a comparison of conventional and high speed hydroforming was first of all the examination of pressure distribution and effects on the workpiece during the process. After that, the forming of strongly contoured workpieces with difficult geometrical details was subject of intensive research work. As demonstrator geometry a v-shaped groove with a wall angle of 90° and a width of 15 mm was selected. This geometry was chosen being comparable to a sharply contoured geometry element of body in white structures. To realize the desired sharply edged bottom radius with only small acceptable geometry deviations is a demanding forming task. A production using conventional deep drawing processes is extremely difficult and only possible with high expenses. A better solution is the use of hydroforming processes which allow the manufacturing of such parts at a better quality. But there are strong differences of workpiece behaviour and forming result using high speed or quasistatic hydroforming processes. During the according experiments workpieces made of aluminum, mild steel, and stainless steel were produced using the electrohydraulic, the pneumomechanic, and the conventional hydroforming process. Therefore, within the scope of the series of experiments the sheets were deformed by increasing the pressure or energy from experiment to experiment. Subsequently, the geometry of the workpieces was measured.

The experiments showed that the manufacturing of sharply contoured workpieces is most conveniently feasible using electrohydraulic processes (**Figure 6**). The results of the quasistatic hydroforming experiments show that an increasing fluid pressure leads to a decreasing radius as expected. The minimal radius which could be realized by quasistatic hydroforming experiments was 1.75 mm. The required pressure of the working media was 2600 bar. The results of the electrohydraulic forming process show that the increasing charging energy leads to decreasing radii. Here, a much smaller radius of 0.8 mm could be achieved by a discharge energy of less than 6 kJ. Thus, with the help of this process e.g. the manufacturing of workpieces with smaller edge radii was possible compared to conventional hydroforming.

The experiments proved that high speed forming processes require dramatically smaller expenses for machines and equipment. So, for the conventional quasistatic hydroforming process a locking force of up to 6200 kN was necessary compared to 200 kN for high speed hydroforming. A disadvantage at this time was the occurrence of geometry deviations (edge radius and workpiece height) over the groove length. The reduction of those deviations is subject of current research work using improved process strategies.

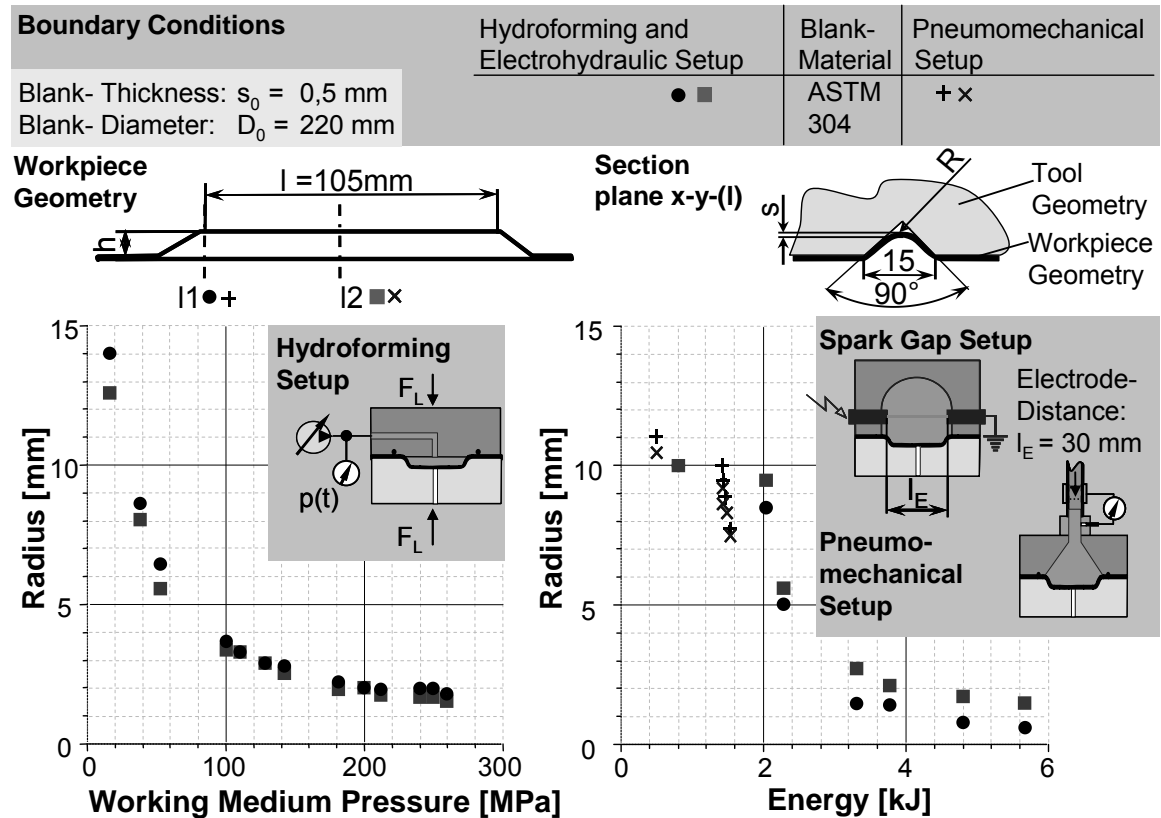


Figure 6: Main influence on the achieved radii depending on increasing pressure and energy

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