White Paper

Hydraulics for high-quality deep-drawn parts

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Key Messages

- Die cushion requirements are becoming more demanding and complex
- Precise analysis, design and installation are one of the key success factors in dealing with this complexity
- Hardware in the Loop (HIL) and test installation leads to early bug elimination. This results in reduced commissioning time and costs, as well as quicker machine operation

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Summary

A Chinese automotive supplier is using a modern mechanical transfer press and a controlled hydraulic die cushion, for the manufacture of high-quality deep-drawn parts for the automotive industry. Working together with its customer, Hagel automation, Moog is providing a complete die cushion solution together with control software. The components produced on these drawing devices can be manufactured at a high clock rate of up to 30 strokes per minute, and they stand out for their forming accuracy and part precision.

Deep drawing is a central function in the forming of sheet metal parts on presses – for example, in manufacturing body parts for the car manufacturing industry. However, the requirements of these presses for the production of deep drawn parts are constantly changing. High-strength sheet metals, more stringent requirements for safety and availability and the forming of ever more complex body parts, require more and more precise process control and overall system design.

The following example of an application employed by a Chinese automotive supplier, shows how a hydraulic die cushion system can be used for precision forming of parts for the car manufacturing industry. The example also illustrates the challenges that were overcome in designing a die cushion system, what needs to be considered when selecting the hydraulic components and how the drawing processes can be optimized with complex control structures.

1)


2)

MOOG

1. Manufacturing car body parts

The goal of the joint project was to use a hydraulic die cushion in the production of body parts for a machine operator involving, for instance, the production of structural components for the A, B, C pillars, exterior structural parts and other parts for body construction. The company makes products for its own automotive brand, and is a supplier for wellknown European and Asian automobile manufacturer. All of the die cushion's components and systems should ideally integrate with the machine design for a compact and custom fit, so as to permit the production sequence to be efficiently used at up to 30 strokes per minute.

A Chinese machine manufacturer initially delivered two presses to the end customer. The company, Hagel Automation, which designs transfer systems and press peripherals for applications used in forming technology and automation, designed and developed both transfer presses for the machine manufacturer and its end customer, the automotive supplier. Moog, a leading global specialist in motion control technology planned, designed and delivered hydraulic, electronic and software components for the die cushion system.

The Chinese press manufacturer chose to collaborate with Hagel because of its extensive experience in developing forming presses and automation technology dating back over 50 years. Hagel, which led the project together with the press manufacturer and the end customer, worked closely with Moog. The company's principal motivation for working closely with Moog was securing a reliable partner with industry know-how. Moog developed and delivered a controlled two-point die cushion system for these two presses, and performed the commissioning of the system for the Chinese end customer.

The engineering of the die cushion system consisted of four steps:

1. Analysing customer requirements / simulation
2. Components selection, design and functional specification
3. Software development
4. Test installation and commissioning.

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A Chinese Tier 1 supplier is using a transfer press for the manufacture of body parts for the auto industry. Moog provided a controlled two-point die cushion system for precise and highly efficient part production.

2. Analysing customer requirements/simulation

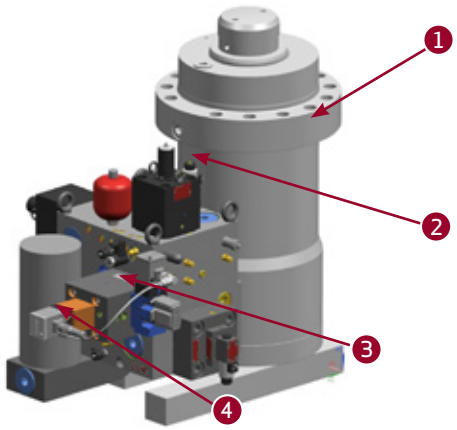
At the beginning of the project, Hagel and Moog analyzed which requirements the die cushion system should meet, so that the required parts could be produced. Important parameters for the system design were: the drawing force, the number of strokes per minute, the masses to be moved, movement profiles and pre-acceleration for a smooth transition of force to the die.

Technical requirements for this application.

Min. force build-up time	80 ms at 100kN -> 900kN
Min. force relief time	150 ms at 900kN -> 100kN
Positioning accuracy	+/- 1 mm
Pressure control accuracy	+/- 5 bar
Max. drawing depth at 30 stroke/min	200 mm
Pre-acceleration to	80% upper ram speed

The question of how best to meet specified output requirements, and with which components, had already been determined during the project planning phase by way of a simulation. By using a MATLAB/Simulink toolbox, the entire mechanical and hydraulic design was mapped out by entering the rigidities, damping and the moving masses. With this simulation, Moog designed a controller structure that was eventually implemented in the controller itself. Using this combination, it was possible to develop settings and evaluations without a real machine for the first time. It also facilitated the evaluation of system feasibility and helped optimize component selection.

3. Component selection, design and functional specification

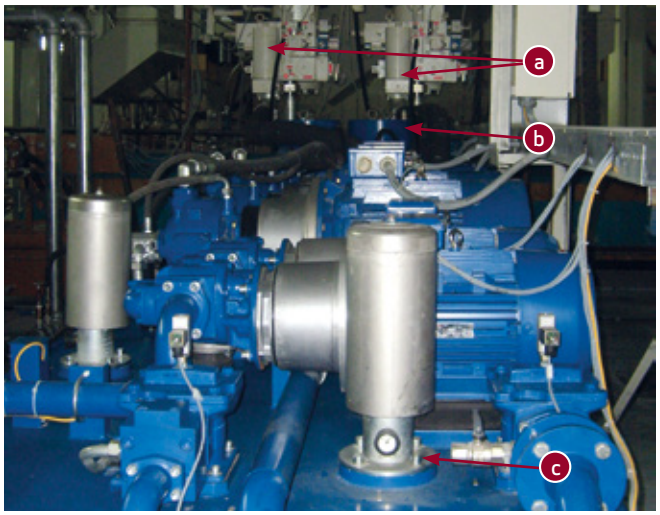


1 Cylinder
2 Safety gate valve
3 3-way servo cartridge valve
4 Hydraulic shock absorber

The die cushion system from Moog composed of a cylinder with manifold, including damping accumulator and all safety-relevant valves.

Moog delivered a hydraulic die cushion system with hydraulic power unit, manifolds, radial piston pumps, valves, a filter and a cooling circuit. A piston accumulator station was also implemented. For force generation, two separate die cushion axes, each consisting of a cylinder with flanged manifold, were also included. This cushion manifold includes safety features, a damping accumulator and an SE3 servo cartridge valve.

The hydraulic power unit's manifolds secured the pumps and realized the heating operation. Here, pressure-controlled radial piston pumps are used. The configuration of these pumps was selected in order to allow the pump to be changed without risking any interference with current operation. In case of any malfunction, the other pumps thus continue running and production can continue at reduced speed.



The die cushion system supplied by Moog comprises a cylinder with manifold, piping and hydraulic power unit.

a Manifolds with cylinder b Piping c Hydraulic power unit

During the initial stage of the press, the sheet metals parts are deep-drawn using a die cushion, and are transported by the transfer system to further stages inside the press. The die cushion is the real "heart" of the forming process, and has a significant influence on the quality of the manufactured parts. The role of the drawing process is to form a sheet metal blank into a form that is determined by the upper and lower tool (2), with a constant sheet metal thickness. With a controlled holding force, the sheet metal is pressed into the form, and without causing cracks and/or creases.

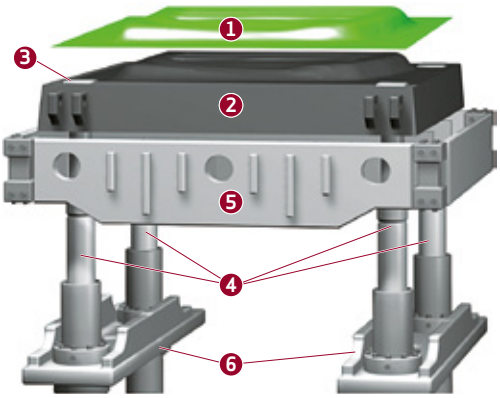
4. The production process sequence

Pre-acceleration

To reduce shock load on the tools and machinery, the die cushion axis is pre-accelerated. The die cushion begins moving before the ram impacts, with the result that the relative speed between the ram and the blank holder is far lower than with an uncontrolled die cushion. Due to the soft contact of the ram, the stroke count is increased with constant part quality, while the noise level falls and tool service life is increased.

Drawing procedure

During the drawing procedure, the sheet metal is tightly held by the blank holder. The ram with the attached upper tool travels at a speed of up to one meter per second, and a press force of up to 2500 tons on the die cushion then presses the sheet metal into the lower tool. The Moog SE3 servo cartridge valve controls the drawing force of the die cushion, and subsequently ensures that the cylinder returns to the specified starting position at the desired time. Depending on the work piece – e.g. roof, door or fender – different drawing forces are established for a specific tool in the press controller. These are controlled through a separate axis controller, thereby allowing for optimal material flow. To prevent pressure shocks in the unit, a damping accumulator was also built into the return line.



Die cushion system design

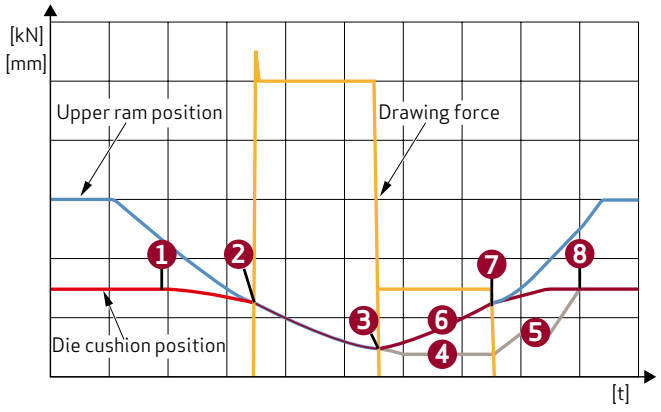
1 Drawing component
2 Lower tool
3 Clamping bolt
4 Die cushion cylinder
5 Die cushion plate
6 Cylinder bearing seat

Upward motion of the cushion

A precise position measuring system, which is integrated into each of the two cylinders, measures the position of the die cushion. In this way, the die cushion can be precisely positioned in a specified position after the drawing procedure, by up to a 10^{th} of a millimeter. The sensors integrated in the cylinder measure the pressure, and relay the information to the controller. Pressure is guaranteed to be precisely controlled within +/- 5 bar in this application. A maximum speed of up to 1.4 m per second allows 30 strokes per minute with this press. All hydraulic control products and features, like the servo cartridge, the position measuring system and the safety technology, are integrated into the manifold. Because of the compactness of the unit, the production area can be used efficiently. The pipes can also be kept short, resulting in lower losses and costs.

5. Software development

The control structures, which have already proven effective in component selection and performance analysis, should likewise be used as drive software for the die cushion in the real press. To avoid errors in the transfer of control structures between the MATLAB/Simulink and the software, a toolchain was developed for MATLAB/Simulink to automatically generate source codes. "The challenge was to integrate the resulting C code into the Moog Servo Controller MSCII ", says Andreas Heydlauff, software developer at Moog. "This required the development of a special toolchain and firmware interface. The function blocks had to be linked to the hardware IOs and the Profibus interface with the superior machine controller".



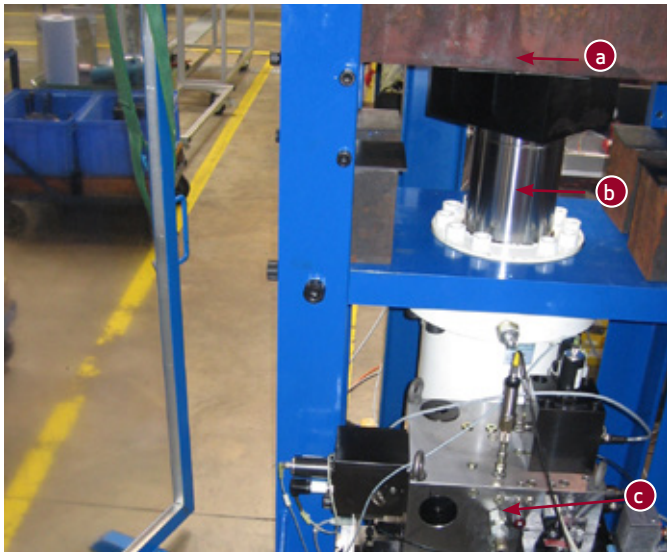
Functional description of drawing process

1. The die cushion starts the pre-acceleration
2. Low impact closing and build-up of the cushion force with programmed profile
3. Lower dead point of the upper ram press, decompression of the die cushion
4. Drop out of the die cushion
5. Programmable extension of the die cushion
6. Bolstered extension of the die cushion under a freely programmable drawing force
7. Open the damping pin and move to the pickup position
8. Start position for a new cycle

6. Test installation and commissioning

To test the full requirements, a test installation was designed, including moving mass, at Moog Luxembourg. The results from this test installation fulfilled the required speeds and positioning accuracy.

A basic mechanical and hydraulic simulation module also formed part of a hardware in the loop (HIL) test environment. The Moog controller and a HIL-PC were connected so that the controller controls the die cushion simulated on the PC. In this way the controller and the software were tested, and software errors corrected before the real machine was commissioned, thus resulting in a commissioning time reduction of eight to two weeks, and significant cost reductions. The physical press was commissioned in China without problems.



a Moving mass b Cylinder c Manifold

Moog in Luxembourg designed a test installation with moving mass, a cylinder and a manifold. The commissioning time was thereby reduced from eight to two weeks.

7. Project results

Moog worked closely with Hagel and other service providers throughout the project. Specialists from Germany, Luxembourg and China, who handled system planning, design and commissioning, were involved. As Reiner Kohlhaas, project manager at Moog Luxembourg, observes: “We had to overcome some coordination challenges between the different specialist areas, and external partners and suppliers. But it was the result that ultimately counts, and that was a huge success. All of the parameters were implemented as we defined and simulated them at the beginning of the project. This gives us and the customer a good feeling, and especially trust in the collaboration”. Martin Hagel, managing director at Hagel, is also satisfied with how the project went and added: “It paid off. The end customer realized a significant increase in part quality, stroke count, output and productivity. They have seen a drastic increase in order volume as a result”.

Summary: the first unit, a 2500 ton press with a two point die cushion, was installed in July 2014 and commissioned. Since then it has been producing parts precisely, and with up to 30 strokes per minute. Because of the successful collaboration and the solution, which was precisely tailored to the requirements, the Chinese automotive supplier decided to purchase additional units. In 2015 a 2400 ton press with a six point die cushion, and an additional 3200 ton press with a two point die cushion, was successfully installed and commissioned. All three units have since been running successfully in two and three shift operations with high availability.

8. Information

Hydraulic, electrical and hybrid solutions

Moog's Industrial Group designs and manufactures high performance motion control solutions combining electric, hydraulic, and hybrid technologies. Moog servo and proportional valves, servo-cartridge valves, actuators, radial piston pumps and hydraulic manifolds can be found in many of today's applications – forming machines for the production of bodywork and automobile structural parts as well as for the production of consumer goods. For this purpose, Moog delivers hydraulic systems as partial or complete solutions. This includes hydraulic control and aggregate. Further information you will find on www.moog.com/industrial or www.moog.de.

Moog Global Support

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For personal consultative expertise, contact a Moog representative in your region. For your nearest Moog loacation visit:
http://www.moog.com/worldwide-locations.html

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Picture sources

1) Form hardening press (source: Schuler)
2) Plastic press (source: Dieffenbacher)

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