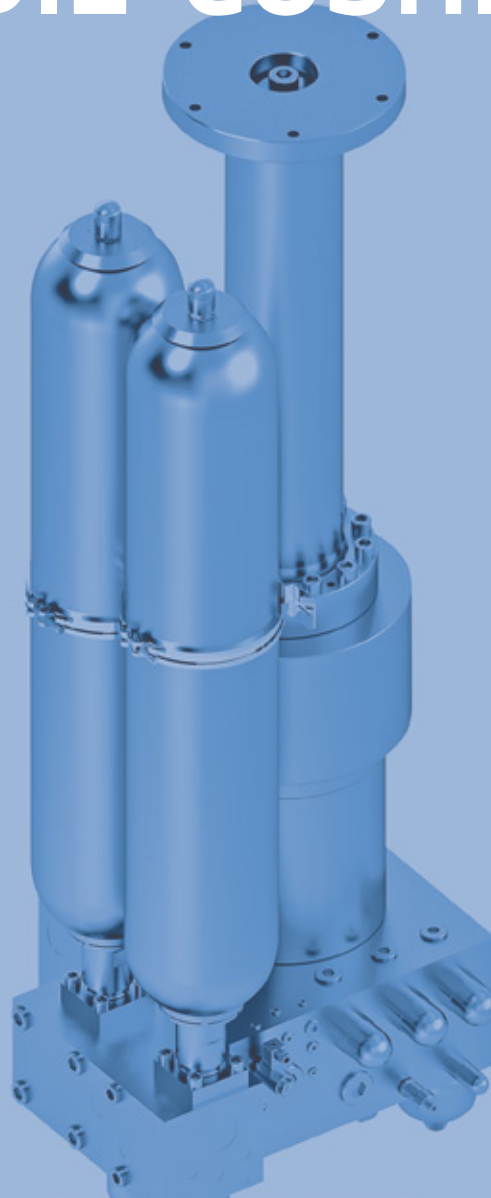


MODULAR DIE CUSHION SYSTEM



Rev. A, July 2018

FOR DIE CUSHION APPLICATIONS WITH HIGH LEVEL
PRECISION AND DYNAMICS REQUIREMENTS

If demanding motion systems and highly flexible designs are required, then Moog expertise is here to assist you. Through our collaborative approach, our creativity and first class technology, we help you to solve even the most complex motion tasks, increase the performance of your products and create solutions that far exceed today's expectations.

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This catalog was written for readers with technical knowledge. Users should check the suitability of the products described here, to ensure that all of the general conditions required for the function and safety of the system are fulfilled. All products described here are subject to technical alteration. If you have any further enquiries, please contact Moog.

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PRODUCT OVERVIEW

Hydraulic die cushions that satisfy the highest requirements for accuracy, dynamics and reliability can be designed using Moog's Modular Die Cushion System. The hydraulic, electronic and software modules used here represent a complete die cushion system that, in conjunction with a qualified higher-level PLC, is suitable for use in hydraulic presses made to DIN EN 693.

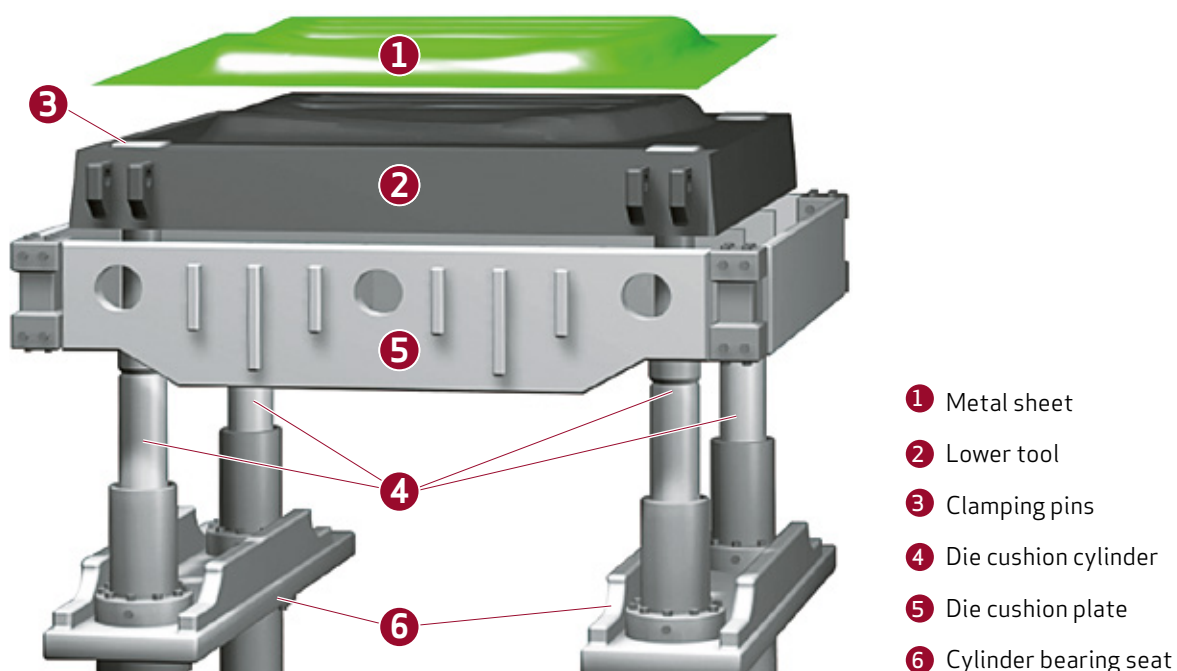
Moog's Modular Die Cushion System consists of hydraulic cylinder components, hydraulic manifolds, accumulators and a hydraulic power unit, as well as electrical control components and their software. However, the individual components can also be used independently. Due to the modularity of the components, the die cushion system can be adapted to optimize customer-specific requirements. This concept is suitable for mechanical and hydraulic single presses as well as for press lines.

With the help of pre-acceleration and very high control accuracy, damage to tools and metal sheets can be reduced during operation, and cracks and creases can be avoided. With Moog's Modular Die Cushion System, even complex geometries and materials that are difficult to form can be pressed.

Design of a drawing press

A drawing press consists of elements of the upper ram press as well as components of the die cushion. The die cushion is placed beneath the clamping pins **3** and includes the die cushion plate **5**, the pins as well as the die cushion cylinders **4** and their hydraulic modules. The cylinders are connected to the press frame via the cylinder bearing seat **6**. The upper ram press can be actuated electro-mechanically as well as hydraulically.

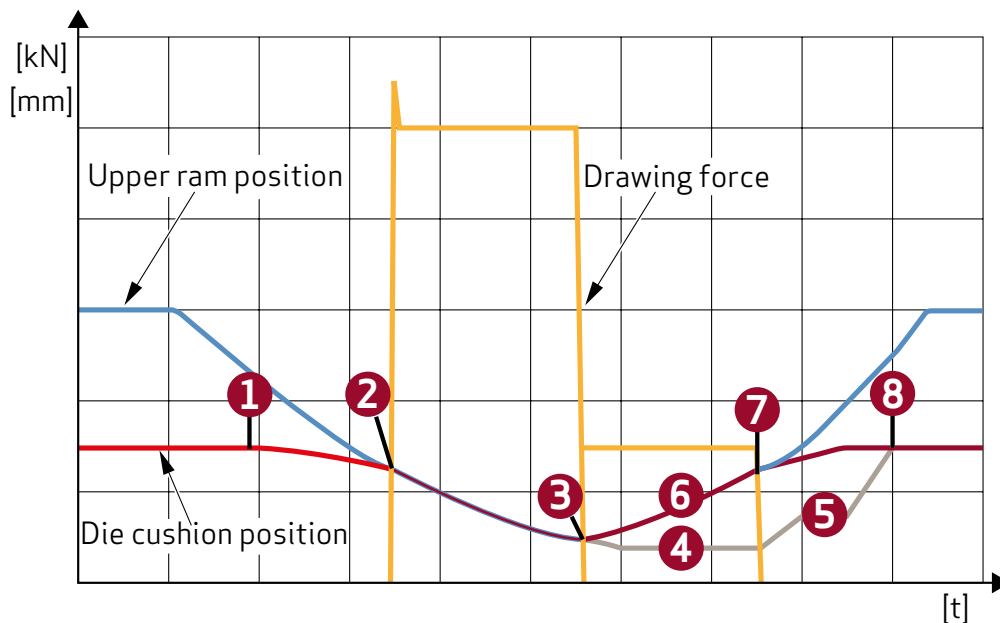
Hydraulically actuated upper ram offers high flexibility in the force and distance profile, whereas the mechanical drive delivers high output. The combination of the upper ram press with a hydraulic die cushion offers the advantages of both: the high variability of hydraulics, and the high production capacity of the upper ram press. The force of the upper ram passes through the clamping pin into the die cushion. In this case, the moveable elements of the die cushion can be pre-accelerated. After clamping the metal sheet to the clamping pin, the die cushion is displaced by force control. The controls are highly dynamic and prevent damage to the metal sheet **1** and the lower tool **2**.



DRAWING PROCESS AND REQUIREMENTS

The objective of the drawing process is the forming of a sheet metal blank into a form defined by the upper ram and die. At the same time, the material should be solidified by a degree of forming and a change in the cross section of the sheet metal. For this purpose, a controlled holding force must be applied to the metal sheet to prevent creases and cracks in the work piece. Pre-acceleration is an additional die cushion function. This reduces the impact hit of the upper ram on the metal sheet, and prevents damage to the materials and dies.

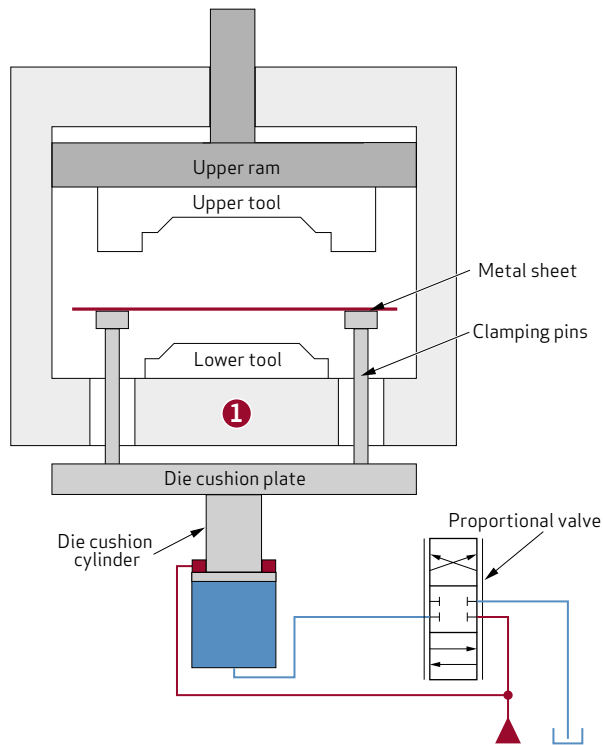
Moog's Modular Die Cushion System provides a flexible, adaptable work cycle. For example, the die cushion can continue its downward movement at the lower dead point of the upper ram, or otherwise move upwards with a defined press force at the closed upper ram. In both cases the die cushion can move the pressed component for transfer to a defined position.



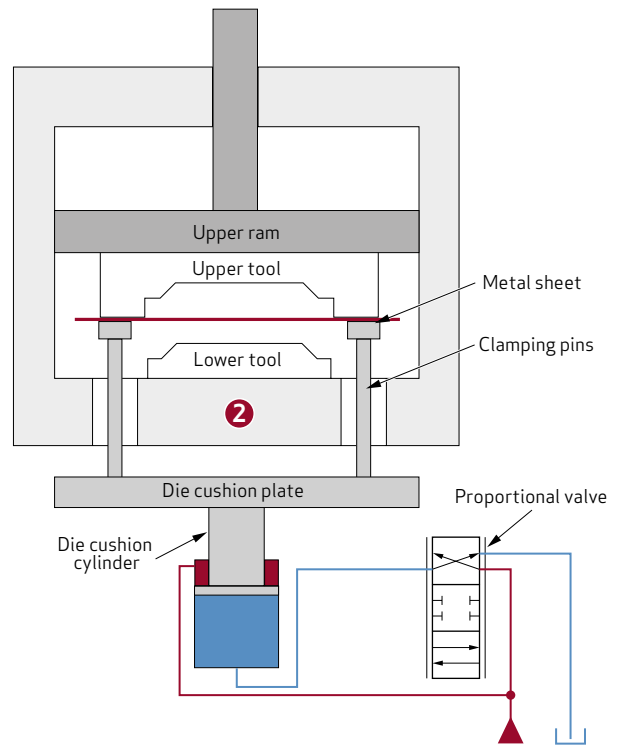
- ① The die cushion starts the pre-acceleration
- ② Low impact closing and build-up of the cushion force with programmed profile
- ③ Lower dead point of the upper ram press, decompression of the die cushion
- ④ Drop out of the die cushion
- ⑤ Programmable extension of the die cushion
- ⑥ Bolstered extension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

DRAWING PROCESS AND REQUIREMENTS

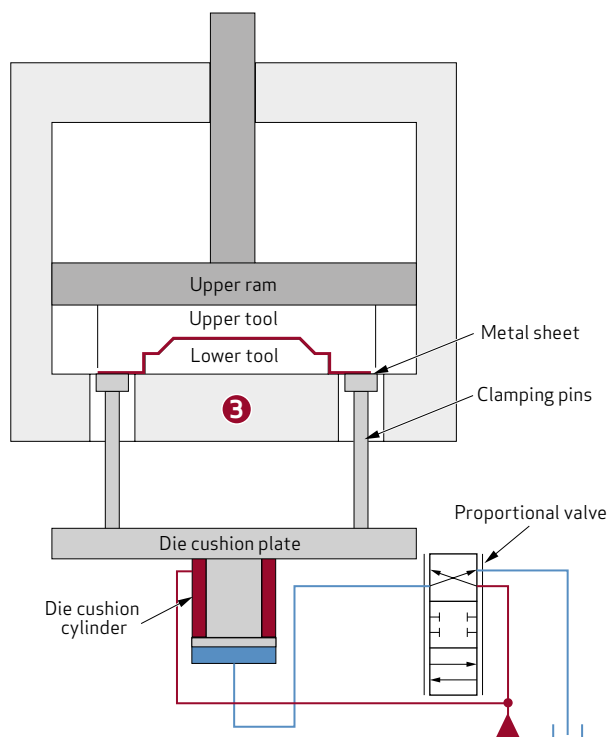
Start of the cycle in the upper end position, pre-acceleration of the die cushion



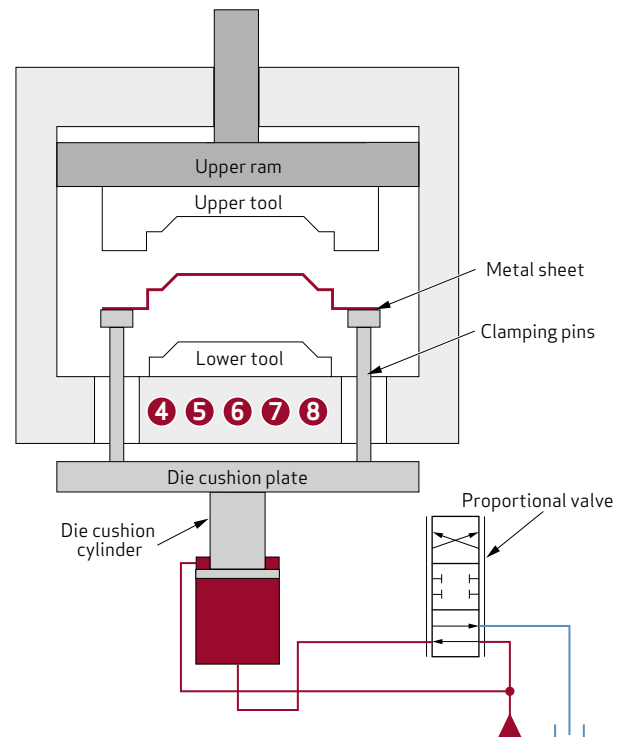
Low impact closing and start of the force profile



Lower dead center of the upper ram, start of the die cushion's extension cycle



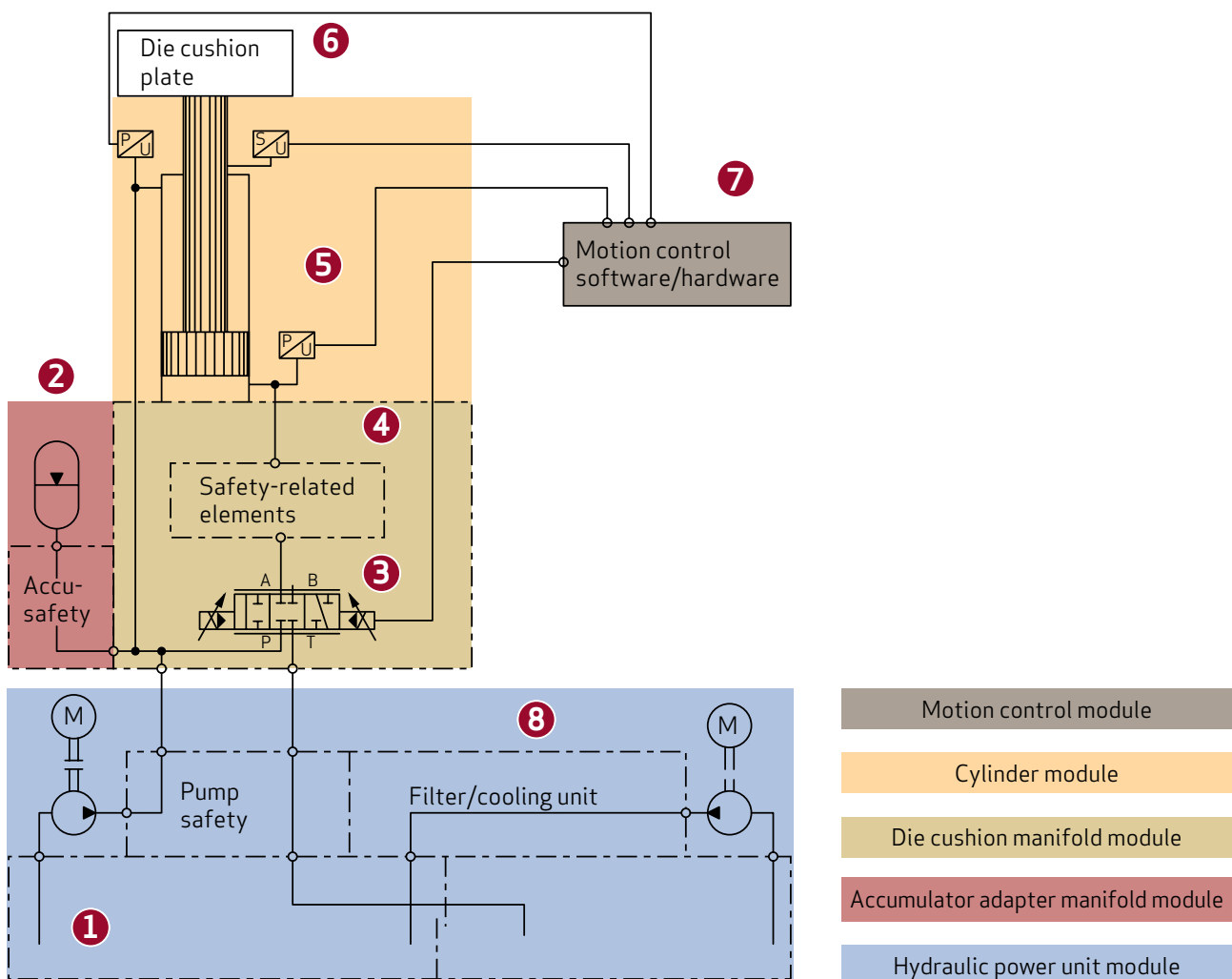
Part pickup and extension to the start position



MODULAR DIE CUSHION SYSTEM DESIGN

Moog's Modular Die Cushion System consists of the main components cylinder with an integrated position transducer, an accumulator, a hydraulic power unit and several manifolds, together with software blocks and the control unit's hardware components.

The cushion manifold is flanged directly to the cylinder, and is connected to the main hydraulic accumulators via a separate adapter manifold. This design provides a compact, rigid hydraulic system that enables highly dynamic control. The control unit is implemented in the system using separate hardware and software modules. This design can reduce force overshoots, and customer-specific force profiles can be realized in the drawing process with a high level of high accuracy.



- ① High pressure pumps
- ② Accumulator safety
- ③ Moog Proportional Valve
- ④ Safety-related elements
- ⑤ Cylinder
- ⑥ Die cushion plate
- ⑦ Control software/hardware
- ⑧ Filter/cooling unit

MODULAR DIE CUSHION SYSTEM DESIGN

The modular die cushion's hydraulic system design is identical in all nominal sizes. It consists of a hydraulic power unit with high-pressure pumps ①, which provides the hydraulic system with oil and a separate auxiliary filter and cooling unit ③, which conditions the hydraulic oil. The pump's pressure connection is constantly present on the rod side of the cylinder, ⑤ and loads the oil into the high-pressure accumulator ②. The proportional valve ③ positions the cylinder ⑤, which supports the die cushion plate ⑥. The control concept is superordinate ⑦. It reads the pressure and position sensors' data and, using the proportional valve, moves the cylinder in a force or position control. The Modular Die Cushion System includes the safety-related part of the hydraulic control system ④ in accordance with Machinery Directive MD 2006/42/EC. This prevents possible hazards during the drawing process, such as any dangerous upward motion of the axis. And it adds the possibility of safely disconnecting the pressure supply. In addition, the hydraulic accumulators are certified in accordance with safety regulations that apply in the country of purchase.

The following options for the cylinder's delivery unit are available as standard. Upon request, we would be pleased to offer additional combinations and project specific designs.

	Cushion manifold, module 1	Cushion manifold, module 2	Cushion manifold, module 3	Cushion manifold, module 4
Cylinder, module 1	✓			
Cylinder, module 2	✓	✓		
Cylinder, module 3		✓	✓	
Cylinder, module 4			✓	✓
Cylinder, module 5				✓
Accumulator adapter manifold module	1, 2 and 3	1, 2 and 3	1, 2 and 3	1, 2 and 3

Moog supports you when selecting the correct hydraulic modules, and helps design the overall system in accordance with your general conditions and cycles.

In addition, further modules, such as damping units or return oil manifolds, can be integrated into the Modular Die Cushion System.

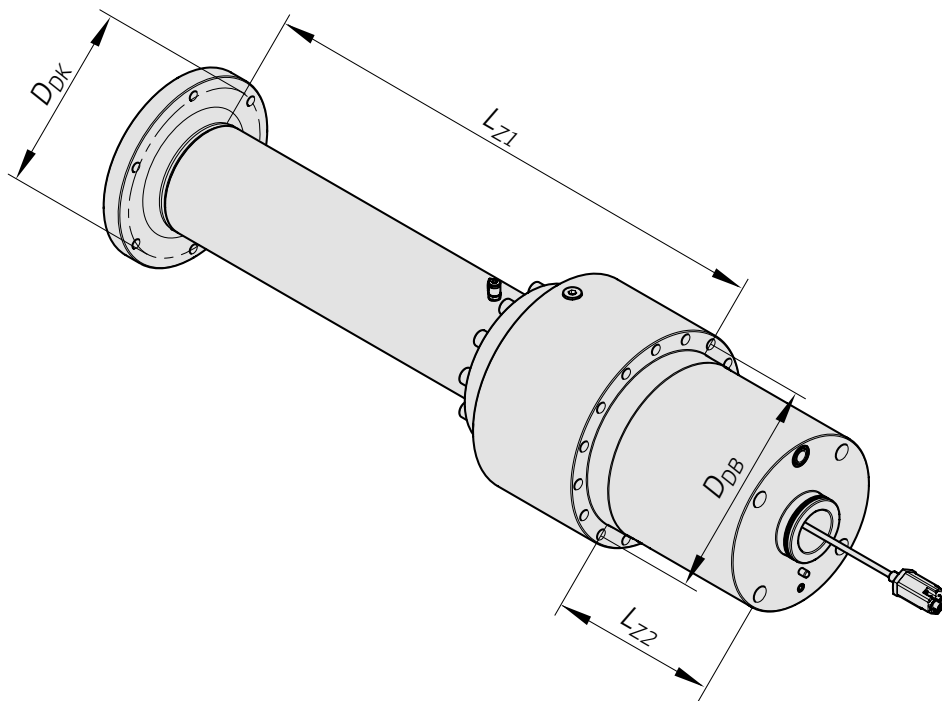
By combining several die cushion modules different drawing forces can be realized, based on the pressure point. Each axis is independently fully functional and is controlled by a control unit of the overall system. To keep the spare parts inventory as manageable as possible, all modules consist of standard components.

DESCRIPTION OF HYDRAULIC MODULES

The Modular Die Cushion System hydraulics consists of the following standardized modules: a cylinder, a cushion manifold, an accumulator adapter manifold and an hydraulic power unit. Moog would be pleased to support your module selection in accordance with the following criteria.

The cylinder module is determined based on the maximum drawing force and the number of pressure points. Standardized modules with fixed dimensions and variable strokes are available. The maximum drawing force of the cylinder modules can be increased by adjusting the system and drawing pressure.

The benefits of this cylinder design include easy and compact installation of the hydraulic manifold at the fastening level of the D_{DB} cylinder. This design's position transducer is guided through the hydraulic manifold, which permits a compact design. Furthermore, the position transducer is protected against damage. The cylinder will be integrated into the press frame through an extended cylinder rod. It is flanged to the die cushion plate using a calotte plate, which can compensate for a tilt angle of up to two degrees. The cylinder is mounted on the die cushion plate through fastening level D_{DK} . Furthermore, all cylinders are equipped with low friction sealing to prevent a stick-slip effect.



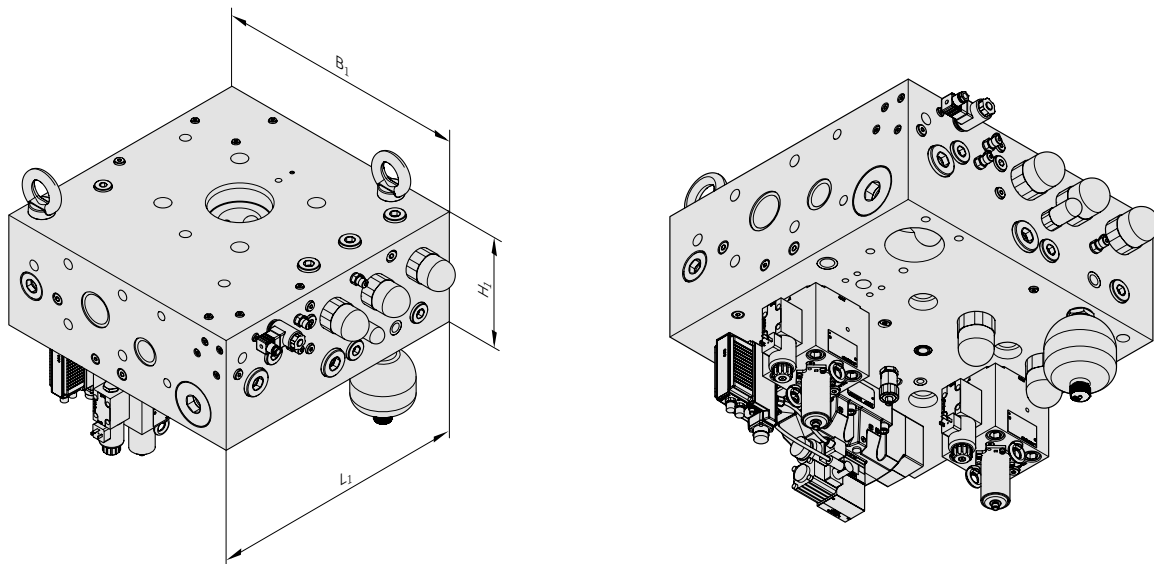
Modules	Force range	L_{Z1}	L_{Z2}	D_{DK}	D_{DB}
	[kN]	[mm]	[mm]	[mm]	[mm]
Cylinder, module 1	Up to 500	1,156	350	270	295
Cylinder, module 2	500 to 800	1,156	350	320	345
Cylinder, module 3	800 to 1,000	1,156	350	320	375
Cylinder, module 4	1,000 to 1,500	1,156	350	325	435
Cylinder, module 5	1,500 to 2,000	1,156	350	325	500

DESCRIPTION OF HYDRAULIC MODULES

The cushion manifold module relies on maximum flow rate, and therefore on the selection of the cylinder module and maximum cylinder speed. The modules are configured in such a way as to enable the operation of each cylinder module at 500 to 700 mm/s. Higher speeds are possible, however they must be determined and specified on a project-specific basis. Four module sizes with variable cylinder flange versions are available for selection.

Module	Max. volume flow [l/min]	Nominal size [-]
Cushion manifold, module 1	1,000	32
Cushion manifold, module 2	1,500	40
Cushion manifold, module 3	2,000	40 HF
Cushion manifold, module 4	2,500	50

Valves and pipe connections are installed on the bottom of the manifold for the assembly of the cushion manifold modules. This design of the manifold offers very good accessibility to all valves, and very high variability for the positioning of the hydraulic power unit. In addition, the manifold can be rotated into any position to be able to freely align the position of the accumulator adapter manifold. Moog sub-plate mounted Proportional Valves used in digital or analog designs, are a special 3/3 way version. These valves reduce pressure losses during the movement of the cylinder, and therefore provide a higher ejection force and a lower minimum drawing force.



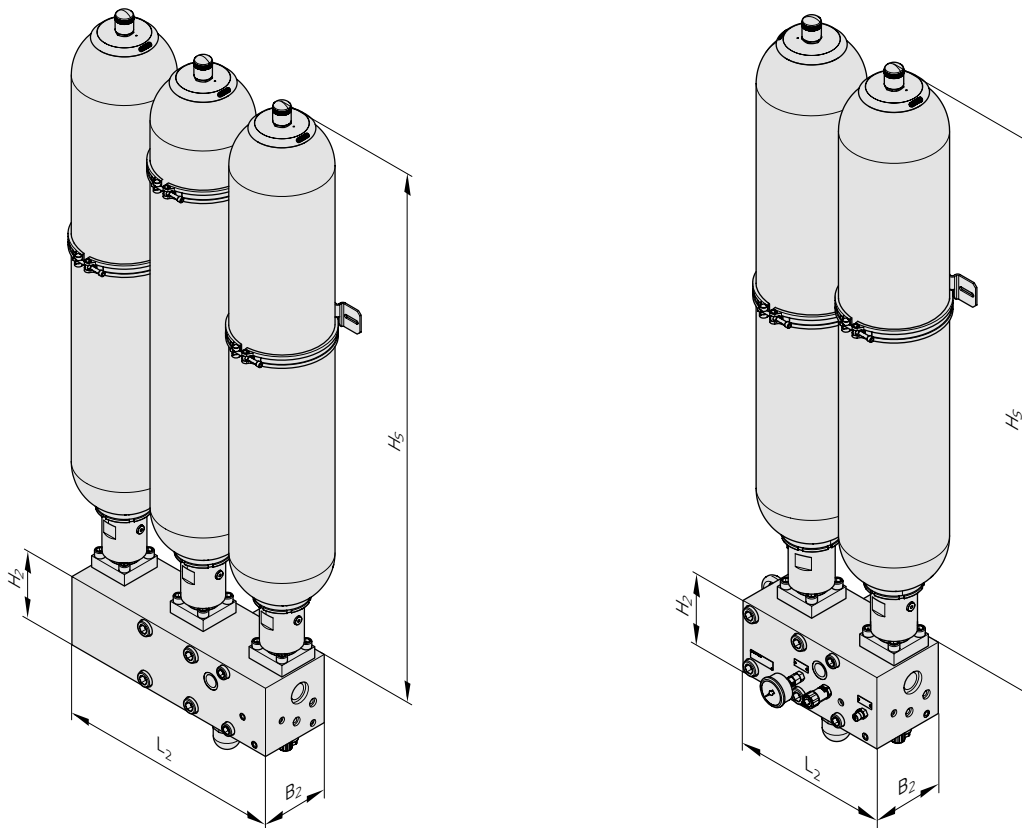
Module	L ₁ [mm]	B ₁ [mm]	H ₁ [mm]	m [kg]
Cushion manifold, module 1	530	580	230	555
Cushion manifold, module 2	575	560	245	619
Cushion manifold, module 3	650	810	245	1,013
Cushion manifold, module 4	720	855	255	1,232

DESCRIPTION OF HYDRAULIC MODULES

The modules of the accumulator adapter manifolds are available for one, two or three accumulators (NS 10 to NS 50), and can be used with all cushion manifold modules. The number and size of the accumulator used will be determined by the type of cylinder chosen, and by the die cushion's cycle data. You can choose between standard and high flow bladder-type accumulators.

The accumulator adapter manifold includes all safety-related components, together with the required certificates for each respective country purchase. The adapter manifold is flanged to the side of the cushion manifold. The bladder-type accumulators are installed vertically and in parallel to the cylinder.

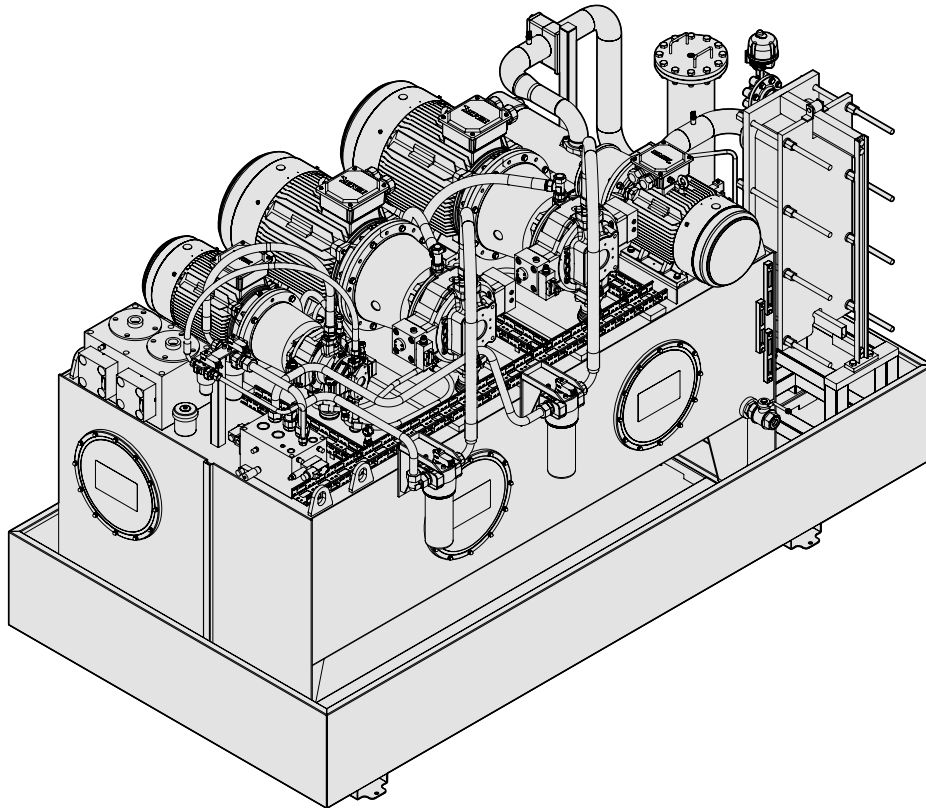
Characteristics	Number of pressure accumulators NS 10 to NS 50
Accumulator adapter manifold, module 1	1
Accumulator adapter manifold, module 2	2
Accumulator adapter manifold, module 3	3



Modules	L ₂	B ₂	H ₂	H ₅	m _{manifold}
	[mm]	[mm]	[mm]	[mm]	[kg]
Accumulator adapter manifold, module 1	290	180	180	582 to 1,968	74
Accumulator adapter manifold, module 2	415	180	180	582 to 1,968	106
Accumulator adapter manifold, module 3	640	180	180	582 to 1,968	162

DESCRIPTION OF HYDRAULIC MODULES

The hydraulic power unit module will be determined based on the cylinders used, the number of pressure points and the cycle data. The components and modular pump manifold are installed on a tank with a two chamber system, and several manhole inspection openings. The design and dimensions of the hydraulic power unit can be adapted on a project specific basis in accordance with customer requirements, and are shown here as an example.



The hydraulic power unit building blocks consist of several modules, which cover all commercially available combinations of our Modular Die Cushion System. The hydraulic power unit can be specified individually for special requirements.

If the hydraulic power unit is positioned at a distance from the die cushion system, then it can be equipped with an additional modular return oil manifold, to prevent cavitation and interruption of the returning oil column.

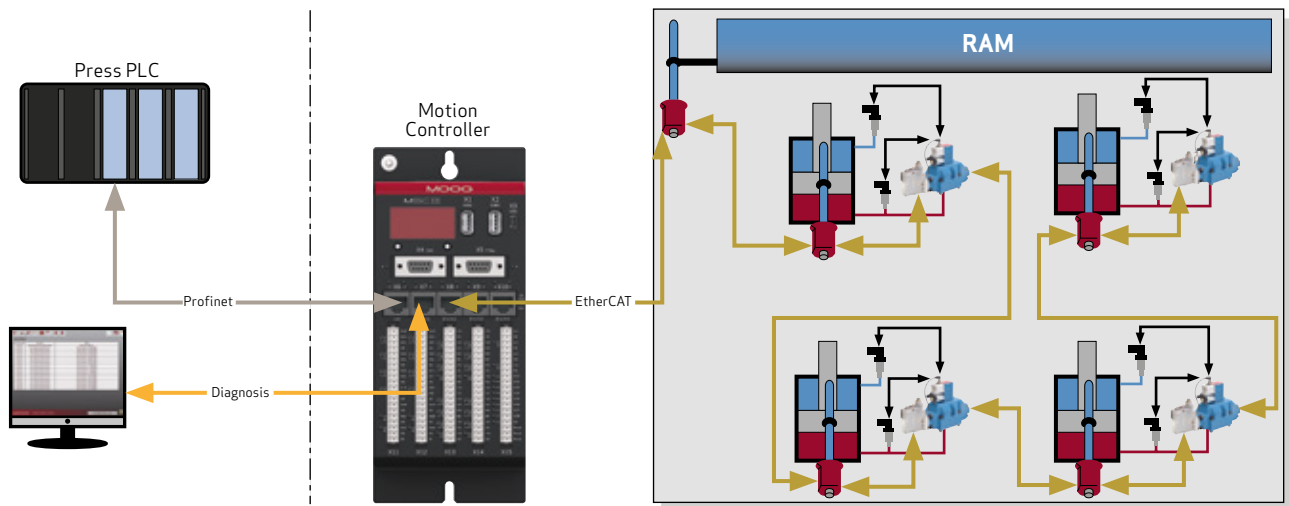
MOTION CONTROL FOR DIE CUSHIONS

Moog’s Modular Die Cushion System software is based on the continuous development of four generations of die cushion control systems: starting with analog control circuits, through digital die cushion control boards developing into freely programmable, PLC-based motion controllers and finally to state-of-the-art industry PCs.

This development generated a software library for use with Codesys or TwinCAT based (IEC 61131-3) Motion Controllers, which includes traditional pressure control as well as force and position state control. Another key component is pressure or force profile generation with smooth and, therefore, tension-free force profile for the metal sheet. This prevents cracks and creases on the metal sheet and, along with the precision control system, is another important feature. Equally important is pre-acceleration, given that the impact is reduced at the start of the drawing process. For this purpose, Moog has developed a unique algorithm. It synchronizes the pre-acceleration trajectory on the upper ram position.

The scope of delivery includes state machines with auxiliary functions, which cover the entire drawing process. They are executed directly on the Motion Controllers with a high clock rate, together with the control algorithms. Overall, motion control ensures the precise repetition of the drawing process.

The software library is matched with the hydraulic components of the Modular Die Cushion System, which permits a large number of possible combinations. The special requirements needed to achieve drawing forces and the number of strokes are provided by the appropriate sizing of hydraulic components. While the size of the components is less significant for the control unit, the number of die cushion modules and the design of the valve interfaces are important. The planned application area is in 1 or multi point die cushion systems with independent pressure and force profiles.

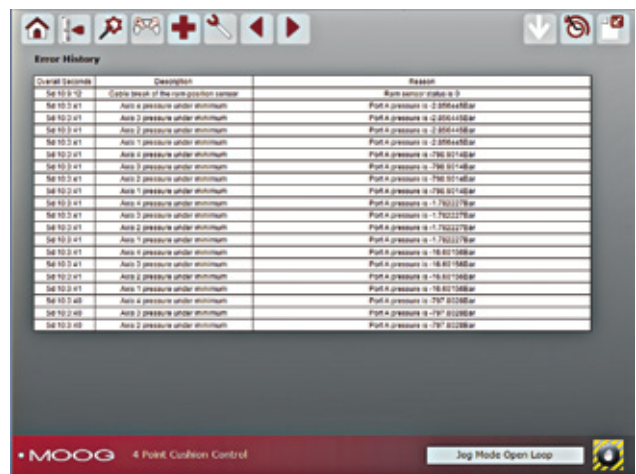
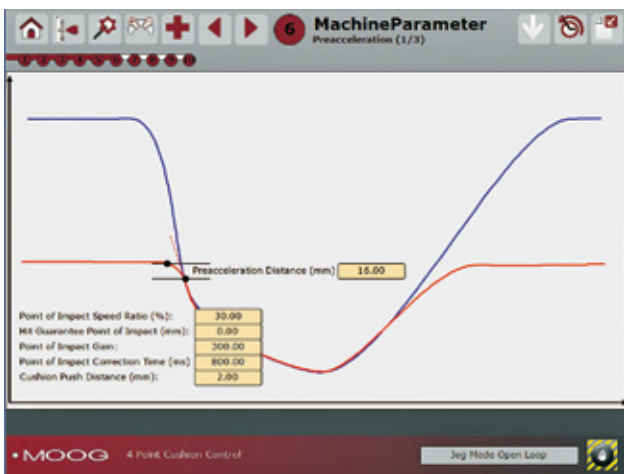
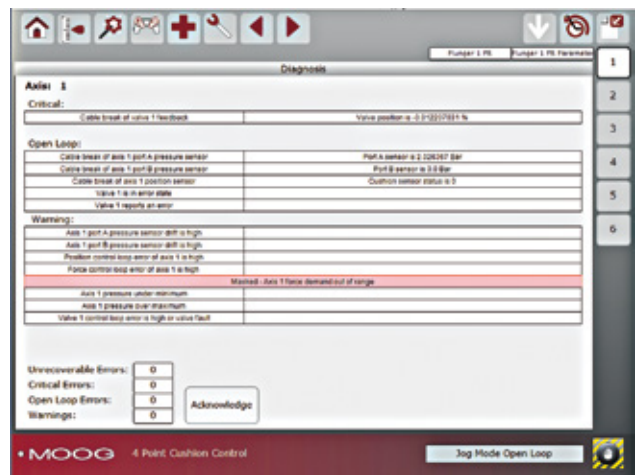
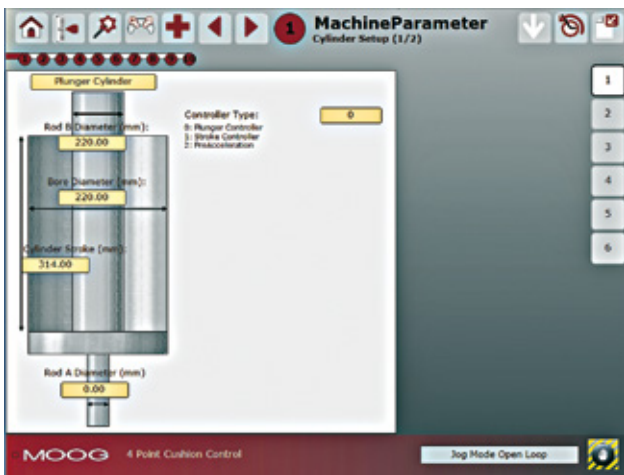


MOTION CONTROL FOR DIE CUSHIONS

Moog offers three options:

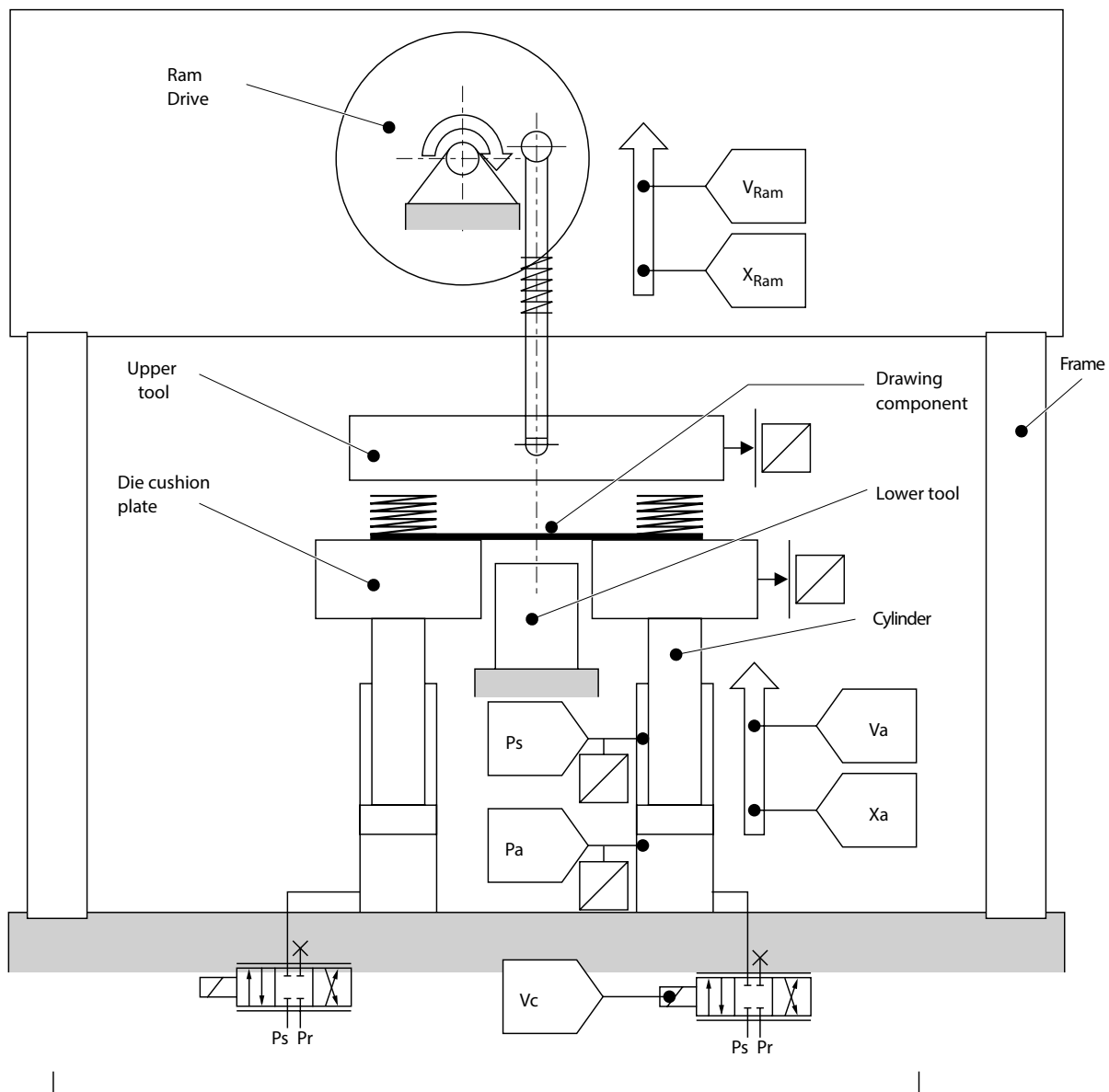
- 1) Several function block libraries available, which can be assembled by the customer.
- 2) A complete package delivered by Moog based on these function blocks for die cushions with the same configuration.
- 3) An individually programmed solution.

The total package includes a motion controller and requisite software for the actuation of Moog valves. Moog's EtherCAT field bus valves permit a noise free digital set point and detailed diagnostics options, and offer an integrated IO functionality for decentralised reading of the pressure sensors. A Profinet interface is used to connect to the machine control, which then transfers drawing and position parameters and provides the release for the die cushion control. Afterwards, the control unit independently processes the parameterized work cycle depending on the linear upper ram position. An HMI connection provides easily readable diagnostics.



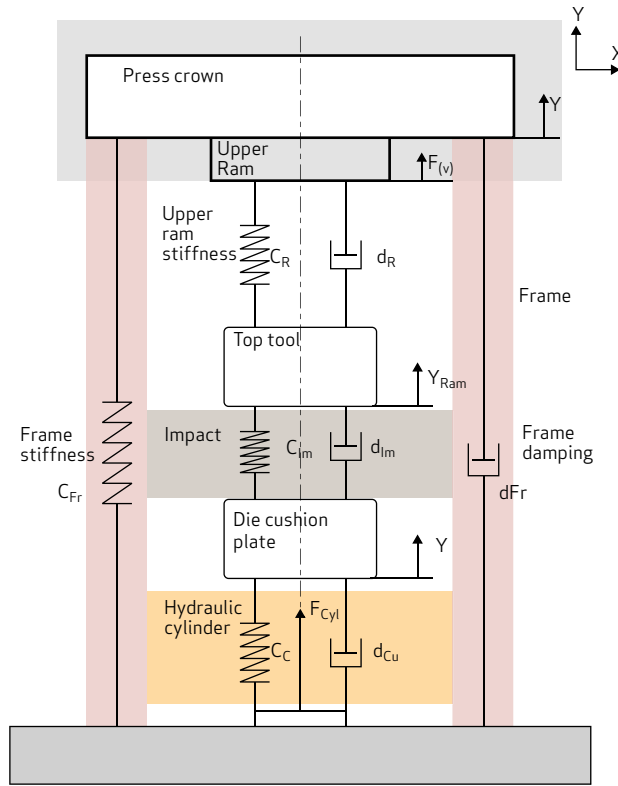
SIMULATION OF DIE CUSHIONS WITHIN A PRESS

A die cushion simulation contained within a press is a valuable testing tool offered by Moog for use with critical applications. In addition to the hydraulic modules and the algorithms available as control software, the simulation also presents the upper rams, die cushions and press frames in physical modules. Information about the press, such as the upper ram and drawing table dimensions with additional advice from experienced Moog engineers, is also included. During project planning for a new system, this type of simulation helps to predict the dynamic behavior in reality, and the checking of stringent performance requirements.



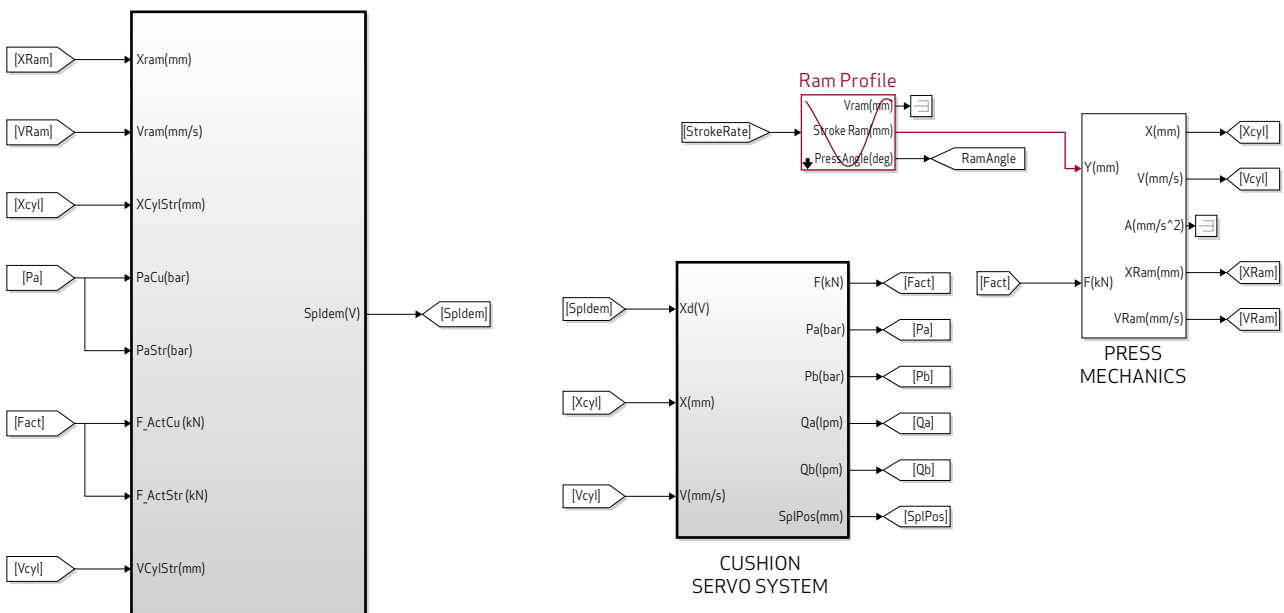
Critical points, such as the pressure peak during the impact of the upper ram on the die cushion, can be analyzed by employing control algorithms. In addition, the Moog simulation permits the verification of stroke rates with an ejection speed that is close to the physical limit, as well as the calculation of energy consumption and the pump output for these cycles.

SIMULATION OF DIE CUSHIONS WITHIN A PRESS



Simulation permits simple comparison of the hydraulic modules for borderline cases. Based on the results, an informed selection can be made or an individual solution can be considered.

An additional area for the use of a press simulation is in the verification of the final software in a hardware in the loop environment (HIL). This final software can be installed on the selected PLC as a collection of software library blocks, connected to a simulation computer. A real time model of the press is executed on the simulation computer. This makes it possible for the software developer to develop and test in a cost-effective way some time before a press has been completed, and as if a press had been available. Ultimately, this allows short, smooth software commissioning on the completed system.



ABOUT MOOG

Moog Inc. is a worldwide designer, manufacturer and integrator of precision control components and systems. Moog's Industrial Group designs and manufactures high performance motion control solutions combining electric, hydraulic, and hybrid technologies with expert consultative support in a range of applications including energy production and generation machinery, industrial production machinery and simulation and test equipment. We help performance-driven companies design and develop their next-generation machines. Moog Industrial Group, with sales of US\$843 million during the 2017 business year and more than 40 locations worldwide, is part of Moog Inc. (NYSE: MOG.A and MOG.B) with sales of US\$2.5 billion.

This vast scope ensures that our engineers remain close to the needs of machine builders and provide flexible design solutions and technical expertise tailored to our customers' toughest challenges.

Moog experts work in close collaboration with machine builders and application engineers to design motion control systems for greater productivity, higher reliability, superior connectivity, less costly maintenance and more effective operations. Our regional presence, industry knowledge and design flexibility ensures Moog motion control solutions are tailored to their environment — from meeting operating regulations and performance standards, to taking machine performance to a higher

Products

At the heart of every Moog solution is an array of products engineered for precision, high performance and reliability. For more than six decades, Moog products have been specified for critical machine applications.

Some are developed specifically for unique operating environments. Others are standard equipment on machines across many industries. All are continuously improved to take advantage of the latest technology breakthroughs and advancements.

Moog products consist of:

- Servo and Proportional Valves
- Servo Motors and Servo Controllers
- Motion Controllers and Software
- Radial Piston Pumps
- Actuators
- Hydraulic Manifolds and Cartridge Valves
- Slip Rings
- Simulation Platforms



Servo Controllers



Servo Motors



Servo Valves



Radial Piston Pumps

ABOUT MOOG

Hydraulic Solutions

Since the invention of the first mass-produced servo valve in 1951, Moog has stood for hydraulic actuation systems. Moog Servo and Proportional Valves, Servo Cartridge Valves, Actuators, Radial Piston Pumps and Hydraulic Manifolds can be found in many of today's applications. For this purpose, Moog delivers hydraulic systems as partial or total solutions. This includes hydraulic control and aggregate.

Electric Solutions

Clean operation, low noise generation, less maintenance and reduced power consumption make Moog electric solutions ideal for applications worldwide. Moog is the ideal partner for applications where transitioning technologies requires special expertise.

Hybrid Solutions

By incorporating the advantages of existing hydraulic and electric technologies - including modular flexibility, increased efficiency and cleanliness - into innovative hybrid solutions, Moog offers new performance potential in specialized applications.

Moog Global Support

Moog Global Support is our promise to offer world-class Repair and Maintenance Services delivered expertly by our trained technicians. With the reliability only available from a leading manufacturer with facilities around the world, Moog offers you service and expertise you can count on to keep your equipment operating as it should.

This promise offers many benefits to our customers including:

- Reduce your downtime by keeping critical machines running in peak performance
- Protect your investment by ensuring reliability, versatility and long-life of products
- Better plan your maintenance activities and make systematic upgrades
- Leverage our flexible programs to meet the unique service requirements of your facility

Look to Moog for global support including:

- Repair services using OEM parts are performed by trained technicians to the latest specifications
- Stock management of spare parts and products to prevent unplanned downtime



Plastic press [source: Dieffenbacher]



Form hardening press [source: Schuler]

- Flexible programs, tailored to your needs such as upgrades, preventative maintenance and annual/multi-year contracts
- On-site services bring the expertise to you, providing quicker commissioning, set-up and diagnostics
- Access to reliable services that are guaranteed to offer consistent quality anywhere in the world

For more information on Moog Global Support visit www.moog.com/industrial/service.



NOTES

NOTES

MORE PRODUCTS. MORE SERVICE.

Moog designs a range of motion control products to complement those featured in this document.

Moog also provides service and support for all of our products. For more information, contact the Moog facility closest to you..

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