INDUSTRIAL NEWSLETTER
MOOG

**Issue 3, February 2004**

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# Product Design and Testing at Moog

## Turning High Performance into Reality

Feature Article
Product Design and Testing at Moog

How does a product become the high performance leader for motion control for the most demanding applications in the world? It starts with innovative ideas of the product design experts. It is then proven using the most advanced simulation tools and testing methods available in the marketplace. Moog's product design and testing are hidden assets that customers buy when they invest in best-in-class products.

While product design and testing may vary slightly among Moog's core products, there are essential commonalities. To explore this, consider Moog's core product range: Servovalves, Servo-Proportional Valves, Servomotors and Drives, Controllers, Pumps, and Electromechanical Actuators. Clearly the design and testing of a 92 gram microvalve will be different from the process used for a 5,000 kilogram (kg) manifold or a 432 kg. electromechanical actuator. What is common is the ability to ensure precision motion control by simulating product performance in complex control systems, and rigorous testing to verify performance in real world conditions.

Moog is profiling in this article two examples to demonstrate the complex role of product design and testing when creating performance-based products. The first example involves two types of simulation for Servo-Proportional Valves and the second addresses reliability testing for RKP Pumps. Similar examples are available for other products as well.

## I. Simulation Tools used by Moog for Product Design of Servo and Proportional Valves

Simulation tools are an accepted way for engineers to understand and predict the behavior of a system. Moog is known for providing Servo-Proportional Valves that are exactly customized to provide the performance needed in a machine. Applying simulation to this product is a challenge and it involves the expertise Moog has gained in over 50 years in the business. In the section below, we will explore the details of valve simulation.

All of our simulation tool examples are based on the finite element method (FEM), where a spatial field is divided into finite elements. By giving these elements a specific physical property and applying the correct boundary conditions, an analysis of the physical behaviour of solid materials and even fluids can be performed. The only difference between determining stress and strain in a valve body made of ductile gray cast iron and determining the flow induced force on a spool are the governing equations.

## A. Structural Analysis

During the design process it is useful to know how the structure (e.g. valve body) will react under the applied loads. One way Moog's product designers obtain the answer is by using the software packages NASTRAN 4W and ANSYS to obtain detailed information about the deformations, stresses, and strains in the analyzed parts. These results can be used in further investigations such as estimation of fatigue limits or reducing stresses and deformation by modifying the actual geometry.

Figures 1 and 2 show typical applications of the FEM software looking at the deformation of a valve body.

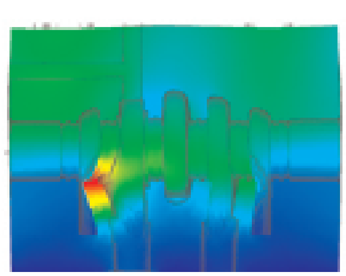


Figure 1: Deformations in Cast Body

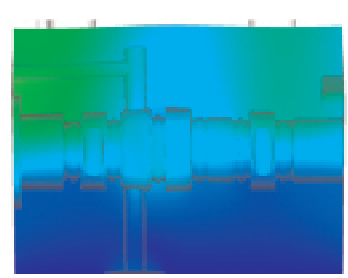


Figure 2: Deformations in Machined Body

## B. Computational Fluid Dynamics (CFD)

A common application of CFD software (“Cfdesign“ from Blue Ridge Numerics) is to predict the steady state flow induced forces in hydraulic spool valves. The CFD-code is based on the following fundamental fluid equations:

- Momentum conservation
- Mass conservation
- Energy conservation

Flow force development is based on the momentum of the enforced redirection of the fluid jet and the change of hydraulic boundary conditions which accelerate the column of oil in the valve. The flow force can be divided into a steady-state and a transient part. Both parts have an effect on the moveable elements of a valve.

With the shown conservation equations and the actual software capabilities, the following states can be simulated:

- internal/external flow
- compressible/incompressible
- laminar/turbulent
- subsonic
- steady-state
- heat transfer (conduction, convection and conjugated)

To reach an optimal flow force compensation there are many possibilities. Substantially all of the possibilities can be reduced to the variation of the geometry. The aim of the geometry variation is the focusing of the jet of hydraulic oil close to the wall, so that there is nearly no loss of kinetic energy.

In the following design study the flow force could be reduced from 25 N to 9 N at a pressure drop of 320 bar by adding a compensation cone to the spool and a full angular scallop to the body.

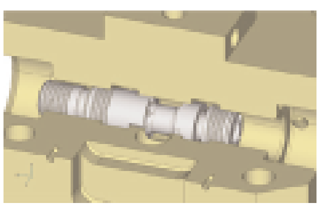


Figure 3: Uncompensated Spool

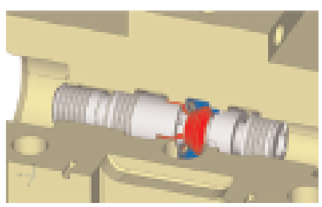


Figure 4: Compensated Spool

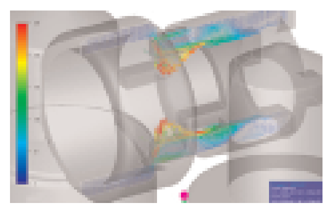


Figure 5: Uncompensated/ Velocity vectors ZY

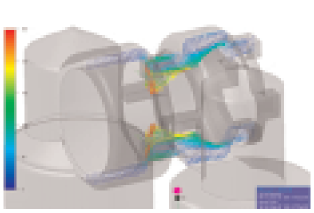
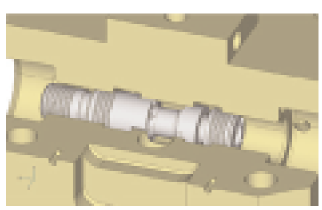


Figure 6: Compensated/ Velocity Vectors ZY



igure 7: Uncompensated /Velocity Vectors ZX

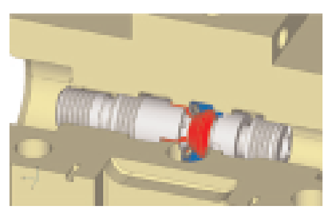


Figure 8: Compensated/Velocity Vectors ZX

## C. Magnetic Analysis

Another specific example of the role of simulation in creating best-in-class products is the design of the linear force motor that drives the spool of Moog's new High Flow Direct Drive Valve (DDV) (D634Pseries). In order to optimize the electromagnetic circuits a software package called Maxwell (from Ansoft) was used. By optimizing the geometry and characteristics of all of the parts involved in the magnetic circuit, Moog has nearly doubled the motor stroke, while maintaining the high driving force levels. The result is the addition of a higher flow capacity valve within the Moog Direct Drive Valve family, that also has the contamination tolerance and low power consumption requirements these valves are known for in the marketplace.

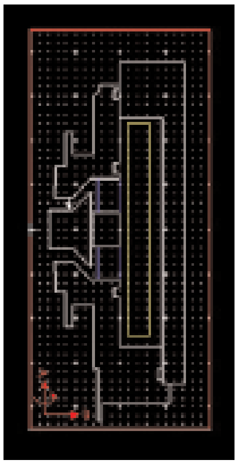


Figure 9: Geometry with Applied Material Characteristics

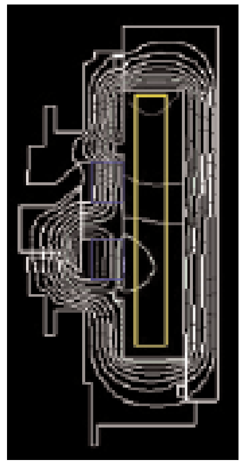


Figure 10: Streamlines of the Field

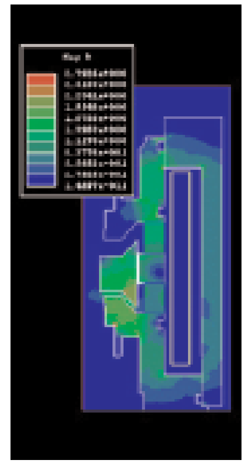
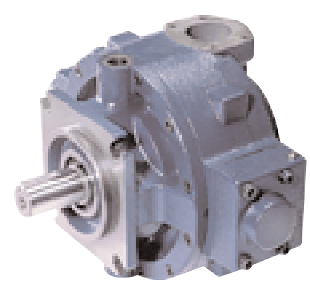


Figure 11:Magnetic Flux Density

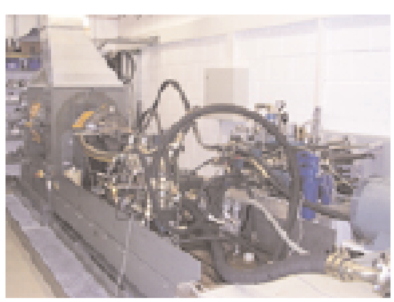
# II. Stringent Reliability Testing for RKP Pump Products Allows for Reliable Customization.

Moog's Radial Piston Pump (RKP) product line is well-known for reliability, low noise, and high performance. This is underlined by its strong reputation in the marketplace and an extended warranty of 10,000 operating hours or 24 months (whichever occurs first) when used with mineral oil.

As with Servo-Proportional Valves, a core advantage to RKP Pumps is Moog's ability to customize the design to meet unique customer needs. When it is necessary to modify the design of single parts or subassemblies, replace one material with another, or to change the processes for heat treatment, testing is critical to product development. In all cases where a completely new design is created, it is necessary to investigate and document the implications of the modifications on function and lifetime.

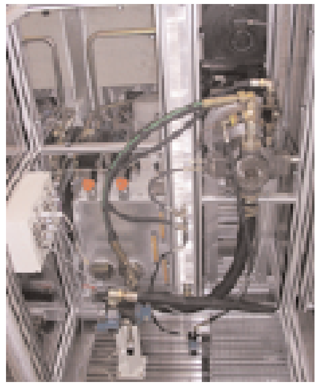


Moog RKP Pump



RKP Engineering Test Bench (250 kW)

Before an RKP Pump with new parts can be released into production and delivered to a customer, it undergoes a stringent fatigue test, where the pump load and displacement must change between zero and maximum in a period of one second. This procedure is repeated for at least 5,000 hours. The engineers that specialize in RKP Pumps have access to six different test rigs that are computer controlled for executing lifetime reliability tests. The tests are automatically generated and sensors for pressure, temperature, and leakage monitor the given range of parameters and allow a 24 hour operation. Moog also performs tests with fluids other than mineral oil, such as HFC fluid. The ability to handle other fluids is a key feature for the RKP Pump.



Lifecycle Test Bench for RKP (110 kW)

After a pump has passed the lifetime test it is disassembled. Visual inspection allows the engineers to decide whether a modified part or subassembly design is ready for customer's application. This ensures that all customized products meet the same stringent requirements that the Moog RKP Pump is known for in the marketplace.

## III. Conclusion

Excellence in product design is a combination of applying advanced technology and engineering expertise. The care that is used to ensure a Moog product is best-in -class starts with design and is carried through to manufacturing and global applications support. While simulation and testing are important components of the overall product design process, an intimate understanding of customers' needs and application requirements is also a key part of Moog's strategy. All of these things combined represent the reasons why Moog has earned its reputation as a world leader in the supply of high performance motion control products.

### *About the Authors:*

Matthias Finke is a Development Engineer at Moog GmbH in Germany where his main focus is on Finite Elements Method Simulation and Calculation. He received his degree in Mechanical Engineering from the University of Applied Sciences in Esslingen, Germany and wrote his Diploma Thesis using Moog as his topic.

Dirk Becher is a Project Engineer, RKP at Moog GmbH, specializing in the design of piston pumps. He graduated with a degree in Mechanical Engineering from the University of Dresden, Institute for Fluid Power in Germany . He finished his Ph.D. in December 2003 with a thesis about the reduction of pulsation in axial piston pumps.

Assistance was also provided by Dirk Hirschberger, Teamleader for Hydraulic Valve Engineering.

## See Also:

- Industrial Contacts/Distributors
- Servo and Proportional Valve Capabilities
- RKP Pumps
- Technical Articles
- Technical Presentations and Papers

# Did You Know?

## Oil Filtration Requirements for Industrial Servo Systems


The most effective way to reduce life cycle costs of an oil hydraulic system, regardless of the types of valve used, is through close attention to contamination control. There is a wide range of information on the subject so we are summarizing the key concepts.

For industrial servo systems the ideal system filter arrangement is summarised as follows:

- Use a 15 micron (Beta 15 >= 75) high pressure filter without by-pass just before the valve or critical parts of the valve (e.g. pilot)
- Use a 3 micron (Beta 3 >= 75) low pressure filter in the return or bypass line.
- Use a filter in the tank breather that is at least the same filtration level as the finest filter in the system.

This recommendation is based on the fact that most servo and proportional valves can accept the odd particle up to 25 microns so the pressure filter will protect the valve from catastrophic failure. The real work is done by the low pressure filter reducing the small particle contamination which is the prime contributor to component wear and silting.

Assuming that the filters are properly dimensioned and care is taken during initial installation and maintenance the aim should be to limit oil contamination to the following maximum levels.

| ISO Solid Contamination Code | Old ISO 4406 | New ISO 4406 |
|---|---|---|
| Maximum Recommended Code* | 16/13 | 19/16/13 |
| Recommended Code for Long Life | 15/12 | 18/15/12 |

(* may vary for some applications and models, please check documentation)

It is important to note that these are maximum contamination levels and with proper care and regular filter change significantly lower levels can and should be achieved. Also attention must be paid to a number of other factors that contribute to oil condition problems such as elevated temperatures, high tank humidity, “dirty” new oil etc.

For more up to date and detailed recommendations on this subject a good place to start is at **Filters for Hydraulic Systems**.

# Hot Websites


### Fluid Power Journal **(www.fluidpowerjournal.com/)**

The Fluid Power Journal is the official publication of the Fluid Power Society, which is an international organization for fluid power and related motion control professionals. Full text of past issues is available online. Links to related organizations and companies are provided.

### RDN (Resource Discovery Network) **(www.rdn.ac.uk/)**

The RDN (Resource Discovery Network) is a collaboration of over 70 educational and research organizations, including the Natural History Museum and the British Library. In contrast to search engines, the RDN gathers resources which are carefully selected, indexed, and described by specialists in partner institutions. Search results and browsing will connect you to Web sites relevant to learning, teaching, and research. The Engineering, Mathematics & Computing collection offers some valuable finds.

# Product Spotlight

## DS2100 Servodrives

The DS2100 is Moog's new fully digital servodrive that was developed as an extension of Moog's successful DS2000 range of digital servo controllers. Like the DS2000, the DS2100 provides full digital control of brushless servo motors and delivers a technologically advanced system with excellent cost, performance, reliability, and flexibility. The DS2100 utilizes high power microprocessors to deliver significantly increased current, velocity, and position performance that is demanded by many modern applications. In addition to increased performance, the DS2100 also provides a full range of interfaces to servomotors, feedback devices, and higher-level controllers. The DS2100 will initially be available with a CANopen interface fully compliant to CiA DSP402a. A series of other industry standard serial digital interfaces will be introduced over the coming months.

### Key Features

- High performance loop closure via full digital control
- Advanced resolver demodulation for high performance at lower cost
- Wide range of interfaces to servomotor feedback devices
- Support of industry standard digital serial interfaces
- Integrated universal power supply
- 7 programmable digital inputs
- Hardware enable input
- 3 Digital outputs
- Drive ready output
- Brake control output

### General Characteristics

The DS2100 Servodrive integrates the following functions:

- Advanced resolver interface yielding 15 bits of useful position information
- Encoder interface (incremental, SSI, Hyperface and Endat)
- 7 segment display for error & status information
- Fully configurable digital loop closure for current, velocity, and position
- Velocity loop closure bandwidth of over 400Hz

### CANOpen Interface

A full CANOpen interface to the CiA specifications DS301 and DSP402a is provided.
This interface provides support for the following modes:

- Factors (allows the use of engineering units)
- Direct torque and direct velocity
- Profile velocity and profile position
- Interpolated position
- 10 homing modes

For more information, contact the Moog Electric Drives Division in:

**Italy:** **sales.italy@moog.com** **USA:** **sales.icd_elec@moog.com**
**Germany:** **sales@moog.de** **Japan:** **sales@moog.co.jp**

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# Ask the Expert

## Bernoulli Forces


Fluid flow across a valve spool generates forces which are caused by pressure drop and change of flow direction. These are named Bernoulli Forces.

Bernoulli Forces tend to close the valve and limit the controllable hydraulic power over the valve. This is mainly a limitation with direct operated valves because of the low spool driving forces available from solenoids or linear force motors. Bernoulli Forces are often a critical factor for proportional or servovalve performance in closed-loop control applications.

With Moog's advanced spool design it is possible to partially compensate for Bernoulli Forces to increase the controllable hydraulic power across a spool valve. Moog uses highly sophisticated CAE tools to find optimum solutions for Bernoulli Force compensation in its direct drive spool valves. This means that Moog can often provide the required level of hydraulic power with a single stage direct drive valve where other companies need a two stage pilot operated valve, thereby saving the customer money and improving reliability.

To submit a question, click on **Ask the Expert**.

## Upcoming Events

Please visit the Moog booth at:

• Taipei Plas 2003 - International Plastics and Rubber Industry Show in Taipei, Taiwan (March 18 - 21, 2004)

• Mecanelem-Mecatronic in Paris, France (March 22 - 26, 2004)

• SimTecT 2004 Simulation and Exhibition - "Simulation - Better Than Reality?" in Capital Territory, Australia. (May 24 - 27, 2004 )

• Fluid Power Society of India (FPSI) Show in Bangalore, India (May 27 - 30, 2004)

• 23 BIEMH - Bienal Española de la Máquina Herramienta in Bilbao, Spain (June 7 - 12, 2004)

For more information, click on **Exhibits and Trade Shows**.

## Moog Training Sessions

- 23 -25 March 2004 and 22-24 June 2004 Software training: Introduction to MACS / IEC 61131 Programming (2.5 days) German Language Session, held at Moog GmbH in Boblingen, Germany (near Stuttgart).
- 25 - 26 March 2004 and 24-25 June 2004 MSC - Moog Servo Controller Hardware and Extension Modules Training (1.5 days) German Language Session, held at Moog GmbH in Boblingen, Germany (near Stuttgart).
- 15 -17 June 2004 Software training: Introduction to MACS / IEC 61131 Programming (2.5 days) English Language Session, held at Moog GmbH in Boblingen, Germany (near Stuttgart).
- 17 -18 June 2004 MSC - Moog Servo Controller Hardware and Extension Modules Training (1.5 days) English Language Session, held at Moog GmbH in Boblingen, Germany (near Stuttgart).

For more information, click on **Training Opportunities**.

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