MOVING YOUR WORLD

IDEAS IN MOTION CONTROL FROM MOOG INDUSTRIAL

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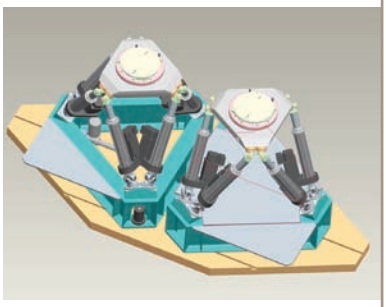
MOOG

ACCELERATE YOUR PRODUCT DEVELOPMENT WITH A MOOG KINEMATICS & COMPLIANCE TEST SYSTEM

By Erik Kuiper, Application Engineer at Moog BV in The Netherlands

In September 2008, Moog installed and commissioned a K&C Test System at a major OEM's site as the first of its kind. K&C stands for Kinematics and Compliance and the system is used for measuring the kinematics and compliance properties of a vehicle's suspension. The development of vehicle suspensions makes extensive use of CAD and CAE tools reducing the need of real-world prototypes. Later on in the development process the K&C Test System is used for design verification, which makes it an important addition to the chassis development process. Additionally, the K&C Test System is used for suspension tuning. The influence of changes in suspension parts characteristics are easily assessed with the K&C Test System. This makes it a versatile and valuable tool. Moog has been leading the industry in the development of high performance electric K&C Test Systems and is actively involved in a new Working Group to develop a K&C Standard for the relevant ISO sub committee (ISO/TC22/SC9).



Hexapod technology and electric actuation provide simpler installation, less required space and lower maintenance costs.

What is K&C testing?

The vehicle suspension is a complex mechanism that consists of links, joints and bushings (elastics bearings). Basically, the wheel has two degrees of freedom; in vertical direction, to cushion road obstacles, and in steer direction, to change direction. The other motions are therefore constrained. This is referred to as the kinematics of the suspension. Since the suspension contains elastic elements, it will deform under influence of external forces and moments. This is the compliance of the suspension.

The general concept of K&C measurements is to separate the kinematics and compliance properties for the different degrees of freedom. For example, consider a vertical motion test. The wheel is moved vertically within the full stroke of the suspension. The longitudinal and lateral forces as well as the aligning (steer) torque are controlled to zero. In this way no reaction forces can be built up in the suspension and therefore the constrained longitudinal, lateral and steer motions are measured. The K&C Test System is able to control each degree of freedom in position or force mode.

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The measurement set-up consists of the vehicle which is fixed to the ground and thus cannot move. The wheels are standing on individual platforms that can move and rotate in six directions or degrees of freedom. The wheel contact force and moment, the platform motion and the wheel motion are measured. A motor is connected to a steering wheel so it can be steered and the steering torque is measured.

Our 6-DOF Kinematics and Compliance measurement systems have been developed in partnership with automotive manufacturers seeking highly accurate stiffness and kinematics measurements using either force or displacement control.

COMPONENTS

The K&C Test System consists of the following components:

Hexapods

The platforms are hexapods or Stewart platforms. The platform has six actuators which allow it to move in all six directions. The platforms move the wheels to move and can move individually but for the K&C rig their motions are coupled, so the wheels can move simultaneously.

Track width adjustment

The hexapods are mounted on a frame which is mounted on the floor. The frame allows the hexapods to be positioned in lateral direction, so the position of the hexapods can be adjusted to the track width of the vehicle under test.

Load cells

The hexapod platforms are each equipped with a six axes load cell to measure the forces and moments applied to the wheels.

Optical position sensor system

The system is equipped with two cameras, each focused on a side of the vehicle and optical targets fitted to the wheels. The positions of these optical targets are measured by the cameras so the motion of the platforms and the wheels can be determined. Both cameras are connected and measure in the same frame of reference with very high accuracy.

Control system

The control system consists of a real-time computer with a data-acquisition system. The control system uses the measured forces and moments and the platform motion as feedback for controlling the platforms and steering wheel to the commanded positions. Each control channel can be in position or force control. The commanded positions are translated to actuator position by a real-time kinematics model of the hexapods. Additionally, the control system handles all data acquisition and recording.

Application software

The application software runs on an operator computer and it manages all the tests. The tests are defined and the appropriate commands are sent to the control system which performs the test. The measurement data is collected from the control system and stored in a database. The test execution can be monitored on-line and measurement reports are generated automatically. By using templates for the tests, a standard test suite is defined but specific tests can be easily created as well. The application supports interaction with the operator for entering additional data and asking for confirmation on-line during test execution. This feature is also fully customizable.

SPECIFICATIONS

Electric actuators

The K&C Test System is an electric actuated system. It doesn't need a complex infrastructure compared to a hydraulic actuated system. The system produces very little noise during operation and maintenance is very limited.

Single closed loop controller settings

The control system uses one set of parameters which is suited for all types of vehicles. There is no manual loop tuning needed. This makes the system very user-friendly and easy-to-use.

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Optical position sensor

The position sensor uses optical targets which are fitted to the wheels with magnets and two cameras beside each hexapod. An automatic calibration procedure is used to determine the alignment properties of the targets with respect to the wheel and is accounted for automatically in the software. Since there is no mechanical contact between the sensor and the vehicle, the sensor does not influence the measured positions.

Automatic vehicle set-up

Once the vehicle is mounted, the K&C Test System determines the vehicle position and orientation with respect to the rig and automatically compensates for the actual vehicle position. The set-up procedure only takes about two minutes. The entire process to be ready for test, including mounting of the vehicle, takes approximately 20 minutes.

Fully customizable application software

The application software comes with templates for standard kinematics and compliance measurements. The user is also able to create templates. Therefore, the user interface, test procedures and data acquisition are fully flexible.

Involvement in International Standardization

In January 2009, the sub-committee ISO/TC22/SC9 – Vehicle Dynamics and Road-Holding Ability of the International Organization for Standardization (ISO) decided to form a new Working Group to develop a K&C Standard. This Working Group is formed by international experts in the automotive industry. The objective of this new working group is to standardize the K&C measurement process and analysis, independent of the type of test system and measurement principle. Moog is actively involved and the author is the convener of the Working Group.

Author

Erik Kuiper is an Application Engineer at Moog BV in The Netherlands. He holds a Master of Science degree in Mechanical Engineering from Delft University of Technology and has over 8 years of experience in the automotive industry.

5 WAYS MOOG CAN HELP YOU MAKE AN EASIER SWITCH TO ELECTRIC ACTUATION

By Don Bockhahn, Electro-Mechanical Actuator Product Application Manager

Moog technicians and engineers are often asked by customers for help in transitioning an application from hydraulic to electric. With a large team of application engineers with great expertise in both hydraulic and electric technologies, the first step usually involves working with the customer to analyze which technology is best for the application. Looking at the forces involved, power requirements, and operating environment as well as each customer's expectations such as lifespan, lifecycle costs and maintenance programs, the answer is always unique to each machine, application and company.

Moog Electric Linear Servoactuation Package is a pre-engineered system consisting of an electric actuator, servodrive and integrated software.

Based on lessons learned from working with many companies who have successfully made the transition from hydraulic to electric, Moog has developed an Electric Linear Servoactuator Package solution that combines performance with ease of installation. Here are 5 ways Moog can help you to make the easy switch to electric actuation.

#1 Complete package, ready to use out-of-the-box

The Moog Electric Linear Servoactuator Package is a pre-engineered system consisting of an electric actuator, servodrive and integrated software. Because the entire system is sized to fit the specific machine application, it is much simpler to integrate than an assortment of components would be. Based upon the analysis of the application, we recommend either a standard or a flexible package depending on the configuration, size and strokes needed.

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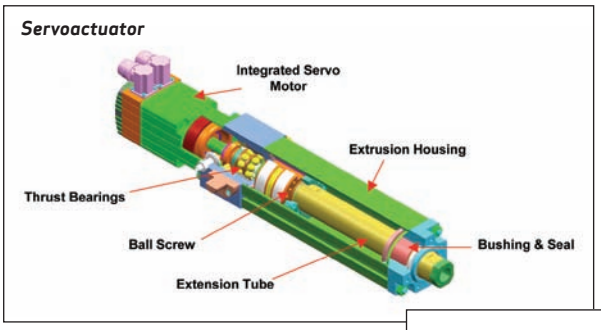
A Standard Linear Servoactuation Package is available in three motor frame sizes that can cover most applications with a continuous force to 28 kN (6,200 lbs), stroke lengths of 150 and 300 mm (5.9 and 11.8 ins) and rod speeds to 600 mm/sec (24 in/sec). If other performance characteristics are needed our Flexible Linear Servoactuator Package has a wide range of choices, including four actuator frame sizes and two styles, and speeds up to 1,600 mm/sec (63 in/sec), forces up to 96 kN (21,500 lbs) and stroke lengths up to 2,500 mm (98 in).

#2 Quick and easy to install

One of the hurdles to successfully installing an all-electric system is matching the performance of a variety of components. If just one component isn't precisely matched to the performance of the others, the engineer risks extended downtime and even damage to the machine itself. The Moog package has been pre-engineered for optimal performance which means, in most cases, the customer can manage their own engineering with little or no assistance from the outside. This makes installation faster, easier and more cost-effective.



Choice of Servodrives

#3 Saves time and added costs

To further minimize application and installation time, Moog has created sizing software that takes the guesswork out of the planning process and helps ensure a perfect fit and optimal performance for the life of the machine. Moog's new software can easily specify the linear electric actuator solution that meets each machine's technical requirements. For example, the sizing software defines system parameters including:

- motion profiles
- force requirements
- operating temperature
- orientation of installation
- system lifespan
- and more

#4 Easy to commission and safeguards your investment

Another key element of the Moog solution is the flexible commissioning software. This software helps the system operate more efficiently, delivering the exact performance characteristics and flexibility for the application. And a user-friendly control panel affords ease of set-up and troubleshooting. The result of this sophisticated software is faster commissioning with less technical support required.

#5 Total support

While the Moog solution is designed for ease of installation and simplified, high-performance operation, support is always available when needed around the globe. Moog has been at the forefront of electric technology for more than 25 years and our experienced engineers are always ready to work with you to provide unsurpassed technical expertise and proactive support.

Moog has several servodrive options that you will work with this servoactuation package. Contact your local office to learn more about the servoactuation package that will best meet your requirements.

Author

Don Bockhahn is the Electro-Mechanical Actuator Product Application Manager for Moog Industrial where his responsibility is to introduce the electric actuators product line to distribution channels as well as develop various applications for customers. He has worked in Engineering and Sales positions for a variety of motion control companies as well as electric actuator manufacturers.

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NEW WELDING PROCESS FOR JET ENGINES OF THE FUTURE

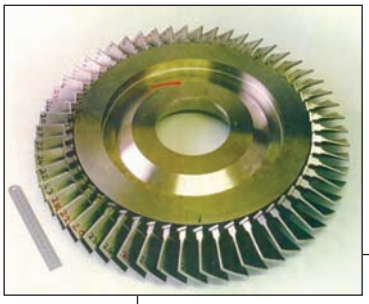
By Rebecca Gunn, Marketing and Sales, UK

When a world-leading developer of advanced manufacturing processes decides to develop friction welding to a point where it can be viable for securing the blades on jet engines, it stands to reason that any partners it chooses will have a similarly robust pedigree. Aiming at producing a machine that would be the biggest in the world and change your business out of all recognition, you know from the outset that the people with whom you find yourself in harness are going to need matched abilities and complementary skills. Joining forces with such a partner will give you confidence that the result of the project will be more than the sum of its parts.

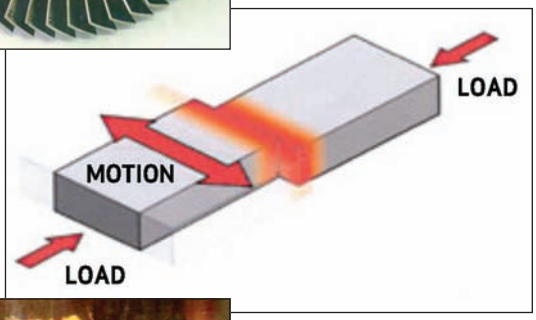
Exterior of E100 machine body in partial build, showing forge and tool assembly on the main slide

That's exactly what happened when UK firms, Thompson Friction Welding (TFW) in the West Midlands engaged Tewkesbury-based Moog to work towards the production of the world's largest linear friction welding machine. The machine in question is the E100, based at the Thompson facility at Halesowen, West Midlands. The key challenge faced by its developers was that never before had the friction welding technology been used with such required accuracy at the high frequency. The desired specifications for the finished product were:

- Power 2 MW › 4,500 l/min @ 280 bar (1,188 USg/min @ 4,061 psi) for a weld time of up to 5 seconds
- Oscillating actuator capable of moving the tooling and component masses
- Frequency up to 100 Hz
- Displacement up to 5.0 mm (0.197 in.)
- Positioning accuracy 13 µm (.0006 in.)
- Forging force 100 tonnes (220,000 lb)



Objective: secure the blades on jet engine blisks



Pieces of titanium are "rubbed" together at tremendous speed (50 Hz) and with high forces (800 kN) to physically weld components to each other (mass of 1500 kg).

TFW has been developing advanced manufacturing processes for a wide variety of industrial components for more than 40 years. In that time the company has supplied more than 550 machines worldwide, and has established an enviable track record of bringing friction welding process innovations to market – mostly rotary friction welding techniques and machines. But rotary techniques are not suitable for all components, so the development of this impressively proportioned linear machine was the logical way forward when the TFW people were deciding several years ago how to expand the business.

To begin with, TFW bought a company specialising in linear friction welding, and that was the company's route to market in terms of credibility, making sure that the Thompson name was linked to that process. Then TFW looked for a team of people who could design and build the proposed piece of kit. What was needed was expertise in servohydraulic systems, and hydrostatics. Trawling the marketplace, including a linear friction welding company in the US, eventually led to 'a shortlist of one, and it was Moog,' explained TFW managing director Alan Shilton.

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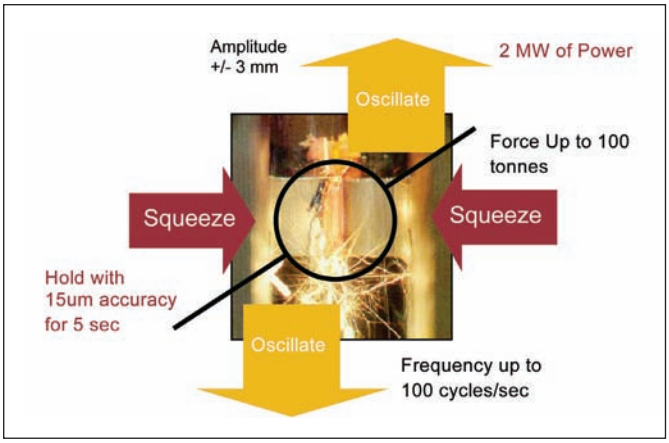

According to the Metallurgists these are the parameters required for this application

It was clear from the start that the two companies gelled; they had similar philosophies. 'As a business, Moog was up for the work,' said Shilton. 'They were positive in their reactions to our questions, while other people in the marketplace shied away from the questions that we were asking. They were open and honest about what they knew and what they didn't, and we moved forward on that basis. And here we are, two and a half years later, with a machine.'

The E100 demanded a high performance servo hydraulic system, which is very much in line with Moog's expertise. So what Moog brought to the table included:

- Multiple Moog servovalves with fieldbus interface, which operate at high flow and high frequency to make the weld
- High response Moog closed-loop control system, in other words advanced digital control techniques that achieve the required control over the weld process
- Hydraulic power unit, which provided the high power source needed to feed the system
- Multiple banks of accumulators, which provide the very high peak oil flow required for the weld
- Manifolds and distribution pipe work installation, a comprehensive sub-system routing oil to multiple active components

Thompson and Moog were clearly the key drivers of the E100 project, but the programme itself was a triumph of collaboration between several parties. The list of partners included:

Thompson Friction Welding

- Friction welding process and mechanical/electrical design of machines

Moog in Germany

- Development of high performance digital servovalves with fieldbus interface (D674 Series)

Moog in The UK

- Consultancy, mechanical design of motion system, design of power system, dynamic modelling and sizing of application
- Load testing of D674 Servovalve for 2 million cycles
- Design, program and development of the Moog Modular Multi-Axis Programmable Motion Control Servodrive (MSD) high speed closed loop duplex system
- Integration of MSD control. x3 MSD.
- Full program management of servo hydraulic system build and Hydraulic Power Unit installation.
- Development of high speed closed-loop communications for EtherCAT servovalves, equipped with fieldbus interface (EtherCAT), sensors and analogue and digital I/O modules. High speed industrial fieldbus systems have been used for communications between the Moog real-time controllers and the TFW overall control and monitoring systems

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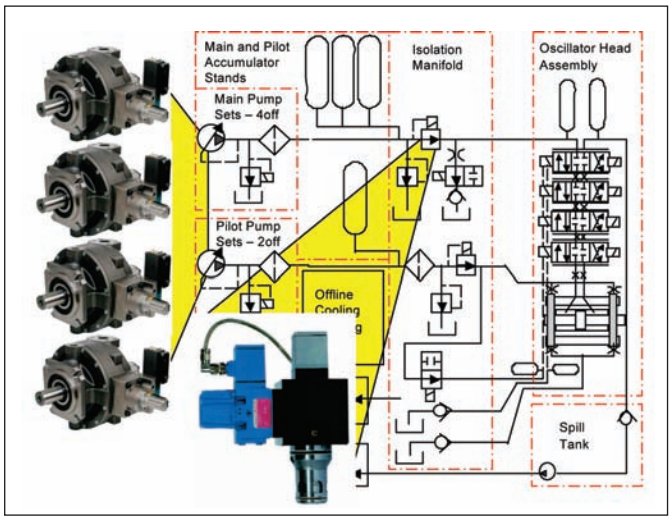
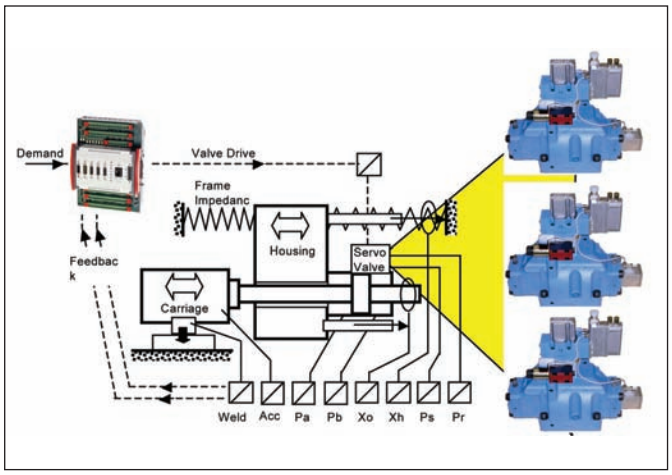
It's clear that Moog's experience and expertise in project management, design, development, manufacture, installation and support services have all contributed to the success of the project. But the company's own practical capabilities in the friction welding process – as well as in high performance servo hydraulic control, high performance hydraulic actuators and the provision of large scale hydraulic power plant and distribution systems – are second to none. Moog's own presentation on the project 'recipe' underlines the technical scope of the project:

'First, take four Moog Radial Piston Pumps (RKP pumps) and a bundle of Moog cartridge valves.



Add a room full of hydraulic accumulators.
Take the oscillating flow of three "turbo charged" Moog D674 Valves (all 6,000 lpm of it!), meaning that four valves would deliver a total flow rate of 6,000 lpm and add the squeezing force of two hydraulic actuators .Connect it all together with a sophisticated pipework and manifold installation, then the intelligence of three Moog Servo Controllers (MSC controllers) and near to 100 sensors. Bind together with the know-how of Moog application expertise, bake for five seconds at 2,000,000 watts and let cool. Repeat for another 50,000,000 cycles.'



Alan Shilton explained, "People expect to see one single tool or machine when we talk about it. In fact it's a facility, not just a machine. Its 100 tonnes capacity (110 ton US or 220,000 lb) and two and a half metres height (8ft 2Đ inch) means that it's huge compared to previous existing machines (just 70 tonnes, 77 ton US or 154,000 lb) so this is much larger and everything else that goes with it has that sort of scale. That was our intention from day one – it's not something that has just come about. We set off knowing that it was to be the largest and most flexible machine ever built. We are very close to making our first weld, which will be a titanium product to start with. We'll begin with a qualifying programme, and then we will put it through its paces – from the very small through to very large (100 tonne) jobs. The smallest is 800 mm2 (1.25 sq. in.), and the largest surface area that we are able to weld is 10,000 mm2 (15.5 sq in)"

'It's a development project, the net result of which is the production of a machine. Throughout the process, Moog has been very accommodating in terms of delivering what we requested of them. We had broad criteria because we set some ground rules at the start, and we had all the tooling, special frequencies of amplitude we wanted the machine to perform at. We depended on Moog to deliver that end result, and they have not been found wanting. It became more of a partnership as each stage progressed; the senior people are fully aware of what we are doing in the marketplace because we keep them informed. They know where our plans and aspirations lie in relation to the marketplace. We are not just in jet engine manufacture - we have come up with a number of novel ideas for using linear welding as a process.'

One of the key motivators is the belief that the E100 machine will alter the way in which jet engines are manufactured, he said. 'It will be five to ten years down the line, because in the aircraft industry you have to

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look a little further ahead than in, say, the automotive industry. That's one of the things we have learned along the way: new processes need to be maturated, you need to be comfortable with the process.'

He concluded: 'We have had some exciting and interesting times but it's always been great. We already have two orders to work on, on a machine that's not yet been finished, which confirms our belief that the marketplace is ready. It's all very exciting. We hope it's something that will change this business out of all recognition and put us in a prominent position for attacking the worldwide market, not just the UK. And we'll be hand in hand with Moog all the way.'

About Thompson Friction Welding
Thompson specialises in providing friction welding solutions, boasting more than 40 years' experience in developing advanced manufacturing processes for a wide variety of industrial components. The company's capabilities includes friction welding equipment with capacities from 4 - 300 tons; choice of single or double ended arrangement; variety of load and unload options; internal and external flash removal; weld orientation facility for complex component geometries; market-leading, in-situ TIR measurement; part number stamping for traceability, and all machines include leading-edge, Thompson-designed software control systems.

With more than 550 machines supplied worldwide, Thompson is the technology partner of choice and has established an enviable track record of bringing friction welding process innovations to market. Further information about Thompson Friction Welding is available here: www.thompson-friction-welding.co.uk

Thompson has been awarded a Queen's Award for Enterprise 2009: Britain's most prestigious Awards for business performance. Thompson also won a Boeing Performance Excellence Award for 2008.

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