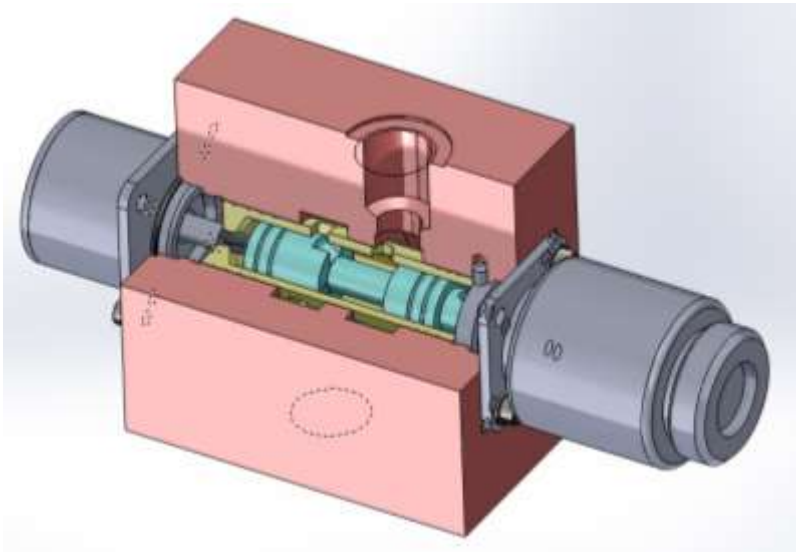
FOCUS CNR ACTIVITIES 2014

A new High Performance roto-translating valve for fault tolerant applications

Pietro Marani, Mobile Fluid Power and Power Transmission Research Group of CNR - IMAMOTER Institute

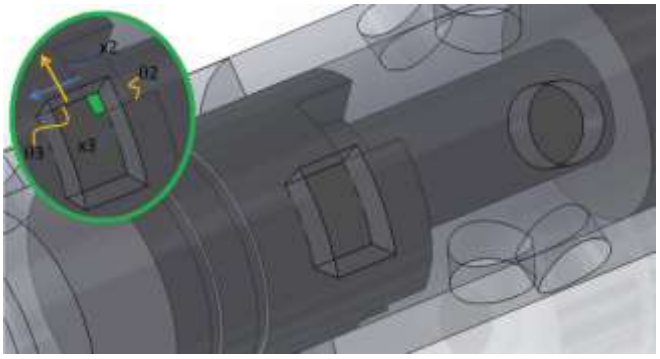
Massimiliano Ruggeri, Electronic Design & Integrated Control Systems Research Group of CNR - IMAMOTER Institute

The new X-by-Wire systems under study for commercial and heavy-duty vehicles, as well as for Agricultural Tractors, are increasingly independent autonomous systems, capable to control the vehicle functionality, actuating the operator's commands, or managing in a complete autonomy a machine function. These applications need an higher Performance Level from the functional safety point of view, due to the risk of malfunction.



3D Model of a Roto-Translating Spool Valve

IMAMOTER institute has developed and patented a new concept hydraulic spool valve that allows the design of new safer and more compact hydraulic circuit architectures, ensuring higher safety performance levels. The architecture presents advantages both in performance (precision, fastness), and in operational environment. The valve presents a secondary rotary type actuator connected to a sleeve interposed between the spool and the valve body, thus composing a roto-translating valve. The sleeve presents holes that can be moved and positioned, partially or totally overlapped, to the valve ports, thus allowing a secondary independent metering. The valve port area is then obtained by the combination of the linear movement of the spool and the rotary movement of the sleeve both supervised by a microcontroller based unit.

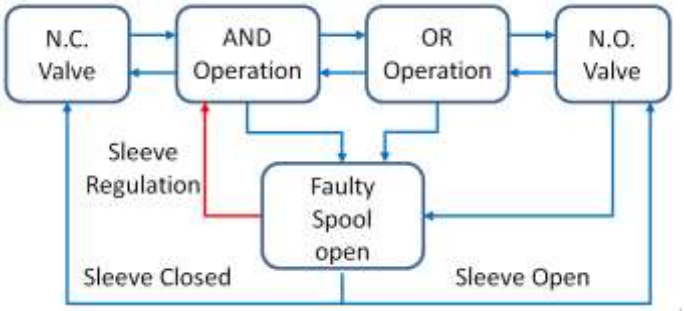


Detail of the Movement Composition for the Metering

The mutual position of the spool notches with respect to the sleeve windows determines the metering area, controlling the flow between the valve ports. Due to the valve structure, the metering control precision and valve speed are virtually quadratic in respect to the traditional valve spool position electronic control, due to the concurrency of two electronically controlled actuators. Moreover the double degree of freedom enables the realization of different logic functions from the basic AND and OR function to more and more complex control strategies.

A remarkable feature of the valve is the possibility to obtain a High Gain Valve or a Low Gain Valve fixing the position of one of the two moving elements and then acting on the other one. Thus the valve has the opportunity to adapt to a specific working cycle performing very slow and accurate control or a full power and very fast operation while two different valves would be necessary according to the nowadays state of the art. Clearly more complex control strategies that combine the rotary and linear control will offer the opportunity to achieve an optimal performance.

It is also worth noting that the feature of precision of the valve depends on the Controllability of Flow Gain, it is intrinsic in its structure and does not rely on sensors feedback, and nonetheless it is possible to implement position sensors on the spool and sleeve, opening the possibility for an even more accurate closed loop control.



Finite State Machines Analysis Example

For the state of art the most common method to assure functionality in case of a failure occurrence, is to double the components, increasing the size, resulting in a significant increase of systems weight and complexity, affecting both fixed and running costs. The novel valve in reason of the diversity of the actuators is fault tolerant and can be employed in safety critical systems, offering a different perspective for redundancy concept in flow regulation techniques and applications. In fact, as the valve functionality finite state machines analysis has shown, in case of fault of one of the two actuators, the valve can be driven in the necessary control position, in order to ensure the safe position, or continuing to control the oil flow with the other one. This feature makes the valve suitable for safety critical systems, like flight controls, brake and steer by wire systems, where the main functionality can't be lost even in case of fault.

The functional safety features, flexibility and high precision characteristics of the new roto-translating valve are a promising scenario for a new class of component design and study for innovative electro-hydraulic applications. The roto-translating valve concept offers a new valve design perspective. The new architecture, coupled with new automatic control technologies, offers solutions and possibilities that can improve many aspects of the flow control in the high precision, high dynamics or high safety performance level required applications. The research activities until now have disclosed the main characteristics of the invention, all related to the concept phase and system design, but some of them really evident and undeniable, thus allowing to develop further the valve concept and new control architectures for safety critical systems.