

## Individualized Structures in Fluid Power Systems



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## From belt transmission

to distributed drives / local intelligence / integrated safety / high level of communication



Central belt transmission - Power transm.



#### Distributed drives – Power & Information transm.





## From todays central hydraulics



## to individual smart drives / local intelligence / integrated safety / high level of communication





## Individualization levels of displacement control systems

- common motor-pump-unit applications with strictly sequential working cycles (no parallel operation)
- common motor but individual variable displacement pumps for each actuator beneficial with other efficient drive technologies, (power split transmissions) recirculation possible / individual pressure levels
- individual motor-pump-unit for every single actuator highest level of individualization and flexibility individual pressure and speed levels / high component effort





#### Potentials of individualized displacement controlled systems





### Structural variants of displacement controlled systems

- depending on application, cycle, potentials
- depending on energy source / domain
- depending on investment acceptance







## Results

- proof of static and dynamic performance
- similar good efficiency as commercially available electromechanical compact drive



## Challenges

- thermo-energetic status
- passive cooling
- heat exchange

# **Structure variants** and possible solutions for compact drives



- operation cycle
- installed power
- fluid life time







#### Results

- Temperature field visualization via thermo-camera
- Simulation based on thermofluidic model
- Measurement confirms simulation
- Opportunities for increased heat transfer????

#### Oil and surface temperatures



## Thermo-fluidic model







#### Results

- 22% reduced temperature level
- thermo-energetic behavior can be simulated for known load cycles and system losses



## Model predictive optimization

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### Speed variable drive and variable pump control

Decoupling of drive speed and volume flow control ٠

**Energy Efficiency** min  $\int P_{Loss,t} dt$ 

Dynamic loss models of motor and pump

- Additional degree of freedom ٠
- Intelligent control strategy through model predictive optimization ٠

#### Simultaneous use of both actuators





**Process Dynamics**  $\frac{dQ}{dt} = n \cdot V_0 \cdot \frac{d\alpha}{dt} + \frac{dn}{dt} \cdot V_0 \cdot \alpha$ 











#### **Optimization aspects on system level**



b) Outlet temperature simulation and measurement

#### Temperature development, simulation and measurement



#### **Optimization aspects on system level**



#### Decentralization of Unit Supply

- System design for key operating conditions according to the specific demands and loads
- Determination of optimal, process-current control strategies for temperature control







#### Individualization levels of independent metering control systems

- differentiation regarding type and arrangement of the used valve technology
- common metering edges individual spool design only
- separate metering of in- and outflow of the hydraulic working ports
- topology of individual valve groups opens up for differential modes of operation (several free flow paths)



Diversity of valve technology



### Potentials of independent metering control systems









## Variety of system and control architecture

- variety of application specific component layout or valve architecture
- system structure combined with control/sensor architecture



Feed-forward control

Closed-loop SISO

control

## Cardboard packaging press - potentials



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#### **Machine structure**





# MIMO Flatness based trajectory control strategy:

- Smooth mode switching
- max. efficiency

## **Duty cycle and measurement results**

with MIMO flatness based control





## Independent metering for power assisted steering systems

- electrical drives offer very often integrated safety functions
- leads to an easy system integration for OEM
- benefits of IM structures in steering systems:
  - driver assisted steering
  - high safety level due to extended control intervention





Independent metering for power assisted steering systems - Safety



• a steering system with independent meter-in and meter-out valves





possibility to compensate single failures and reduce adverse effects of faulty states



Safety and availability

behaviour in case of failure:

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### Challenges in developing future pumps for individual displacement drives





# Challenges and requirements in developing future valves for individual independent metering architecture







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Thank you for your attention!

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