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ELECTRIFICATION AND DIGITAL TRANSFORMATION - CHANCES AND CHALLENGES FOR FLUID POWER TECHNOLOGY

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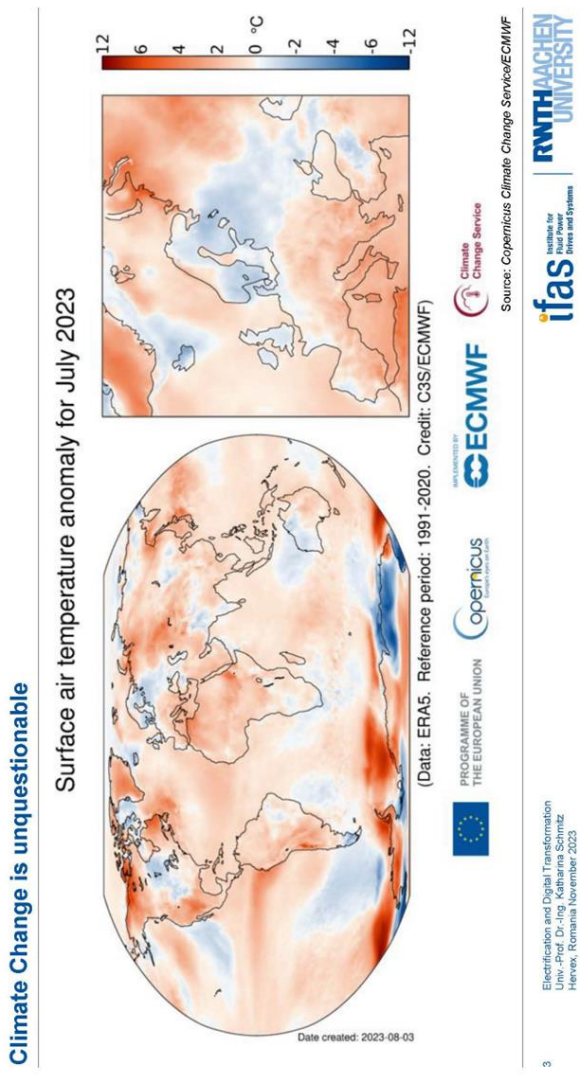
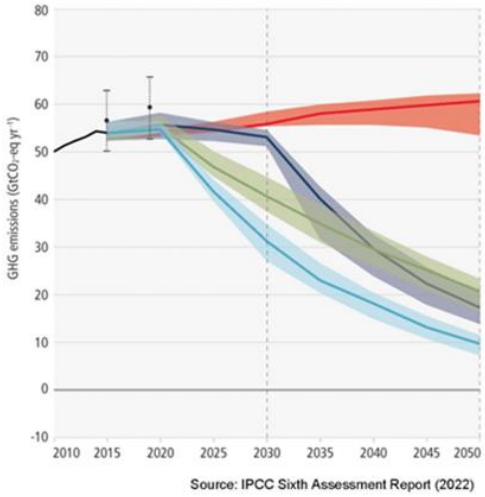


Admissible GHG emissions to limit warming



Source: IPCC Sixth Assessment Report (2022)

Modelled pathways:
- Trend from implemented policies
- Limit warming to 2°C (>67%) or return warming to 1.5°C (>50%) after a high overshoot, NDCs until 2030
- Limit warming to 2°C (>67%)
- Limit warming to 1.5°C (>50%) with no or limited overshoot
- Past GHG emissions and uncertainty for 2015 and 2019 (dot indicates the median)

+2 ºC warming results in:
- Sea ice-free Arctic summers every 10 years
- Loss of tropical coral reefs >99%
- Increase in river floods 170%
- Sea level rise > 1m + x

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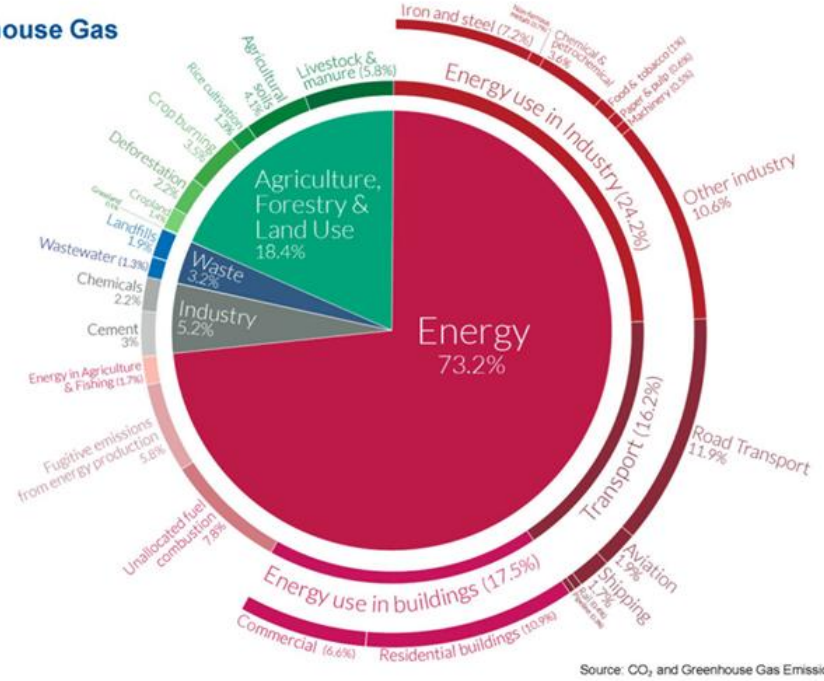
Global Greenhouse Gas Emissions



Source: CO_2 and Greenhouse Gas Emissions- OurWorldInData.org 2020

Traditional use of Fluid Power Drives

- High power density
- Robust design
- Good controllability open and closed loop
- Good dynamic behaviour through low inertia

Mobile Machinery	Industrial Hydraulics / Pneumatics

Future of Fluid Power: Modern & Sustainable Motion Technology

Electrification and Digitization

	Mobile Machinery	Industrial Hydraulics / Pneumatics
Digitization		
Electrification		

Electrification and Digitization

		Mobile Machinery	Industrial Hydraulics / Pneumatics
Digitization	Impact	I	II
	Challenge		
Electrification	Impact	III	
	Challenge		

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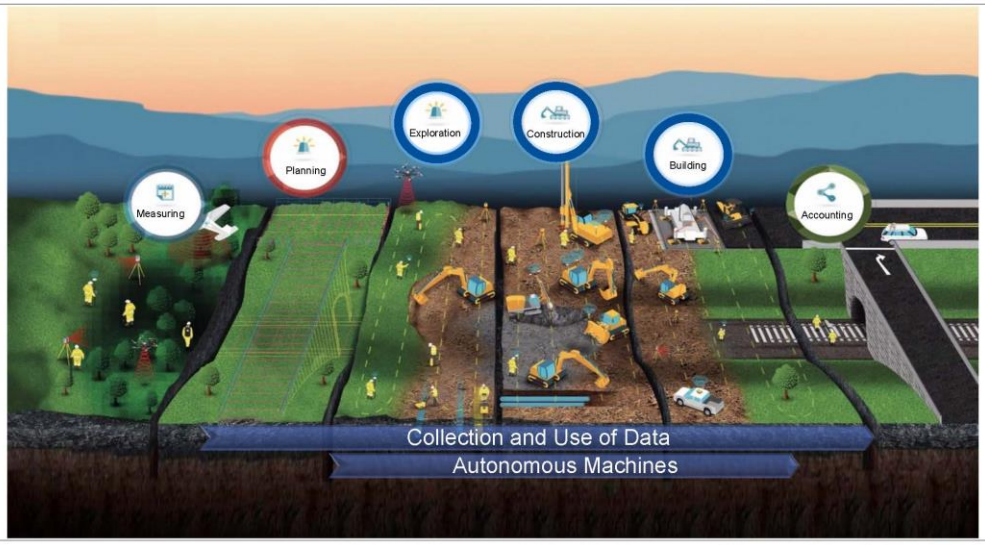
I – Way to an Autonomous Construction Process – Construction Site of the Future



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I – Digitization of Mobile Machinery

Motivation

- Autonomous construction site, account for lack of (skilled) workers
- Safer working environment, more sustainable processes / increase in productivity

Challenges

- Consistency of information
- Connectivity
- Data & algorithm availability

- Legislation

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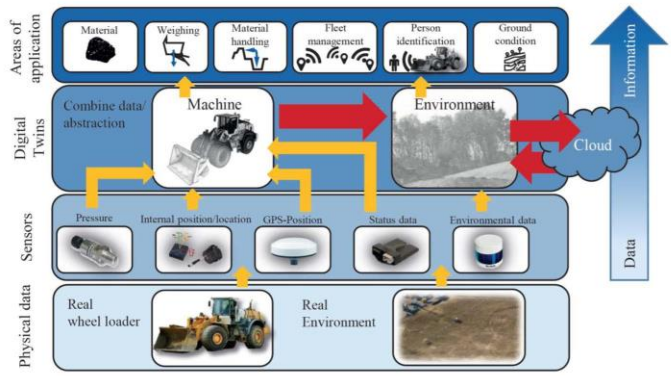
I – Digitization of Mobile Machinery – Research

Research Topics

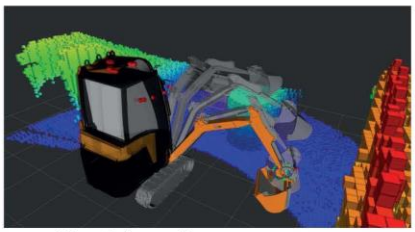
- Environmental detection and use of this data



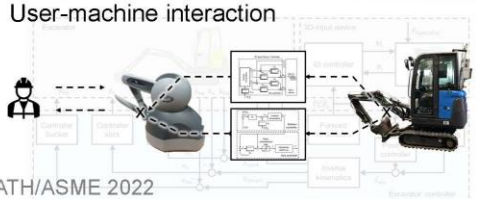
Deuster, IFK 2022

- Trajectory planing

Haas, IFK 2022



- User-machine interaction



Haas, BATH/ASME 2022

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Electrification and Digitization – Summary

		Mobile Machinery	Industry Hydraulics / Pneumatics
Digitization	Impact	Autonomous construction sites Higher efficiency in building / mining	II
	Challenge	Communication, Algorithm, Legislation	
Electrification	Impact	III	
	Challenge		

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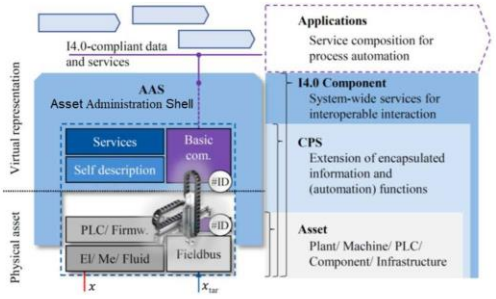
II – Digitization of Industrial Hydraulics / Pneumatics

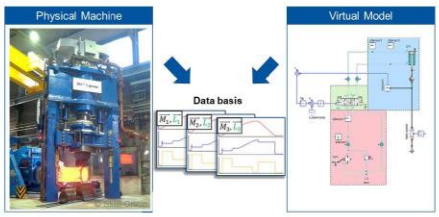
Motivation & Challenges

- Motivation: Flexible, efficient, reliable manufacturing
- Challenges: Connectivity of components, Data & Algorithm

Industry 4.0 / Connectivity



Data & Algorithm



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AAS: Asset Administration Shell
CPS: Cyber-Physical System

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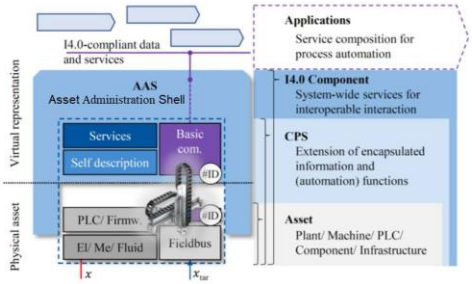
II – Digitization of Industrial Hydraulics / Pneumatics – Research on Industry 4.0 / Connectivity

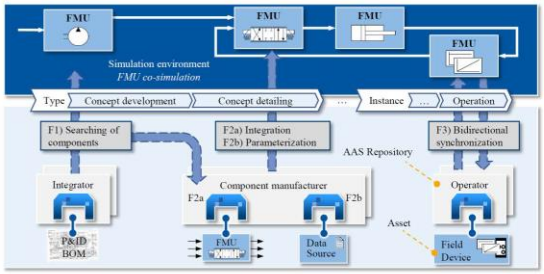
Industry 4.0 / Connectivity

- Connectivity via Administration Shells



Alt, PhD Thesis, 2023

- Building up Cyber-Physical Systems via Administration Shells

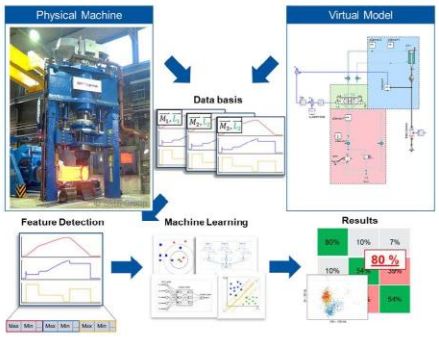


Becker, ASME/FPMC 2023

II – Digitization of Industrial Hydraulics / Pneumatics – Research on Data & Algorithm

Data & Algorithm

- Using data for condition monitoring via Supervised Learning and Neural Networks



- Using Reinforcement learning for optimizing control performance

- Research on generating „big data“
  - Using simulation models
  - Using virtual sensors

Hucko, ASME/FPMC 2023

Makansi, IFK 2022
Makansi, energies 2022
Makansi, ASME/FPMC 2023

Brumand-Poor, IFK 2022
Brumand-Poor, IJFP 2023

Electrification and Digitization – Summary

		Mobile Machinery	Industry Hydraulics / Pneumatics
Digitization	Impact	Autonomous construction sites Higher efficiency in building / mining	Flexible, efficient, reliable manufacturing
	Challenge	Communication, Algorithm, Legislation	Availability of components and services, Communication
Electrification	Impact	III	
	Challenge		

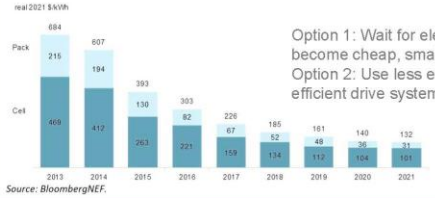
III – Electrification of Mobile Machinery

Motivation & Challenges

- Motivation: Locally reduction of emissions and noise
- Challenges: Cost effectiveness, System integration, Efficient systems, Multiple degrees of freedom

Energy Storage & Supply

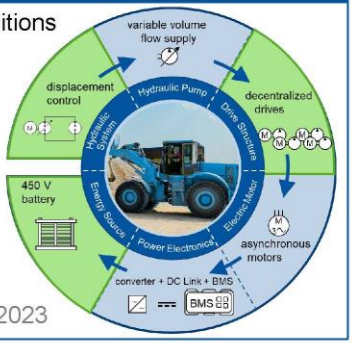
- Energy storage: Battery electric, Fuel cell electric, …
- Energy supply: Charging infrastructure, Hydrogen transportation



Option 1: Wait for electric batteries to become cheap, small, available
Option 2: Use less energy / more efficient drive systems

New System Architectures & New Components

- New boundary conditions for hydraulic system and components
- New Components required (lower / higher speeds)

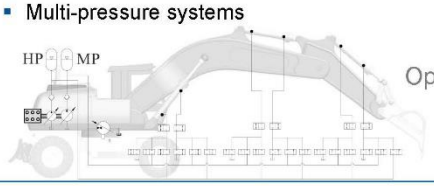


Opgenoorth, SICFP 2023

III – Electrification of Mobile Machinery – Research

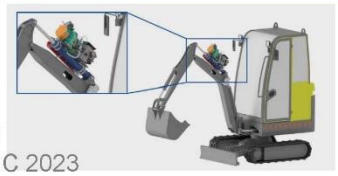
Drive Train Development

- Multi-pressure systems



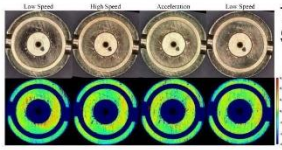
Opgenoorth, IFK 2022

- Displacement controlled actuators



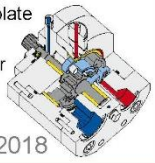
Pietrzyk, IFK 2018
Figge, ASME/FPMC 2023

New / Improved Components



Tribo investigation
Slipper – Swash plate

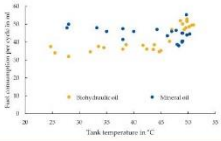
Internal gear pump for 10.000 rpm



Merkel, IFK 2022 Pietrzyk, IFK 2018

Alternative Fluids

- Improving efficiency by using bio oils / synthetic esters



Deuster, Sustainability 2022

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Digitization	Impact	Autonomous construction sites Higher efficiency in building / mining	Flexible, efficient, reliable manufacturing
	Challenge	Communication, Algorithm, Legislation	Availability of components and services, Communication
Electrification	Impact	Local zero emission machines, Noise reduction	
	Challenge	Energy storage and supply, New drive system required	

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References I/II

- Deuster, S., et.al; Methods of Environmental Information Acquisition by Sensor Data and Digital Twins; 13. International Fluid Power Conference (13. IFK), Aachen, Germany, 2022, Open access version, pp. 206
- Haas, C., et.al.; Environment Detection and Trajectory Planning Concept for an Automated Excavator using Open Source Software; 13. International Fluid Power Conference (13. IFK), Aachen, Germany, 2022, Open access version, pp. 1160
- Haas, C., et.al.; Practical Evaluation of a Control Concept for a Remote Controlled 1.8t Excavator Using a 3D Input Device, Proceedings of BATH/ASME 2022 Symposium on Fluid Power and Motion Control (FPMC 2022)

- Alt, R.; Service-oriented architecture for automated commissioning of fluid power systems; PhD Thesis, Aachen 2023; http://publications.rwth-aachen.de/record/958758/files/958758.pdf
- Makansi, F., et.al.; Feature Generation and Evaluation for Data-Based Condition Monitoring of a Hydraulic Press; 13. International Fluid Power Conference (13. IFK), Aachen, Germany, 2022, Open access version, pp. 794
- Makansi, F., et.al.; Reinforcement Learning-Based Process Optimization and Control of a Hydraulic Press With Multiple Actuators; Proceedings of BATH/ASME 2023 Symposium on Fluid Power and Motion Control (FPMC 2023)
- Makansi, F., et.al; Data-driven Condition Monitoring of a Hydraulic Press Using Supervised Learning and Neural Networks; energies, MDPI, 2022
- Becker, M., et.al.; Improving Fluid Power System Simulation Through an AAS-Based Simulation Framework; Proceedings of BATH/ASME 2023 Symposium on Fluid Power and Motion Control (FPMC 2023)
- Brumand-Poor, F., et.al.; Control of a Hydromechanical Pendulum with a Reinforcement Learning Agent; 13. International Fluid Power Conference (13. IFK), Aachen, Germany, 2022, Open access version, pp. 499
- Brumand-Poor, F. et.al; Application of Deep Reinforcement Learning Control of an Inverted Hydraulic Pendulum, International Journal of Fluid Power, River Publishers, 2023

References II/II

- Hucko, S., et.al.; Investigation of Frictional Forces in Hydraulic Spool Valves and Their Effect on the Estimation of Axial Flow Forces; Proceedings of BATH/ASME 2023 Symposium on Fluid Power and Motion Control (FPMC 2023)

- Figge, F., et.al.; Simulative Comparison of Electro-Hydraulic Actuator Circuits for the Application in Excavators; Proceedings of BATH/ASME 2023 Symposium on Fluid Power and Motion Control (FPMC 2023)
- Merkel, A., et.al.; Identification of wear progression due to variating operation modes of small high dynamic piston pumps used in frontline flight control application; 13. International Fluid Power Conference (13. IFK), Aachen, Germany, 2022, Open access version, pp. 242
- Opgenoorth, A., et.al.; Switching procedures of multi-pressure systems for electrified excavators; 13. International Fluid Power Conference (13. IFK), Aachen, Germany, 2022, Open access version, pp. 855
- Opgenoorth, A., et.al.; Algorithm based system synthesis of electrified mobile machines; 18th Scandinavian International Conference on Fluid Power, SICFP'23, Finnland
- Pietrzyk, T., et. al.; Design study of a high speed power unit for electro hydraulic actuators (EHA); 11. International Fluid Power Conference (11. IFK), Aachen, Germany, 2018, pp. 232-245.
- Deuster, S.; et al.; Bio-Based Hydraulic Fluids and the Influence of Hydraulic Oil Viscosity on the Efficiency of Mobile Machinery; Sustainability; MDPI; 2021