NEW SYSTEMS OF LECTRIC-HYDRAULIC BATTERY MOBILE DRIVE

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INSTITUTE OF **MACHINE**
AND **INDUSTRIAL DESIGN**

Limitations of this presentation

LIMITATIONS OF THIS PRESENTATION

only a bird's eye view

*merely in*bird´s*complete mosaic,*

rough sketch of more extensive solutions

SIMILARITY BETWEEN TWOO PROCEDURES

.

Atlas V

THREE STAGES
OF BUILDING OUR FICTIOUS ROCKET

3. DAPPER 5000

2. E19

1. AMMANN AP 240H

STAGES OF DEVELOPMENT OF NEW HYDRAULIC SYSTEMS

THREE STAGES OF DEVELOPMENT OF NEW HYDRAULIC SYSTEMS:

1. **The Amann road tire roller E19 produced by the company Amann, Nocé Město nad Metují**
2. **The excavator E19manufactured by the company Bobcat Doosan, CZ**
3. **The Dapper 5000 wheel loader produced by VOP, s. p., CZ**

oooooooooooooooooooooooooooooooooooooooooooooooooooooooooooooooooooooooo

The twoo solvers: Brno University of Technology + Bosch Rextoth

1. THE AMANN ROAD TIRE ROLLER AP 240 H

The aim of the research:

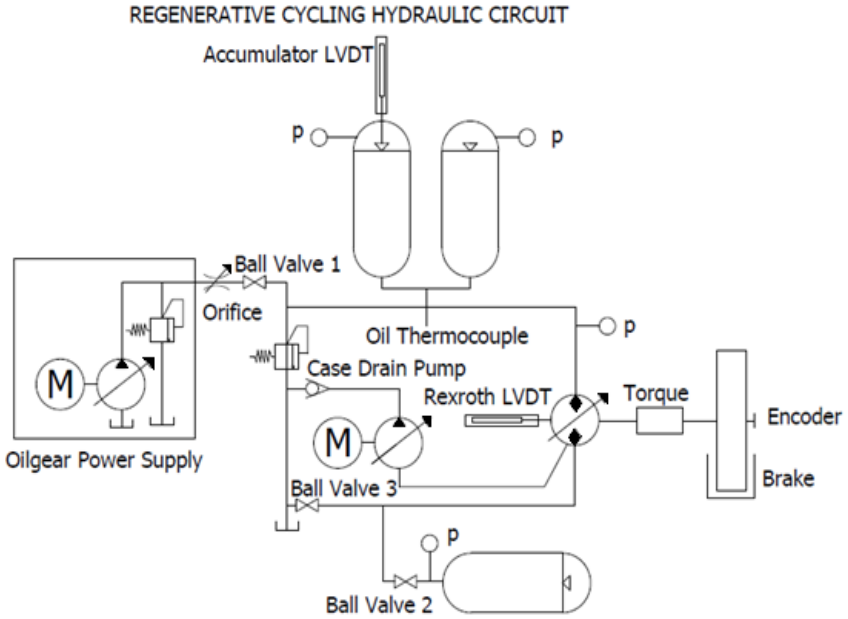
to reduce engine fuel consumption
<u>without any engine modification</u> (!)

The road roller
AMMANN AP 240 H
mass: 24 tons

THE ENERGY RECOVERY SYSTEM

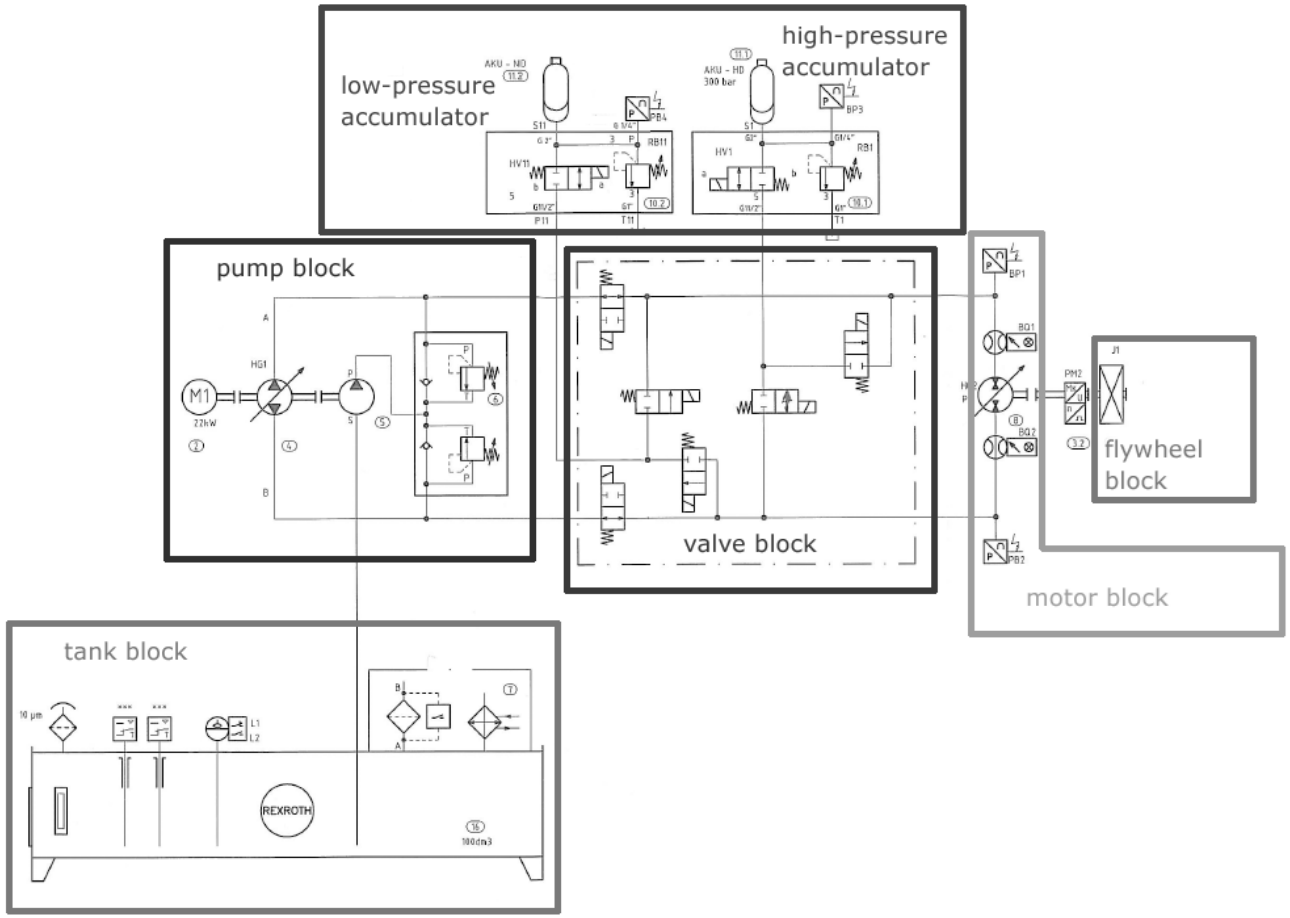
ELEMETS OF THE ENERGY RECOVERY SYSTEM

- the variable-displacement pump/motor
- the electric motors
- the accumulators
- the oil reservoir
- the connecting lines
- the flywheel which is used to simulate vehicle inertia



(Pourmovahed)

THE DIAGRAM OF THE STAND HYDRAULIC CIRCUIT

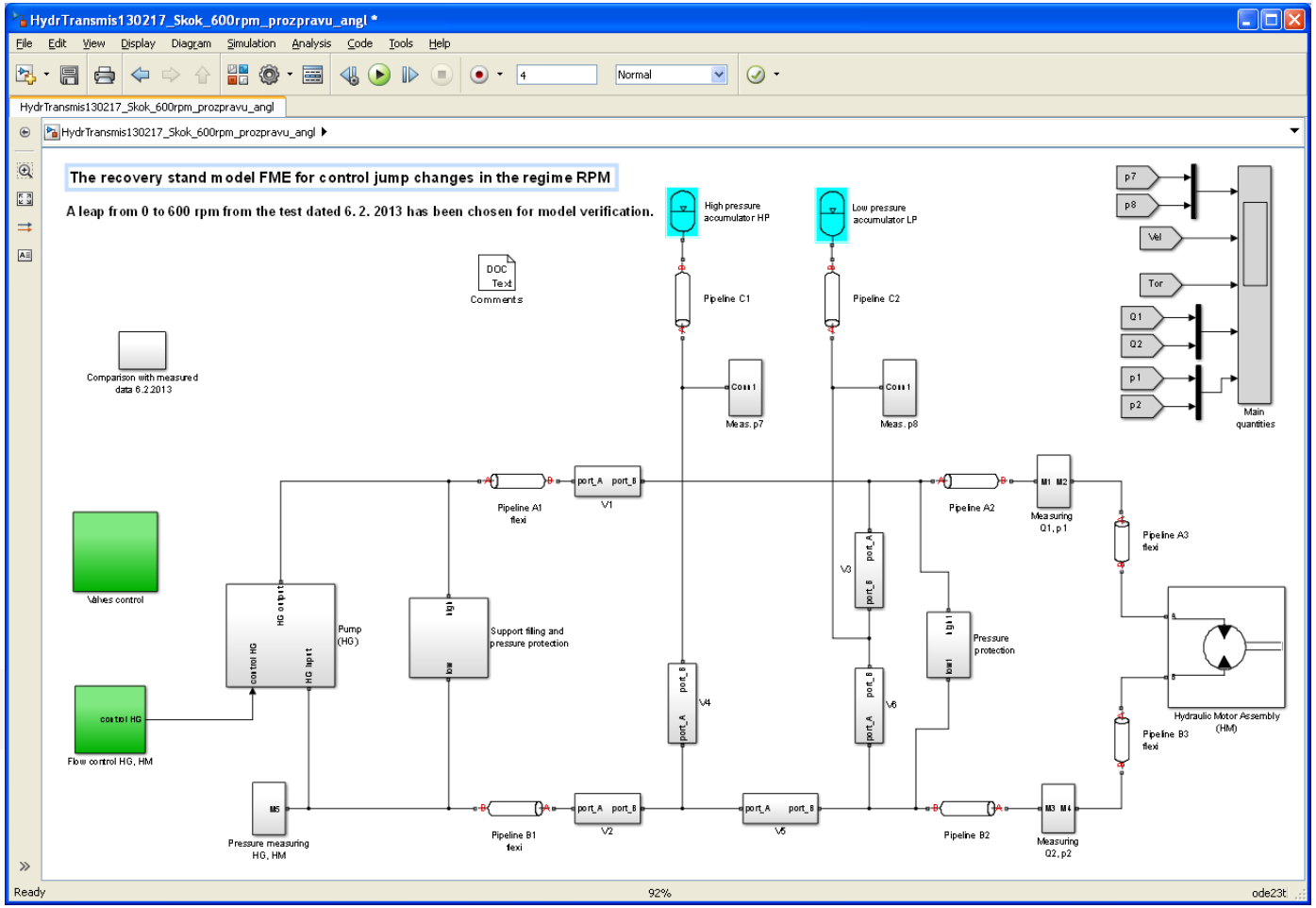


THE SPECIAL EXPERIMENTAL STAND

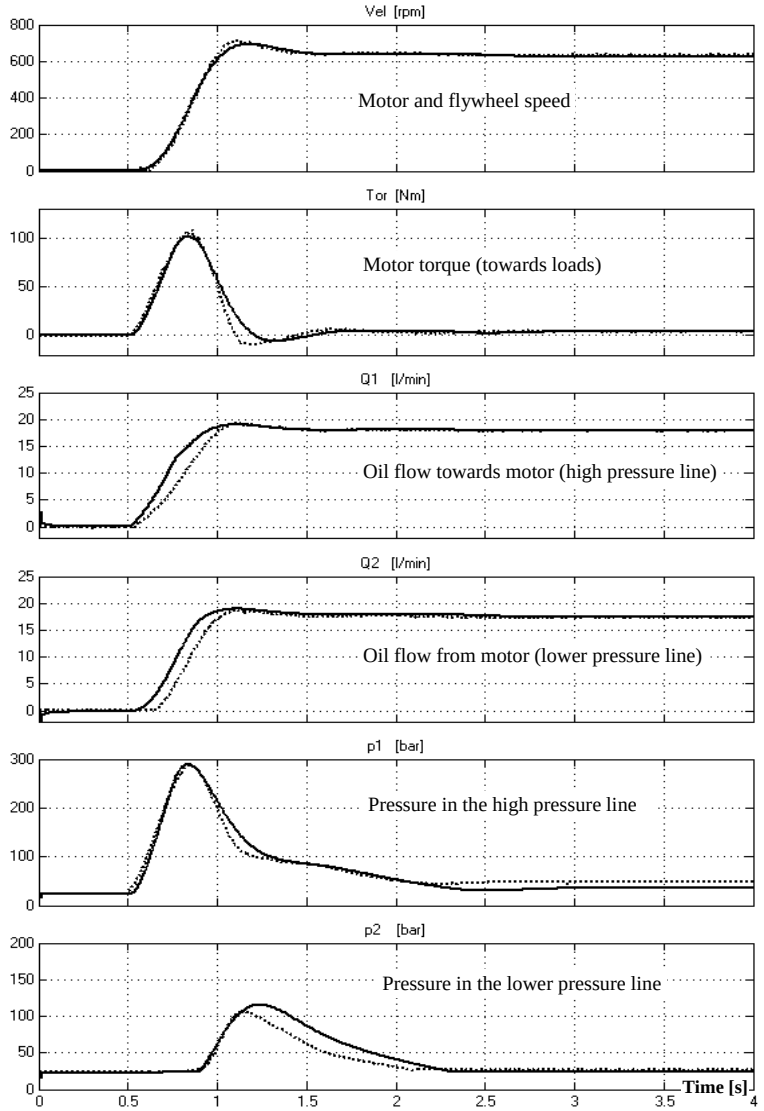
Hydraulic energy recovery system of the stand consists of:

- electric motor
- high-pressure accumulator
- low-pressure accumulator
- valve block
- variable-displacement pump/motor
- oil reservoir
- fly-wheel simulating vehicle inertia
- connecting lines

THE PRINCIPAL MODEL SCHEME OF THE STAND IN MATLAB/SIMULINK

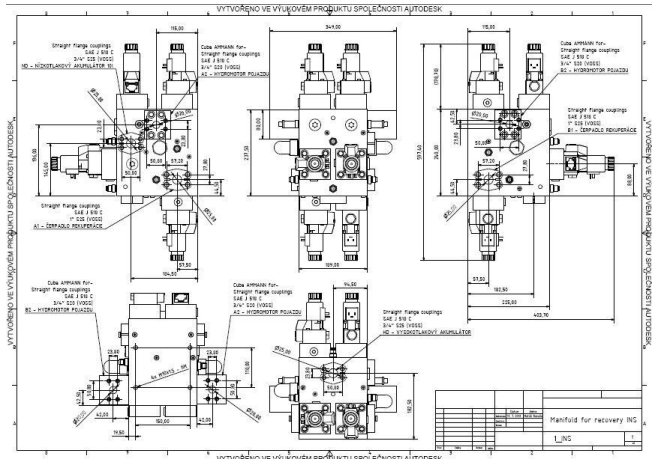


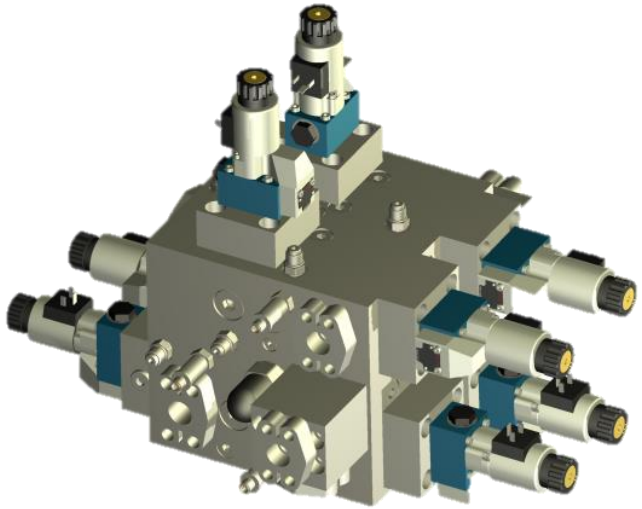
THE SIMULATED COURSES OF THE MAIN QUANTITIES OF THE CYCLIC RECOVERY

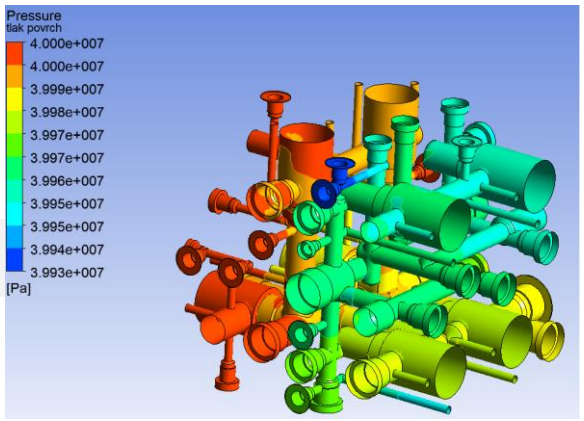


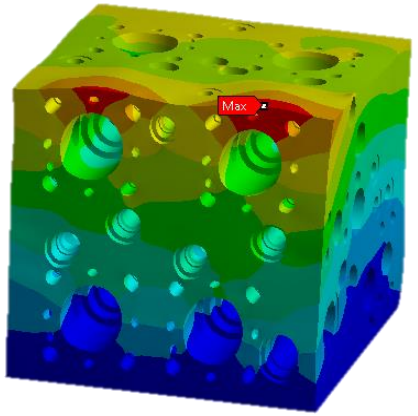
THE VALVE BLOCK OF THE ROAD ROLLER AMMANN

(M. RANUSA)

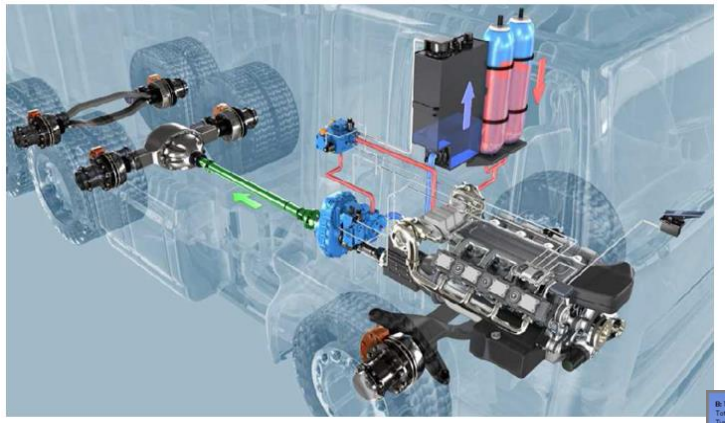


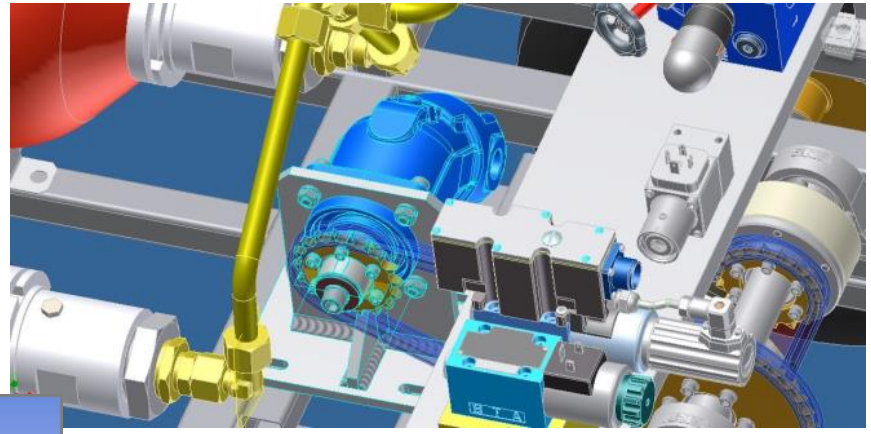


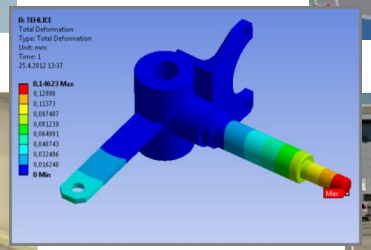


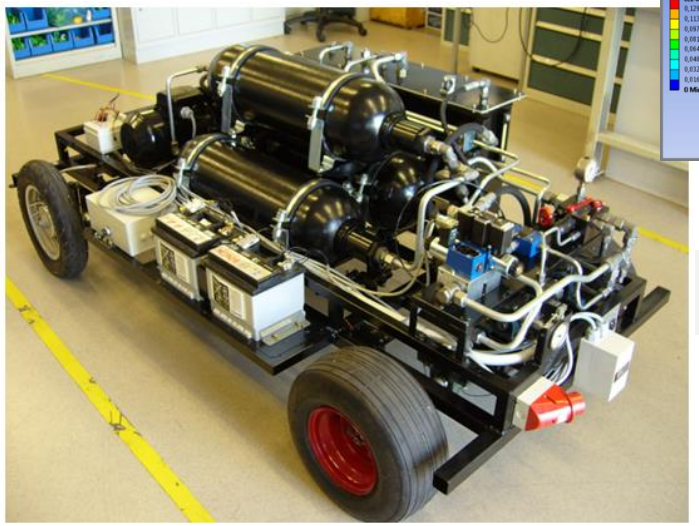


HYDROMOBILE EQUIPPED BY ENERGY RECOVERY, BRNO INTERNATIONAL TRADE FAIR









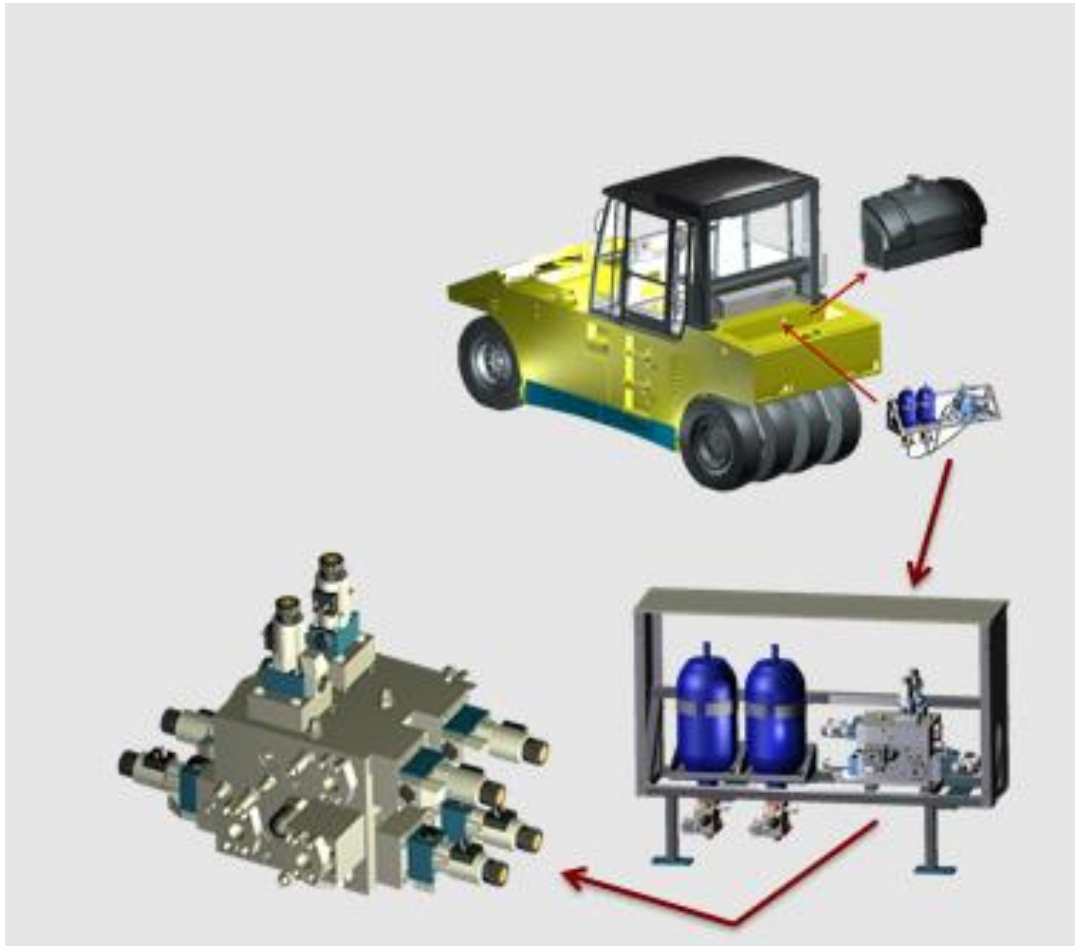
DISTINCTION BY THE RECTOR OF THE BUT

MICHAL STODOLÁK AND MARTIN MIKULA

students of the Institute of Machine and Industrial Design

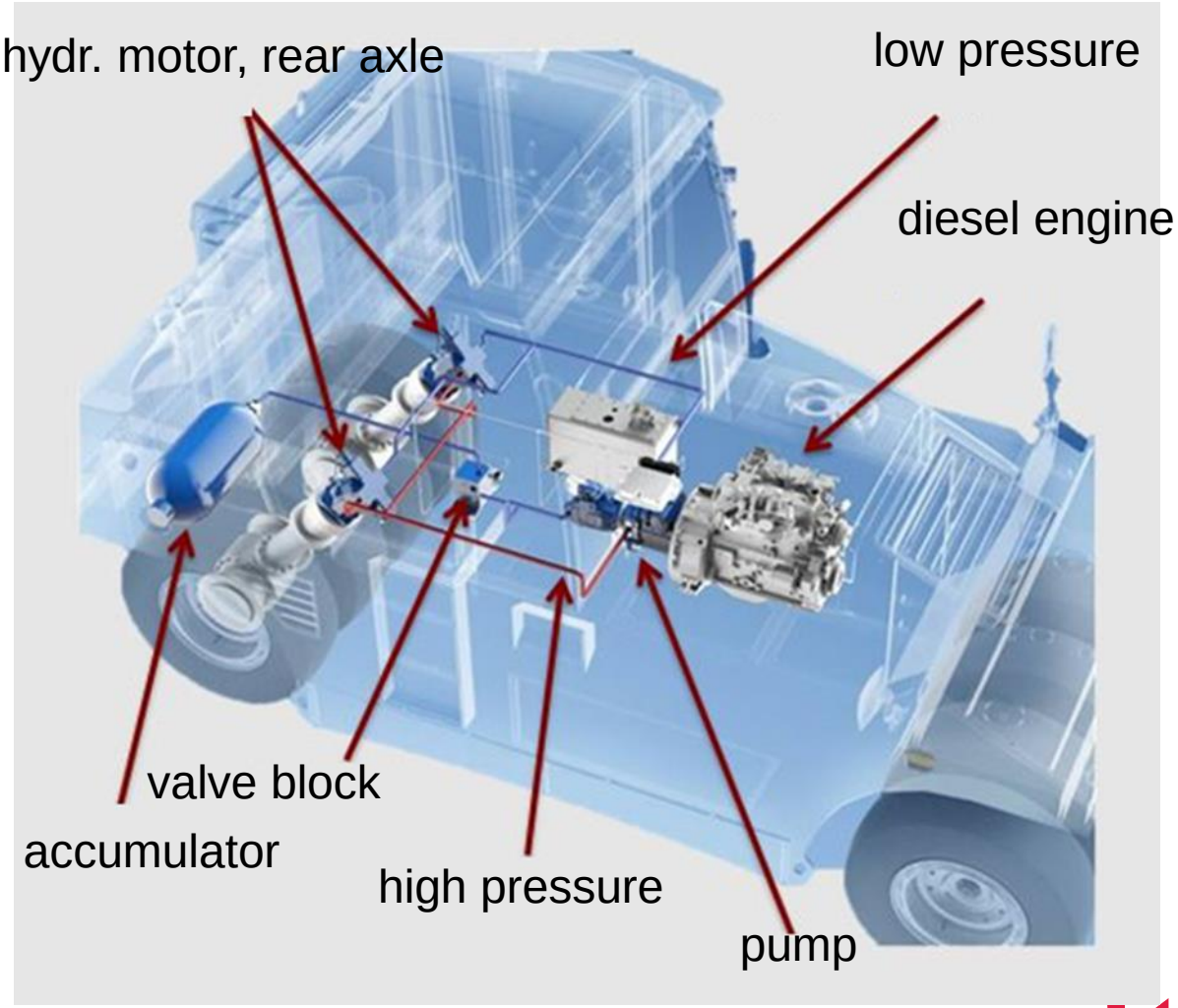
HYDROSTATIC RECOVERY MODULE

(M. RANUSA)



THE ROAD ROLLER AMMANN AP 240H

Maximal weight	**24 000 kg**
Maximal speed	19 km/h
Performance	74 kW



REACHED GOALS IN OUR PROJECT

Fuel savings: till **26.6 %**

Kinetic energy absorption:

96 % of kinetic energy into the recovery system
37 % into the hydraulic accumulator

Lowering of CO2 and NOx emissíons

Prologation of braking system lifetime

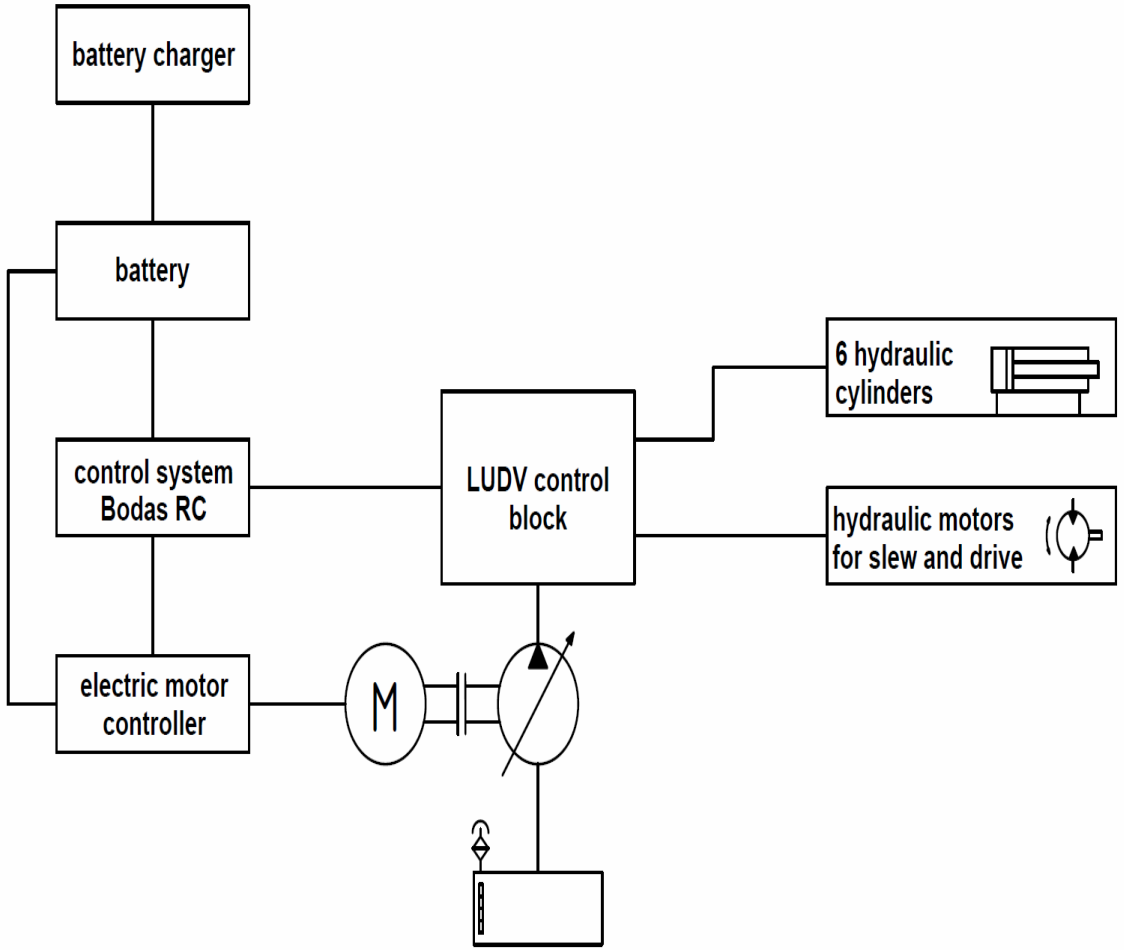
Possibility of the machine acceleration improving

2. THE EXCAVATOR E19

E19 parameters

- Engine: Diesel engine Kubota / D722-E2B-BCZ-7
- Max NET power (ISO 9249): 9,9 kW
- Max NET torque (ISO 9249): 42.3 Nm
- Travel speed range:
  low/ 2.5 km/h,
  high 4.0 km/h

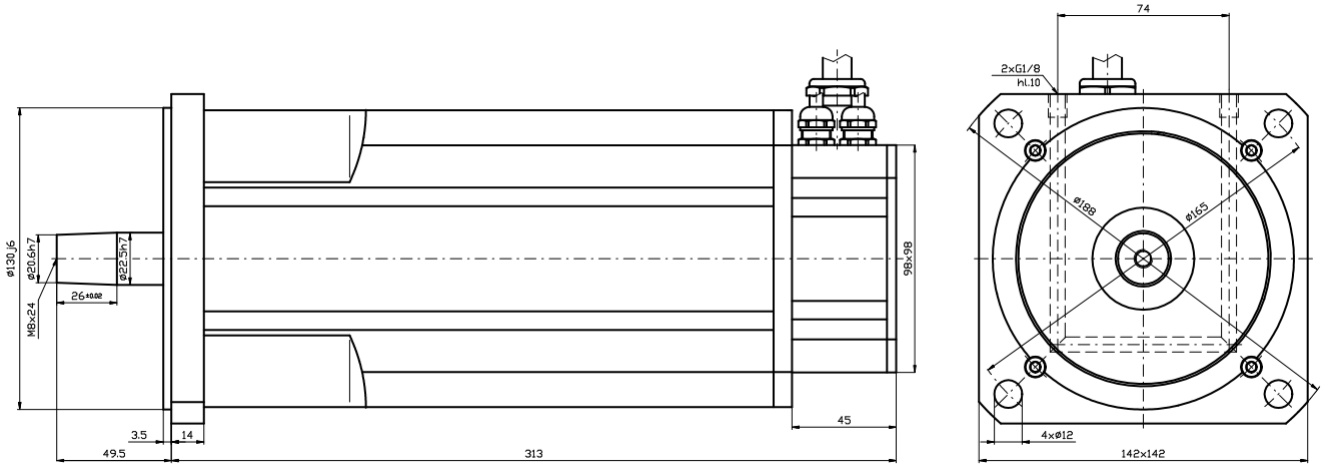
NEW SYSTEM WITH ELECTRIC MOTOR AND AXIAL PISTON PUMP



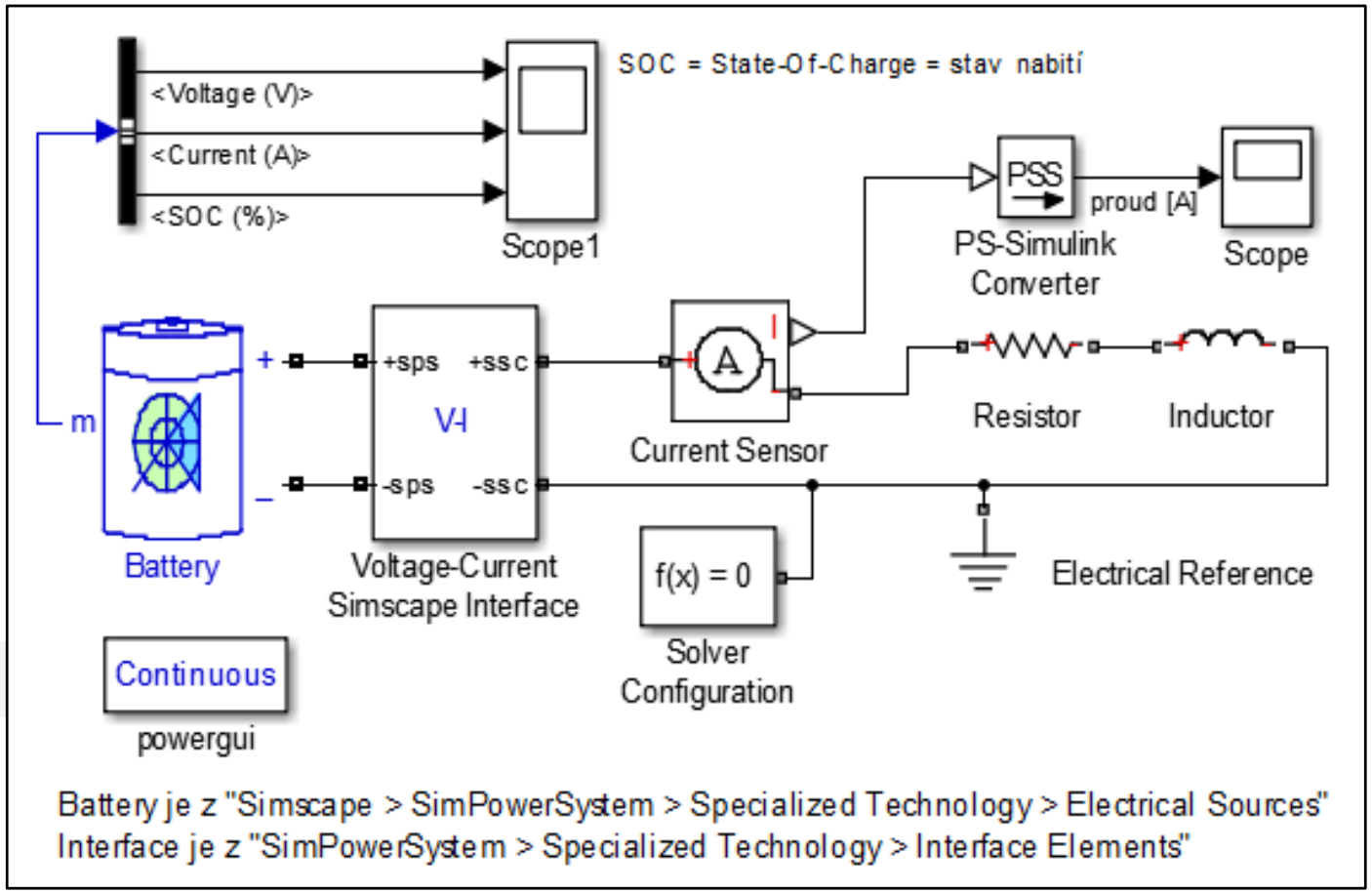
THE ELECTRIC MOTOR

Electric motor

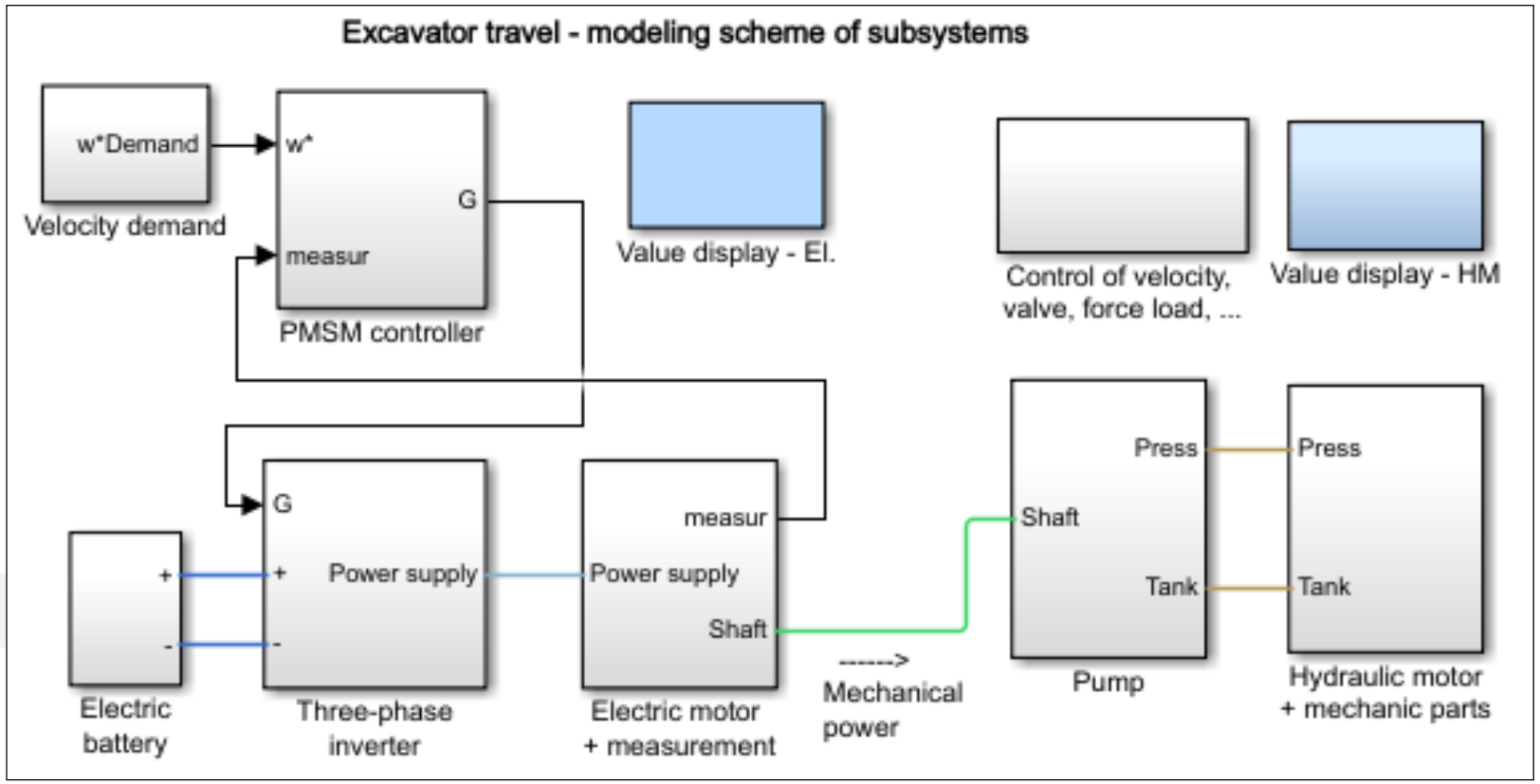
Current	DC
Number of phase	3
Maximum power	10 kW
Maximum torqur	80 Nm



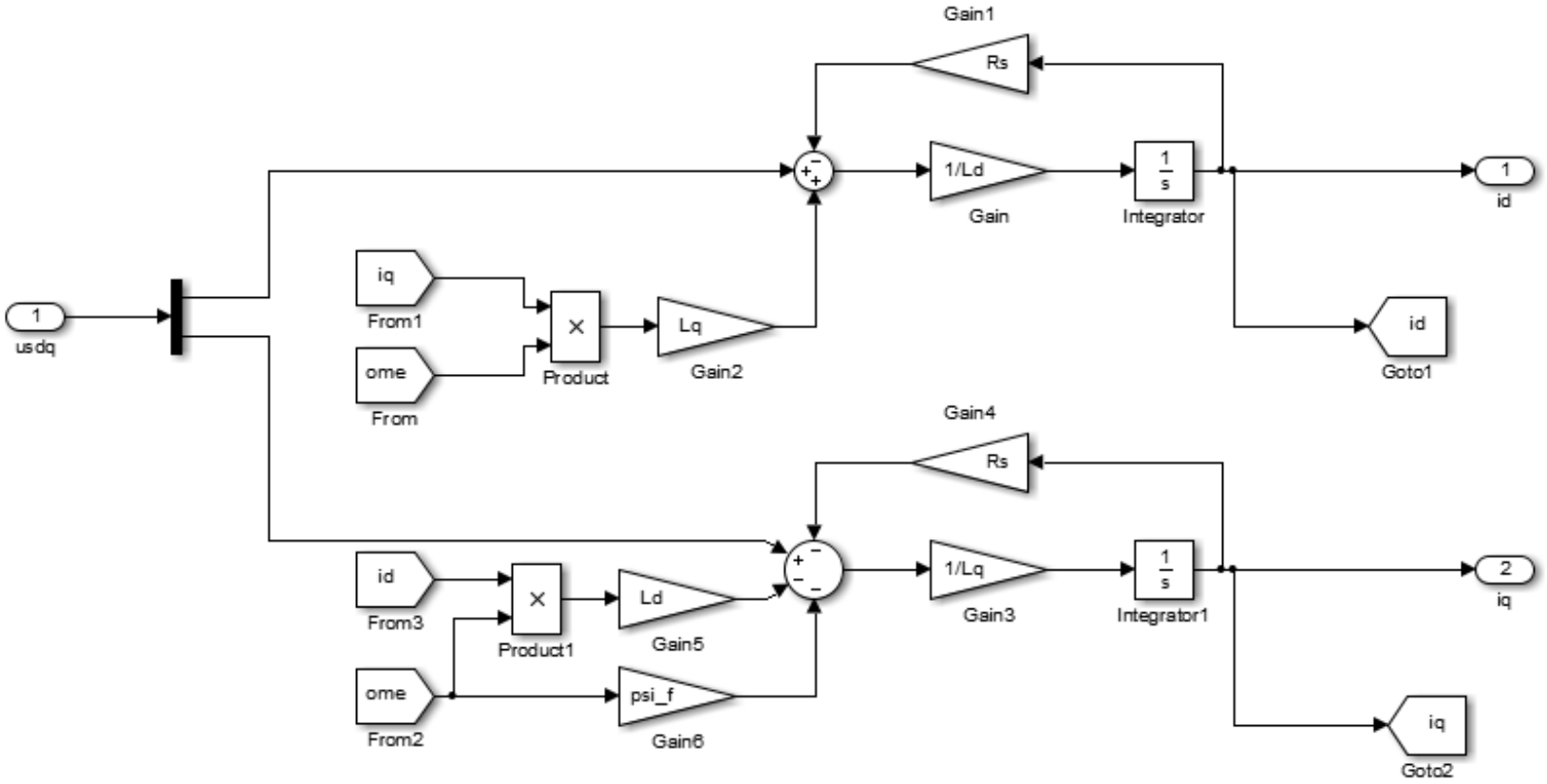
THE MODEL OF THE BATTERY



THE MODEL OF ELECTRIC DRIVE OF EXCAVATOR

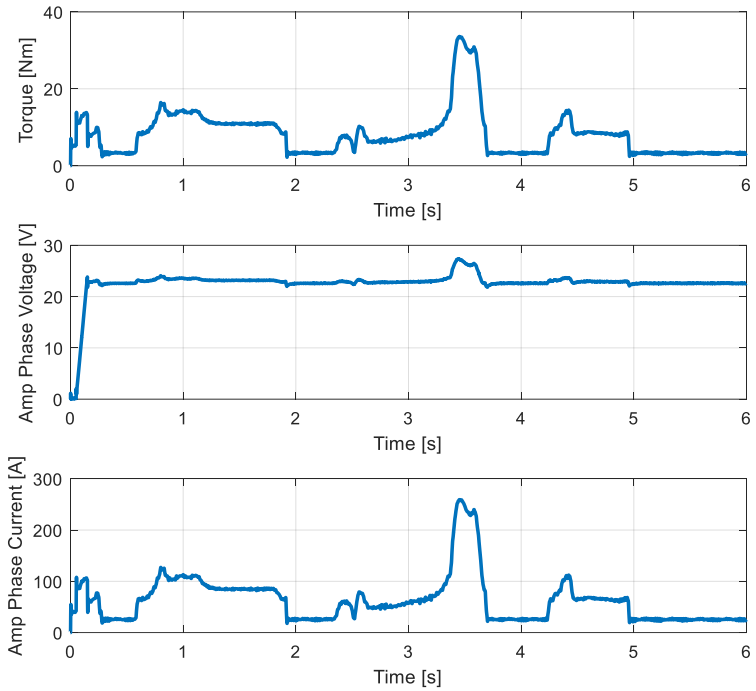


MODELING AND SIMULATION OF ELECTRIC SUBSYSTEMS



Model of voltage differential equations of the synchronous motor

SIMULATION RESULTS



VARIABLE PUMP REXROTH

- Open hydraulic loop
- Pump: axial piston variable pump Rexroth A1VO 18
- Flow rate at 3300 rpm: 59 l /min
- Max. pressure 35 Mpa
- Weight 13.5 kg
- Rexroth closed centre control valves

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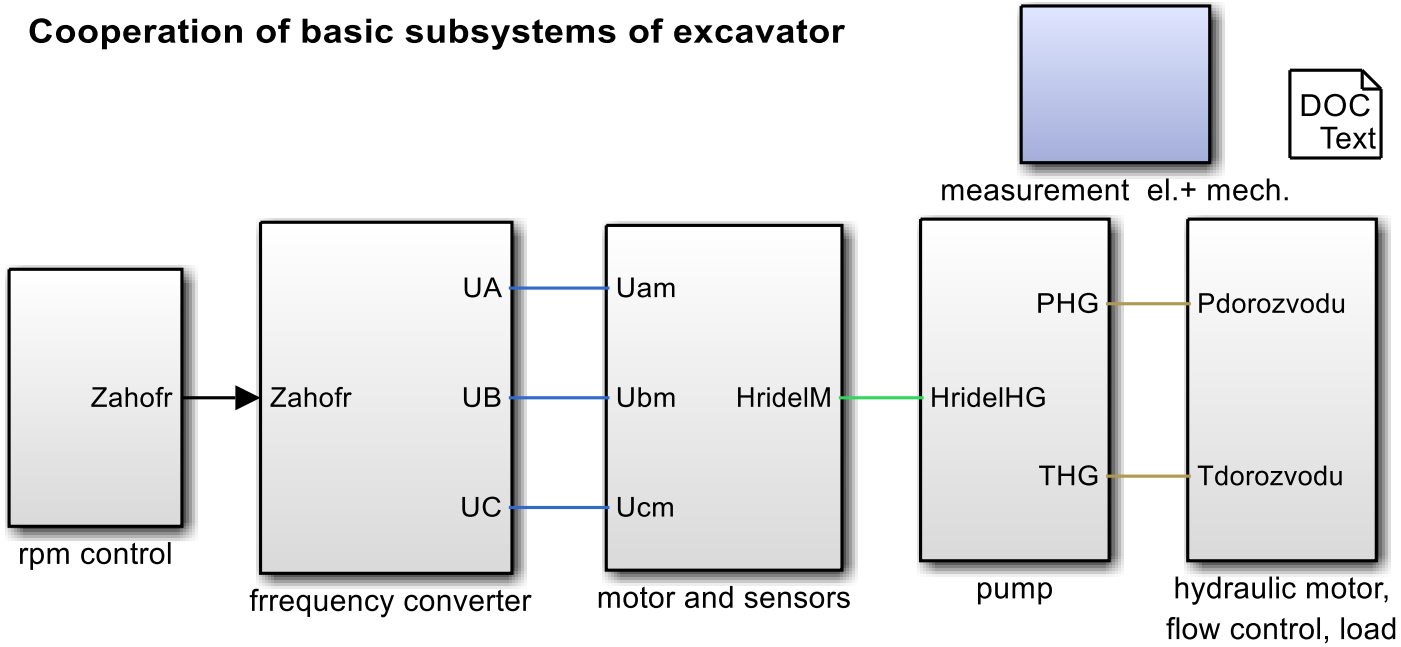
MODELING OF HYDRAULIC SYSTEM



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RESULTS

- modelling and simulation of hydraulic, electric and mechanical systems of drive have enabled to achieve a quality solution hardly attainable by the use of other methods

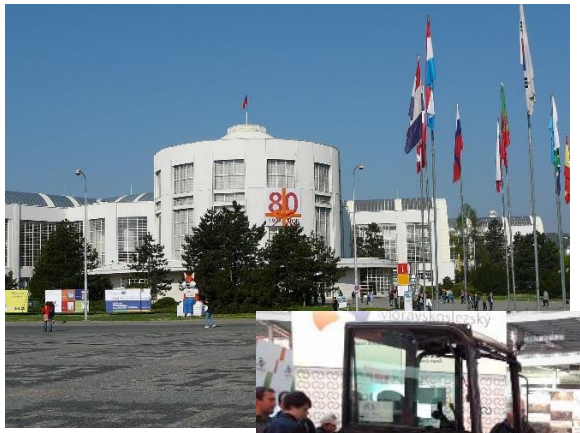
- simulation results confirmed supposed benefit of the electric drive in comparison with diesel engine which was replaced by electric motor

- no gas exhalations
- quiet and economical operation: 93 dB by Diesel, but only ~62 dB by electric drive

- possibility of operation in the environment where no exhalations and noise are allowed, e.g. hospital premises, indoor or protected areas, etc.

- the new descibed drive and control system of the excavator has beem patented

BRNO INTERNATIONAL TRADE FAIR 2018
GOLD MEAL



3. THE DAPPER 5000 WHEEL LOADER

FEATURES	
DAPPER 5000	
Length	2.821 mm
Width	1.270 mm
Height	2.301 mm
Weight	1.640 kg
Max. lift weight	950 kg *
Max. speed	16 km/h
Engine	Kubota V 15052
Power	2.5 kW, 2.600 rpm

PROJECT SOLUTION PARTICIPANTS

Bosch Rexoth

Ing. M. Fichtla, Ing. M. Obert

Brno University of Technology

Faculty of Mechnical Engineering

prof. J. Nevrlý, doc. D. Koutný

Institue of Machine Design

doc. Z. Němec

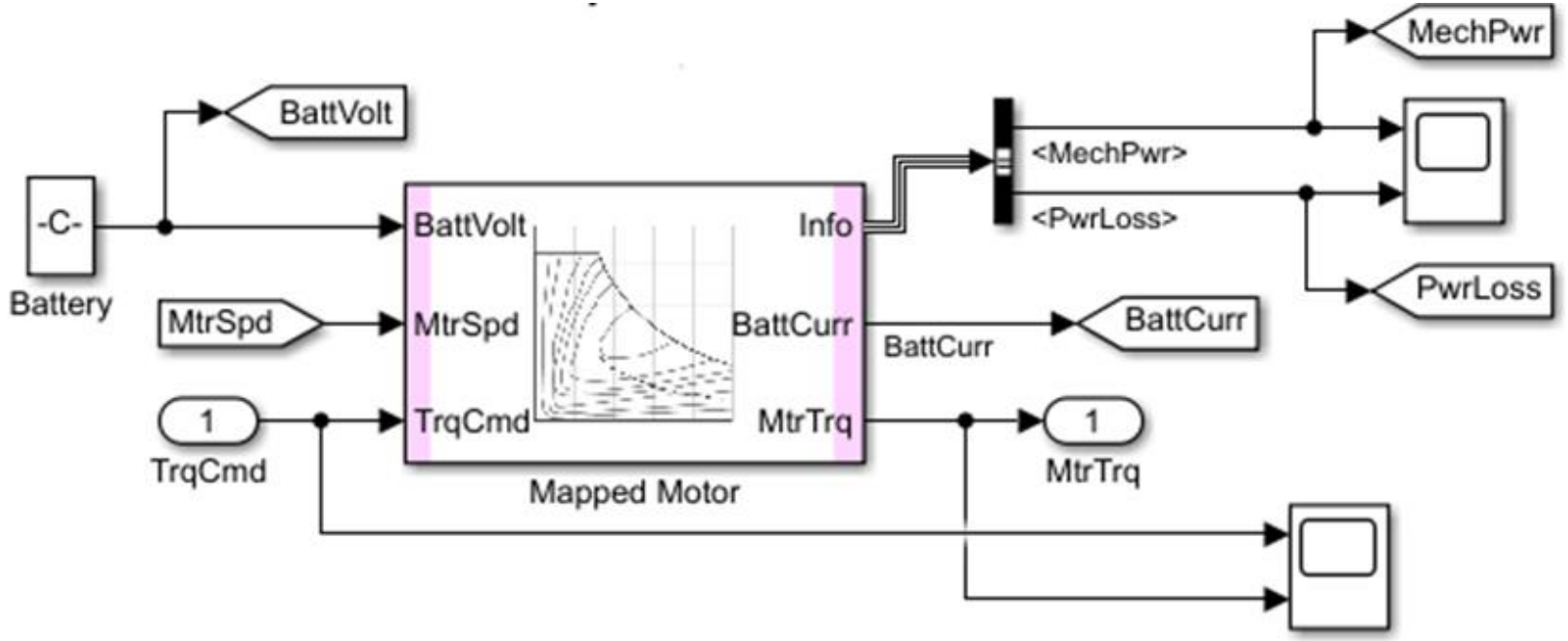
Institute of Automation and Computer Science

Faculty of Electrical Engineering and Communication

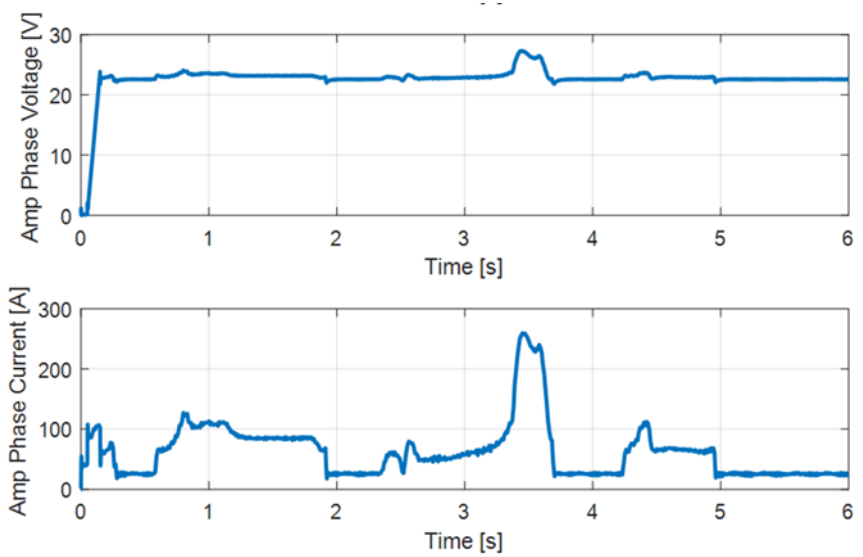
doc. P. Procházka, doc. P. Vorel

Institute of Power Electrical Engineering and Electronics

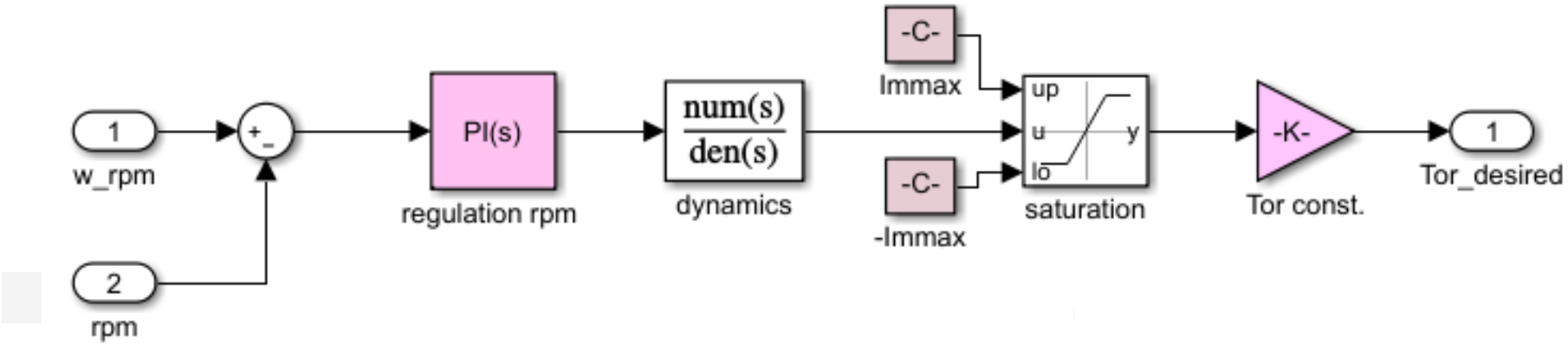
THE MODEL OF THE ELECTRIC MOTOR



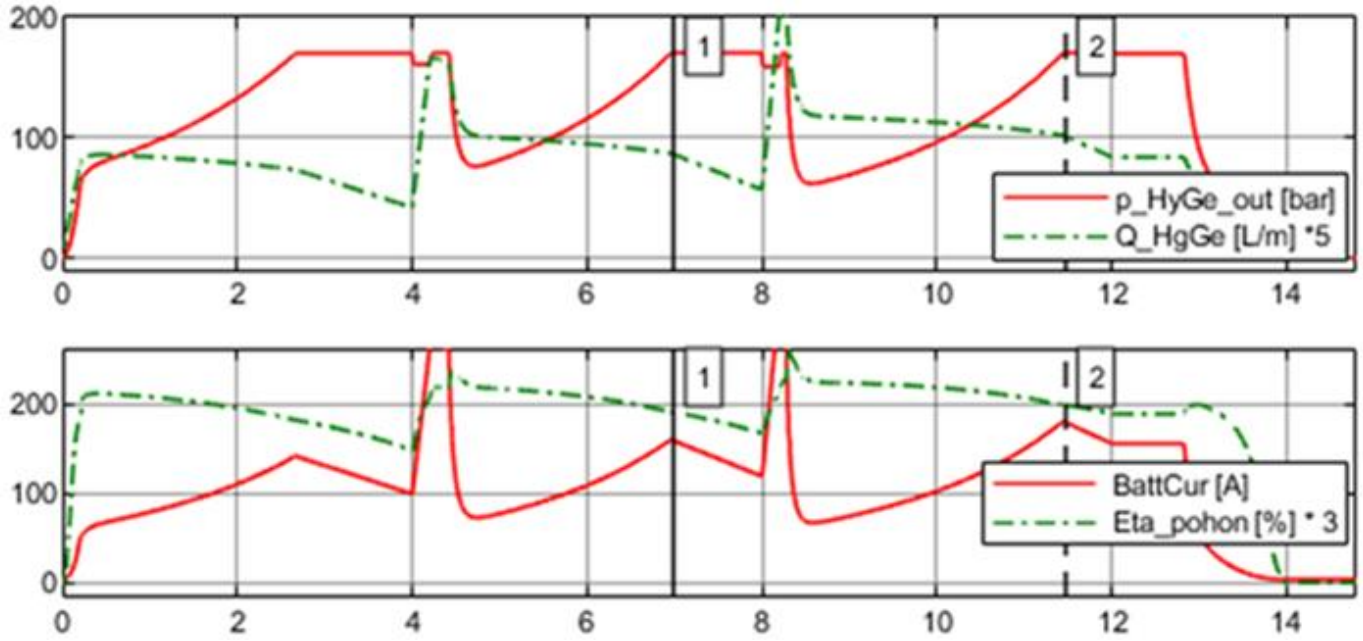
EXAMPLE OR TIME COURSES OF SIMULATED QUANTITIES



ELECTRIC MOTOR CONTROL, PART WITH SPEED AND TORQUE CONTROL



A SAMPLE FROM MODEL VERIFICATION TESTS



CONCLUSIONS

- In all three described cases of earth machines, it became necessary to use mathematical modeling. and simulation.
- Without the use of mathematical modeling in the developed machines
  a) the fuel consumption of the Ammann road roller would not have decreased by as much as 26.6%
  b) the described electrification of the E19 excavator would not have been awarded a Gold medal in 2018 in the International Engineering Fair in Brno
  c) with the Dapper 5000 loader it would not be possible to predict the static and dynamic behavior after replacing the internal combustion engine with an electric motor and to set the optimal parameters of its control

PROJECTS (TAČR, MPO, MŠMT), PATEMTS - UTILITY MODEL

- ELECTRIC LOADER RESEARCH AND DEVELOPMENT

TAČR, OEWL PROJECT FW01010156, 2020 -2022

- RESEARCH AND DEVELOPMENT OF ELECTRIC DRIVE MINI-EXCAVATOR UP TO 2 TONS

MPO, 2016 -2018

- RECOVERY HYDROSTATIC MODULE FOR COMMERCIAL VEHICLES

MŠMT, LF1 2029, 2013 -2015

UITIILITY MODEL

DRIVE SYSTEM OF EMISSION-FREE WHEELED EARTH-MOVING MA

NEVRLY JOSEF, NEMEC ZDENEK, PROCHAZKA PETR, PAZDERA IVO.
REGISTERED BY THE TECHNOLOGY TRANSFER DEPARTMENT BUT
UNDER NUMBER 2022 49, dated: 25. 2. 2022

DIPLOMA THESES 1

- Indruch Jiří: Stand for the analysis of energy recovery in an experimental vehicle (Stend pro analýzu rekuperace energie v experimentálním vozidle)

- Kobza Michal:
  Determination of efficiency of recuperative hydrostatic drive
  (Stanovení účinnosti rekuperačního hydrostatického pohonu)

- Mikula, M.: Hydromobile - design of hydraulic part and transmission (Hydromobil – návrh hydraulické části a převodu)

- Nožka M.: Control of hydraulic valve blocks of the mini-excavator
  (Řízení hydraulických rozváděčů miniexkavátoru)

DIPLOMA THESES 2

- Ranuša Matúš: Design of a valve block of a recuperative hydrostatic module of a vehicle (Návrh ventilového bloku rekuperačního hydrostatického modulu vozidla)

- Stodolák, M.: Hydromobile - design of mechanical-hydraulic recuperation of car kinetic energy (Hydromobil – návrh mechanicko-hydraulické rekuperace kinetické energie automobilu

OTHER ACTIVITIES IN CONNECTION WITH THE DAPPER 5000 PROJECT

- patent searches
- reviews of partial research reports
- modeling support
- searches for partial problems and presentation of these searches
- supervision of students' qualification works

SERCHES AND PRESENTATIONS

- Operating performance of pure electric loaders with different types of motors based on simulation analysis
- Dynamic modeling of a backhoe-loader
- The electrification of loader designs
- Fork lithium batteries
- Current production programs of electrified loader manufacturers
- Battery nodeling

PUBLICATIONS

NEVRLÝ, Josef, NĚMEC, Zdeněk, PAZDERA, Ivo and NOŽKA, Michal. Modelllng of electric drive for excavator pump. In*: 24th International* Conference *ENGINEERING MECHANICS 2018*, *Svratka, Czech Republic, 14 – 17 May 2018*. ISBN 978-80-214-5497-2, ISSN 1805-8248.

NEVRLY, Josef, NEMEC, Zdenek, VOREL, Pavel, PROCHAZKA, Petr, FICHTA, Martin and JURIK, Miroslav. Battery electric drive of excavator designed with support of computer modeling and simulation. Submission to *The First World Energies Forum* (https://sciforum.net/conference/WEF), *14/09/2020 - 05/10/2020,* published on conference website: https://sciforum.net/paper/view/6927

NEVRLY, Josef, FICHTA, Martin, JURIK,, Miroslav, NEMEC Zdenek, KOUTNY, Daniel, VOREL, Pavel and PROCHAZKA, Petr. Battery electric drive of excavator designed with support of computer modeling and simulation. *Paper in: electronic proceedings of the conference The First World Energies Forum, session Ener, 14/09/2020 - 05/10/2020,* MDPI, Basel, Switzerland.
Dostupnost - abstrakt*gy Conversion Systems*: https://www.mdpi.com/2504-3900/58/1/25 , verze v pdf: https://www.mdpi.com/2504-3900/58/1/25/pdf

PUBLICATIONS

NEVRLY, Josef, FICHTA, Martin, JURIK, Miroslav, NEMEC, Zdenek, PROCHAZKA, Petr, KOUTNY, Daniel and PETROVIC, Radovan. New systems of energy recovery and electric-hydraulic battery mobile drive. In: *Proceedings of the 25th International conference on hydraulics and pneumatics. June 8-9, 2022 (accepted for publication), Prague, Czech Republic*. Czech Mechanical Engineering Society, section Czech Association for Hydraulics and Pneumatics, *2022*.

THANK YOU FOR YOUR ATTENTION

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