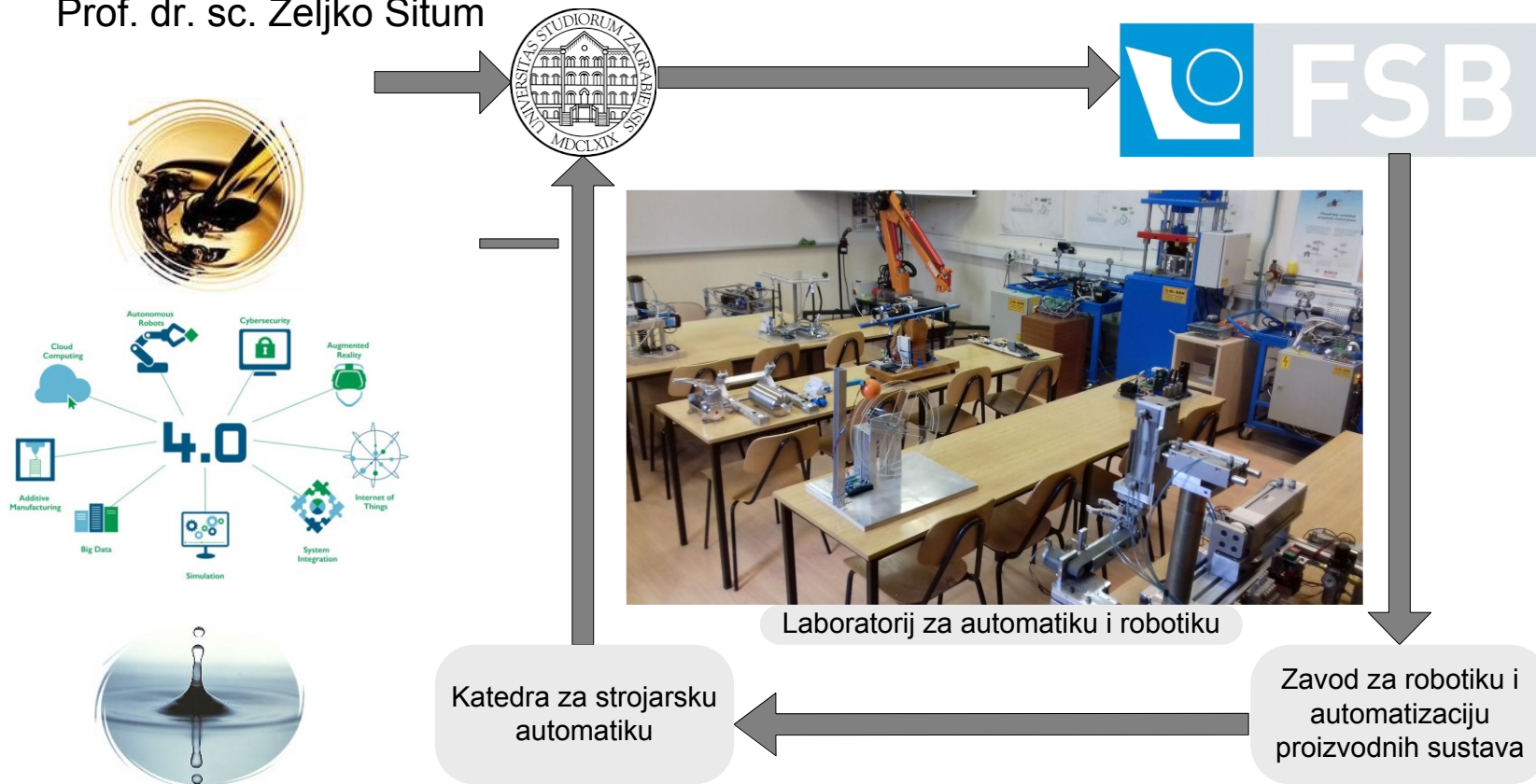


PNEUMATIKA I HIDRAULIKA

PRAVCI RAZVOJA SUSTAVA FLUIDNE TEHNIKE

Prof. dr. sc. Željko Šitum



Izazovi u razvoju sustava fluidne tehnike

- Povećanje energetske učinkovitosti
- Poboljšanje pouzdanosti sustava
- Izgradnja 'inteligentnih' komponenti i sustava
- Smanjenje veličine i težine komponenti
- Smanjenje negativnog utjecaja na okoliš
- Poboljšanje pohrane energije i raspodjele raspoloživih kapaciteta

Važni pravci razvoja hidrauličkih sustava:

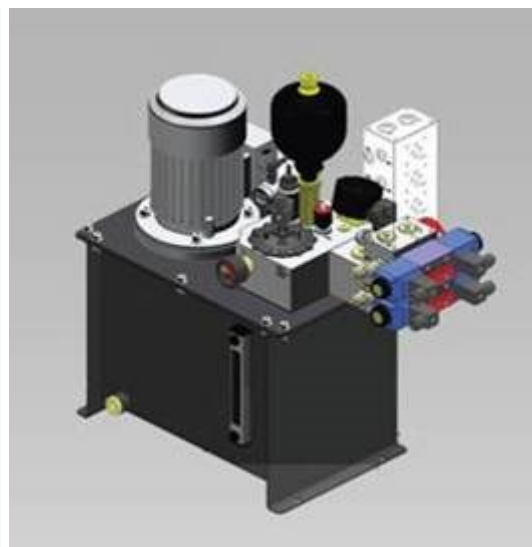
- **TRIBOLOGIJA** – trenje, trošenje, korozija (produljenje vijeka hidrauličkih komponenti)
- **HIDRAULIČKI MEDIJ** – ekološki prihvatljiva biorazgradiva hidraulička ulja
- **MATERIJALI** – povećanje čvrstoće i smanjenje težine
- **AKUSTIKA** – smanjenje razine buke
- **SIMULACIJE** – virtualno inženjerstvo
- **DIJAGNOSTIKA** – nadzor stanja i održavanje hidrauličkih sustava

Poboljšanje karakteristika komponenata:

- primjena novih materijala u izradi elemenata
- primjena modernijih tehnologija izrade
- optimizacija konstrukcije elemenata
- računalom podržana analiza projektiranja sustava

Izvedba modulnih sustava

- zahtijevaju manje prostora, bolja funkcionalnost, lakša zamjena



Novi materijali

- KOMPOZITNI MATERIJALI
- LAKE LEGURE

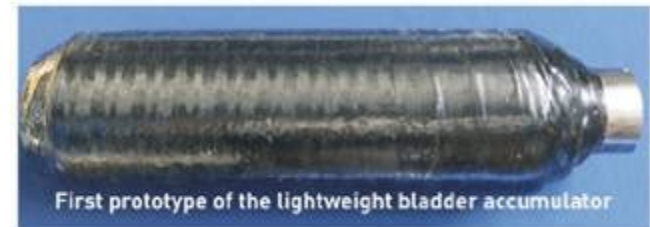
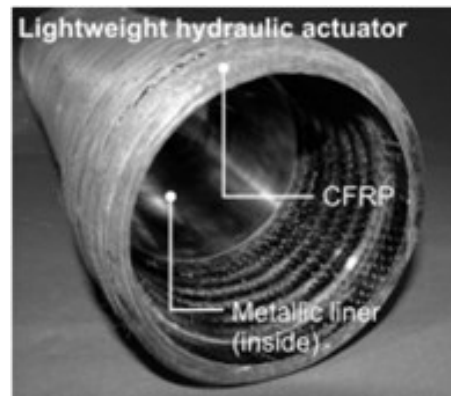
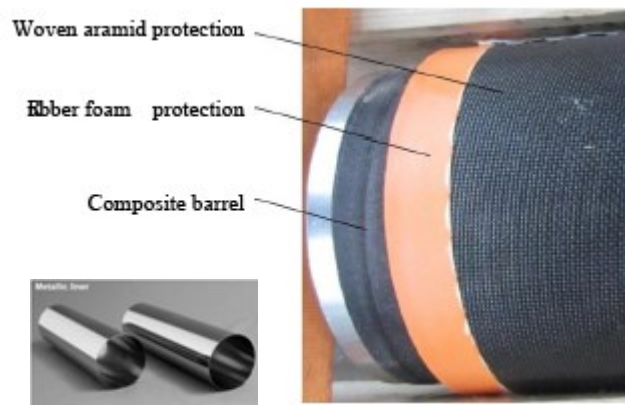
Istraživanje karakteristika trenja i trošenja različitih materijala (npr. polimerni materijali ojačani ugljikovim vlaknima) koji imaju potencijal za primjenu u izradbi hidrauličkih komponenti kao zamjena za metalne materijale.

Konstrukcija komponenata

npr. cilindar s više slojeva načinjenih od različitih materijala (metal + polimer)

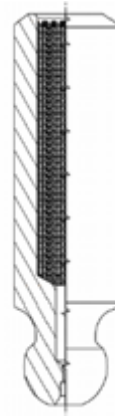
Prednosti:

- Otpornost na trošenje i djelovanje agresivnih fluida
- Temperaturna postojanost



Novi materijali

▪ Klip ispunjen polimernim materijalom



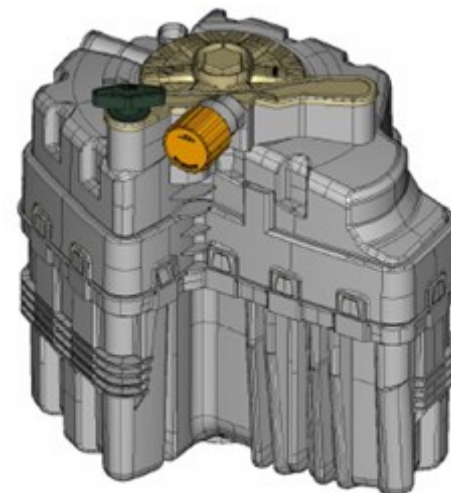
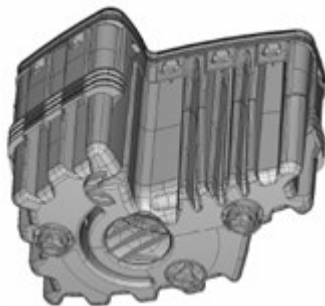
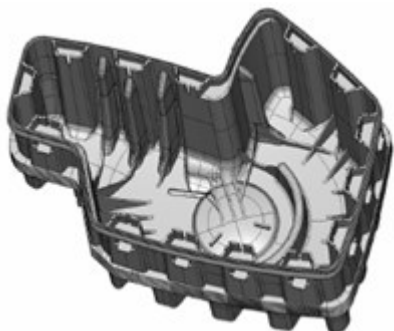
Smanjenje mase klipa ima pozitivan utjecaj na:

- upravljačke karakteristike klipnih pumpi
- sile koje djeluju na klip
- trošenje klipa



▪ Spremnik načinjen injekcijskim prešanjem

Pogodan za mobilne aplikacije

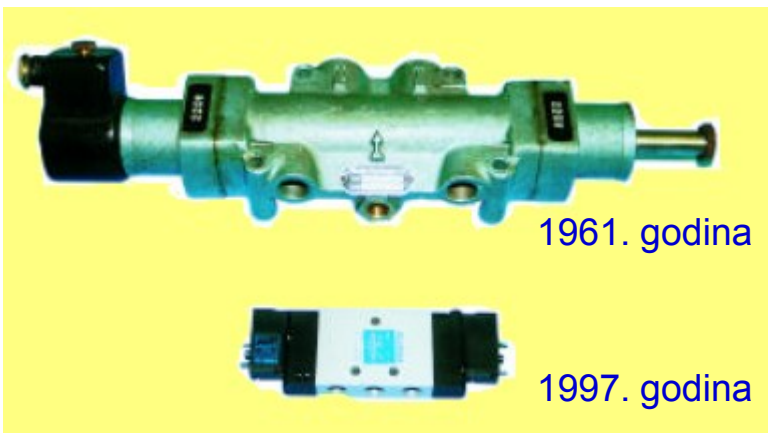


Minimiziranje komponenti

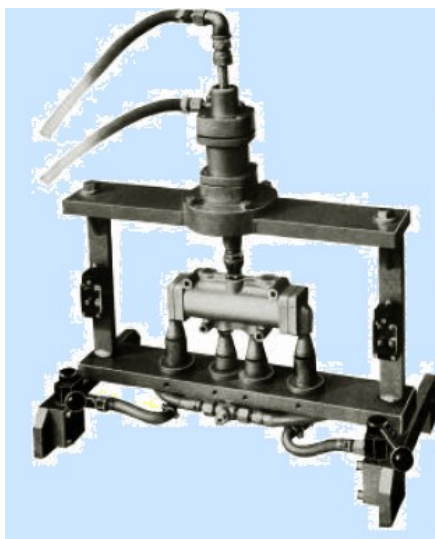


Minimiziranje komponenti

Usporedba pneumatskih ventila
(protok: 400 l/min)

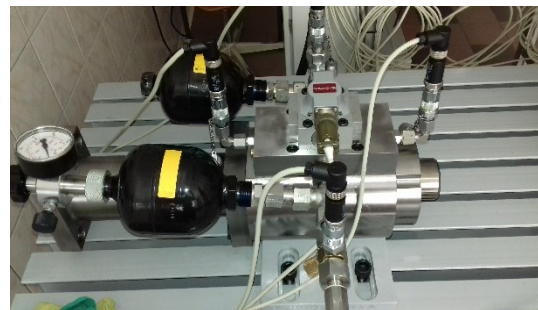
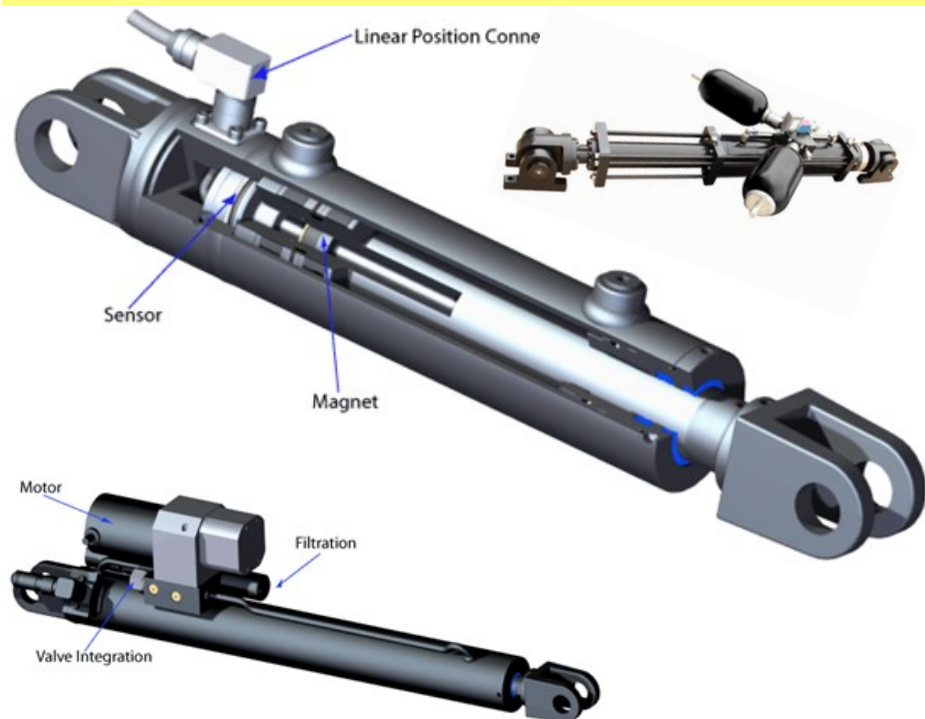
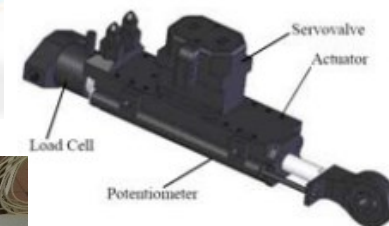
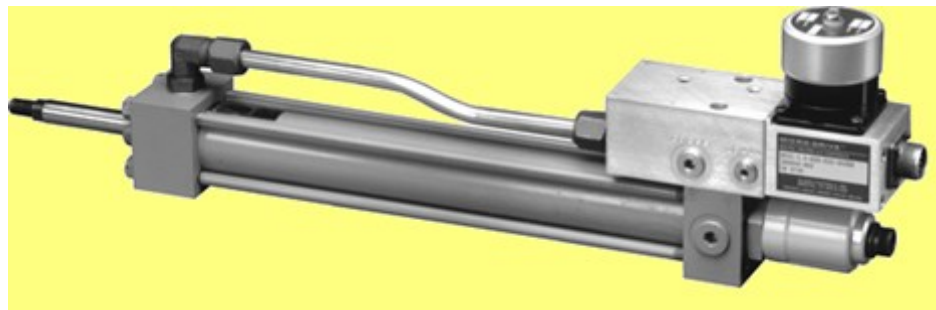


Hidraulički elektromagnetski ventil



Početni razvoj pneumatskih
sustava (1955)

Integracija funkcija aktuatora, upravljačkih funkcija i senzora



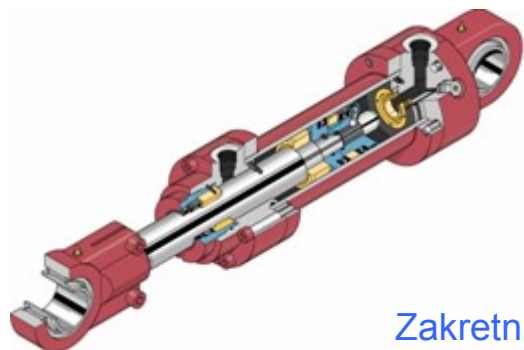
Komponente pogonske jedinice (hid. cilindar, ventil, senzori)

BigDog – Boston Dynamics Corp., 2008

Modularna izgradnja složenijih sustava



Komponente s većim brojem funkcija



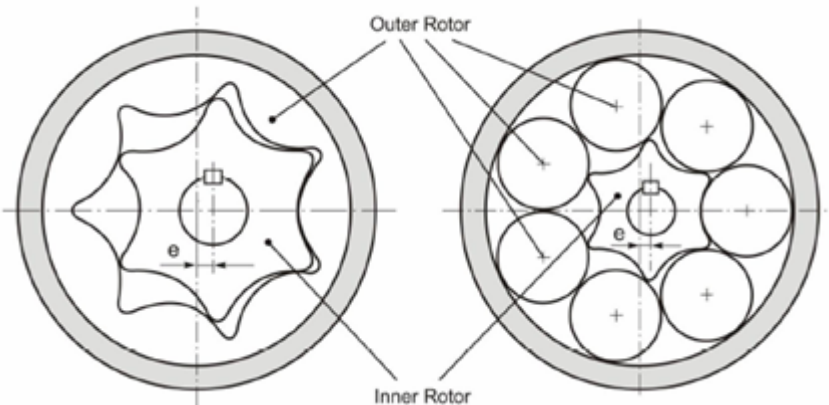
Zakretni linearni cilindar



Inovativni razvoj komponenti

■ GEROTOR pumpa

valjci umjesto vanjskog rotora (statora)



Prednosti

- jeftinija i točnija izrada
- manje pulsacije tlaka i protoka

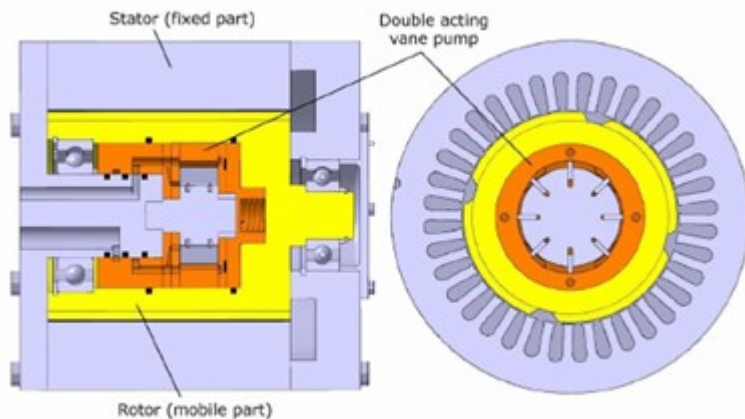
standardni dizajn

novi dizajn

prototip

■ KRILNA pumpa

Integrirana u električni motor

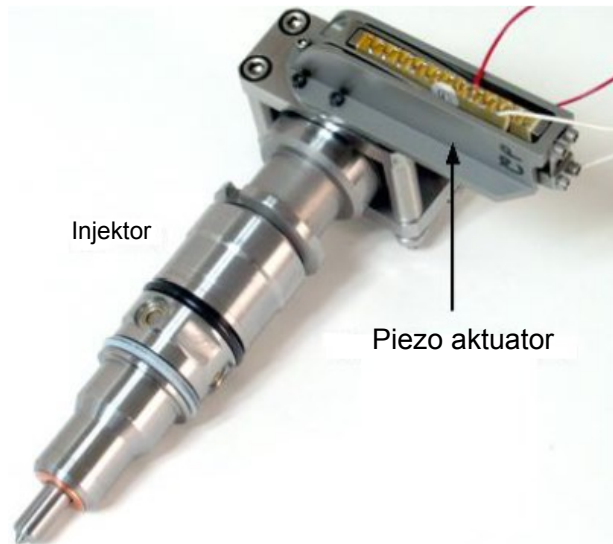
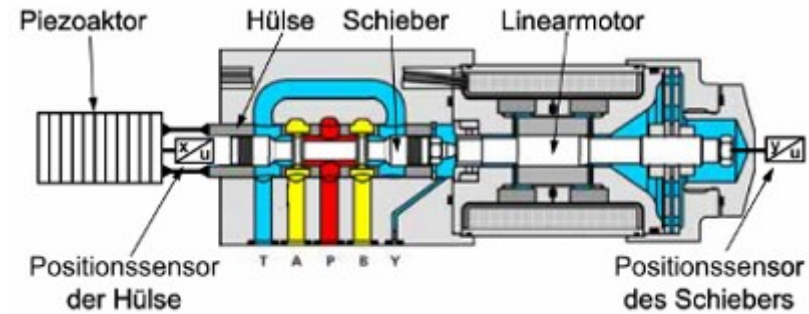
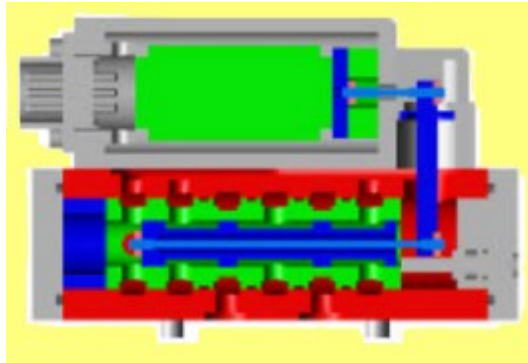


Prednosti

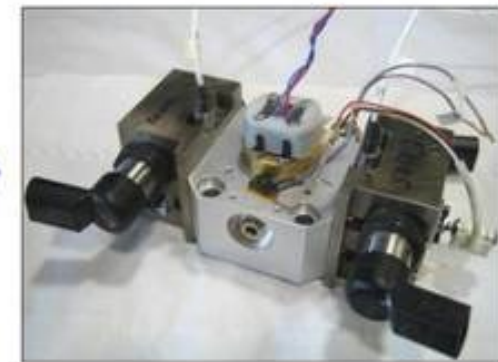
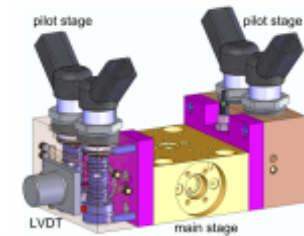
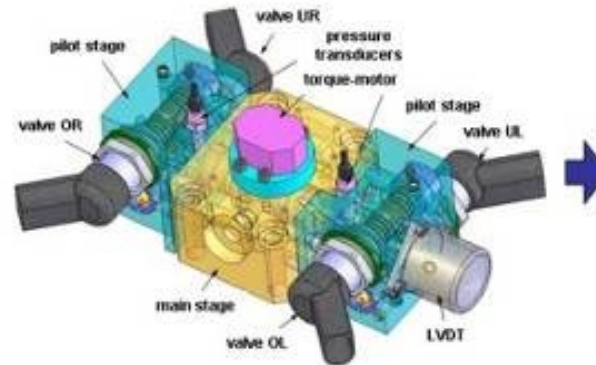
- bolja energetska učinkovitost
- bolja dinamička svojstva

Upravljačke komponente s novim karakteristikama

Piezelektrični ventili



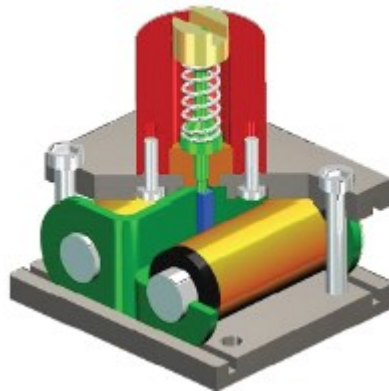
IFAS Institut für
fluidtechnische
Antriebe und
Steuerungen
Univ.-Prof. Dr.-Ing. H. Murrenhoff



Piezo-ventil

Upravljačke komponente s novim karakteristikama

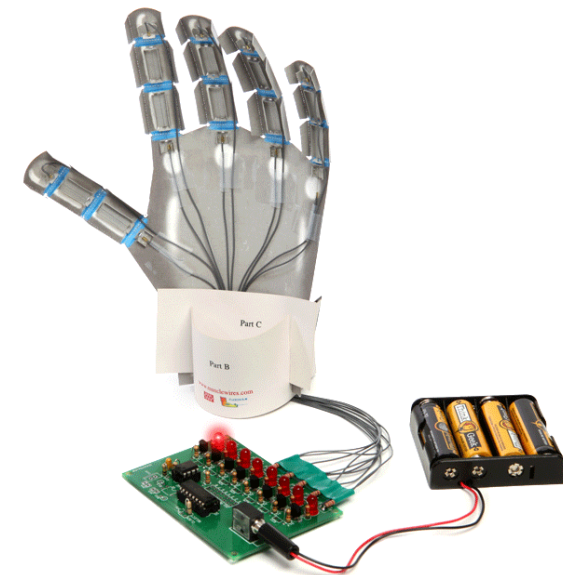
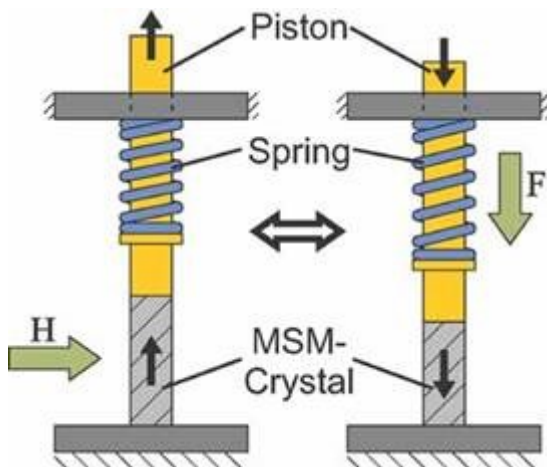
- Izgradnja 'inteligentnih' komponenti sustava



Zamjena za klasični elektromagnet. Vrlo brza promjena dimenzija i oblika što im omogućuje visoke frekvencije preklapanja ventila.

- Frekvencija 400 Hz
- Vrijeme odziva 1.6 ms
- Pomak 0.7 mm
- Struja 3A
- $> 1 \times 10^9$ ciklusa

Magnetic Shape Memory actuator



Upravljačke komponente s novim karakteristikama

Digitalni ventili - "Inteligentniji" upravljački elementi

Parker Hannifin ProPxD

File Options Help Specials

expert

PCD A+B Param. | PCD A Param. | PCD B Param.

PC settings

Type: **PCD00A-40***

Design series: **18 and higher**

Valve

Channel "A"

Channel "B"

Input

Range

☒ 0.8A = 0

☐ 3.5A = 1

☐ 2.7A = 2

☐ 1.8A = 3

☐ 1.3A = 4

PC		Modul	
No.	Value	Description	Module
Ia	0	Current A-channel	0
Ib	0	Current B-channel	0
n	2	allocation of internal command signals	2
P3	100.0	Max [%] A-channel	100.0
P4	100.0	Max [%] B-channel	100.0
P5	5.0	Dither-Amplitude [%]	5.0
P6	300	Dither-Frequency [Hz]	300
P7	0.0	Min [%] A-channel	0.0
P8	0.0	Min [%] B-channel	0.0
Q5	5.0	Dither-Amplitude [%] B-channel	5.0
Q6	300	Dither-Frequency [Hz] B-channel	300
S1	0.0	internal command 1 [%]	0.0
S2	0.0	internal command 2 [%]	0.0
S3	0.0	internal command 3 [%]	0.0
S4	0.0	internal command 4 [%]	0.0
S5	100	ramp up [ms] A	100
S6	100	ramp down [ms] A	100
S7	100	ramp up [ms] B	100
S8	100	ramp down [ms] B	100
E25	0	MIN operating threshold	0

Module settings

Type: **PCD00A-40***

Design series: **18 and higher**

Version: **2.6**

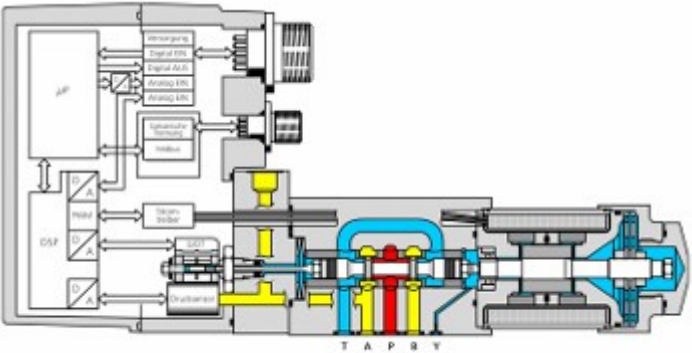
Parker

Receive all PCD >> PC

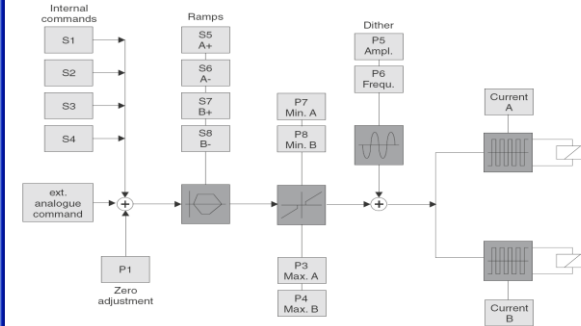
Send all PC >> PCD

Send parameter

Default



Source: MOOG



Integriranje elektronike u hidrauličke komponente



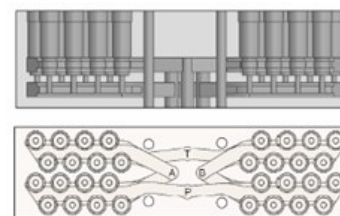
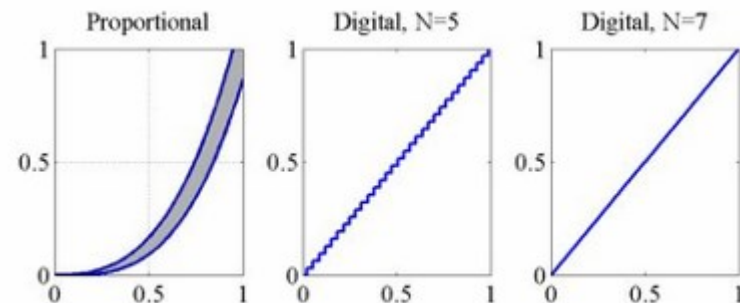
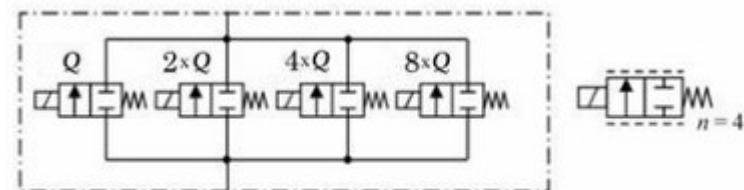
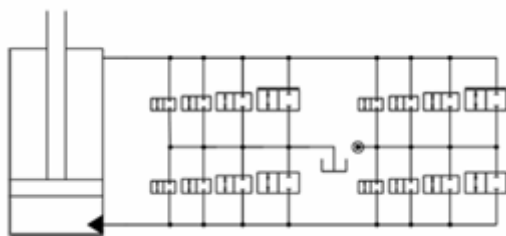
Umrežavanje “inteligentnih” komponenti sustava

Upravljački elementi, aktuatori, senzori, povezuju se u zajednički sustav s mogućnošću brzog komuniciranja i rada u realnom vremenu.

- ❑ **Field-bus** (analogni signali)
- ❑ **CAN-bus** (digitalni signali)

Digitalna hidraulika

4 – 10 on/off ventila u paralelnom spoju → podešavanje protoka ventila prema binarnom kodu



→ Digitalna mikrohidraulika

Koristio bi se veliki broj minijaturnih on/off ventila

Pulse Number Modulation (PNM)

U svakom periodu diskretizacije određuje se broj ventila u aktiviranom stanju.

Prednosti:

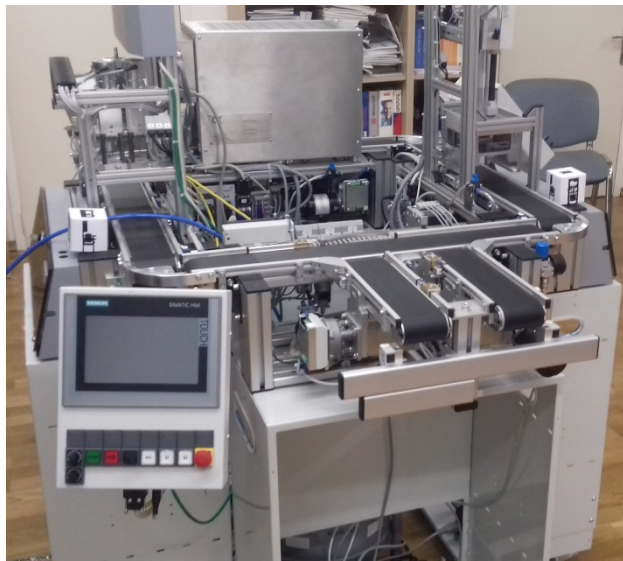
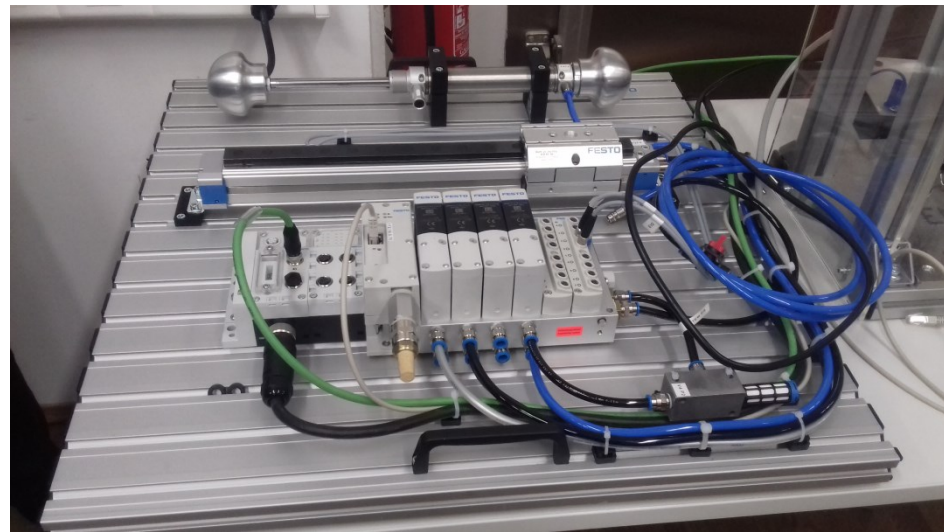
- Neosjetljiva na kvar (fault tolerance)
- Kraće vrijeme aktiviranja ventila - manje mase
- Kraće prijelazne pojave izgradnje i razgradnje tlaka
- Ušteda energije 50-70 % u usporedbi s prop. ventilom

30 – 300 mikro ventila
Protok 0.7 l/min, pri $\Delta p = 0.5$ MPa

Digitalna pneumatika



→ Industrija 4.0



Primjena novih fluida

■ Hidraulički sustavi koji koriste vodu



1994. godine 'Danfoss' uvodi kompletnu paletu proizvoda koje koriste vodu kao medij



'Power Pack'



Aksijalno-klipna crpka



Cilindar



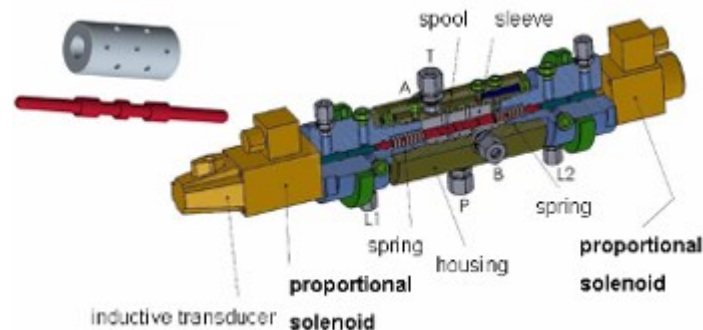
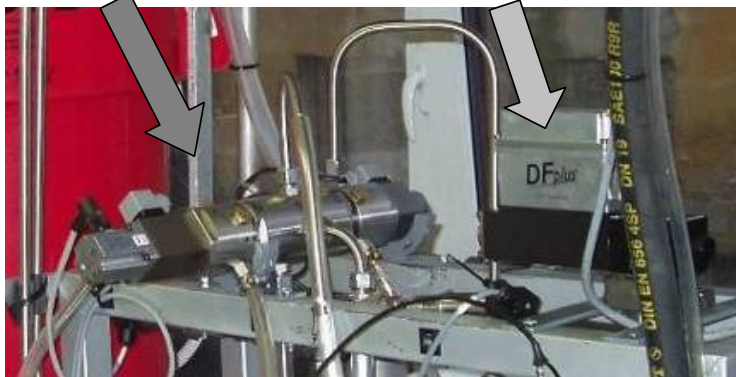
Krilni motor



Proporcionalni ventil

Proporcionalni vodni ventil

Proporcionalni uljni ventil



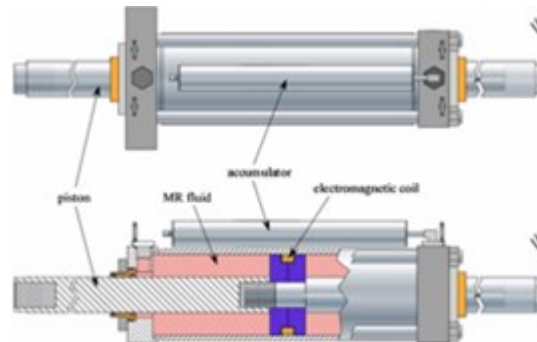
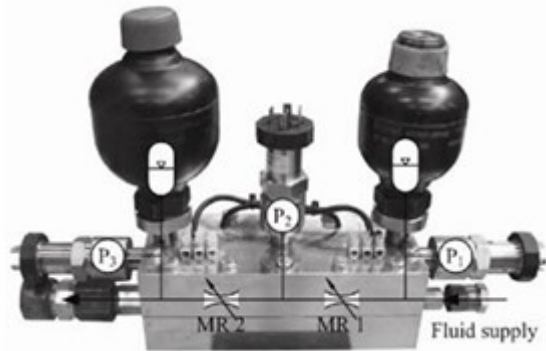
F. Majdič, Fakulteta za strojništvo, Ljubljana

Primjena novih fluida

- Ekološki fluidi ('green' fluids)
biorazgradivi i netoksični fluidi



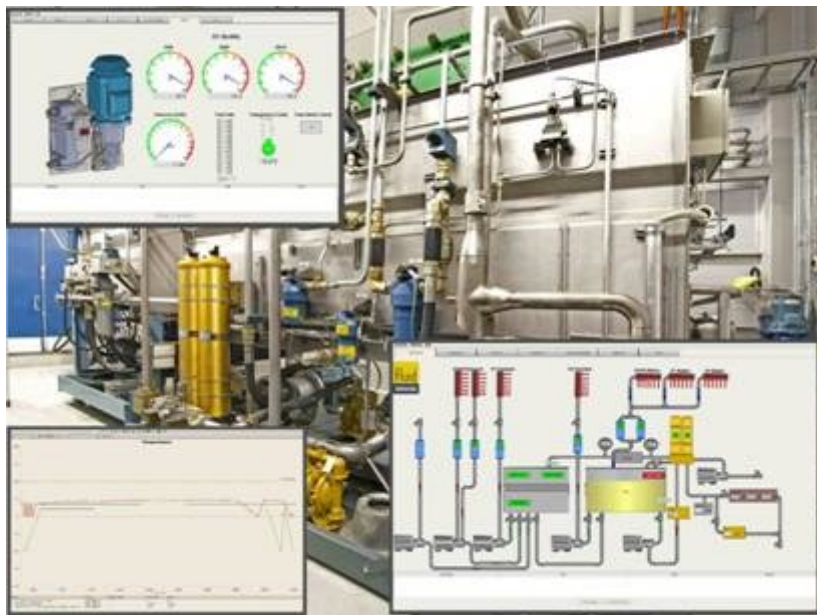
- Specijalni fluidi (magnetoreološki-MR i elektoreološki-ER fluidi)
mijenjaju viskoznost fluida ovisno o intezitetu magnetskog ili električnog polja



- Nezapaljivi fluidi

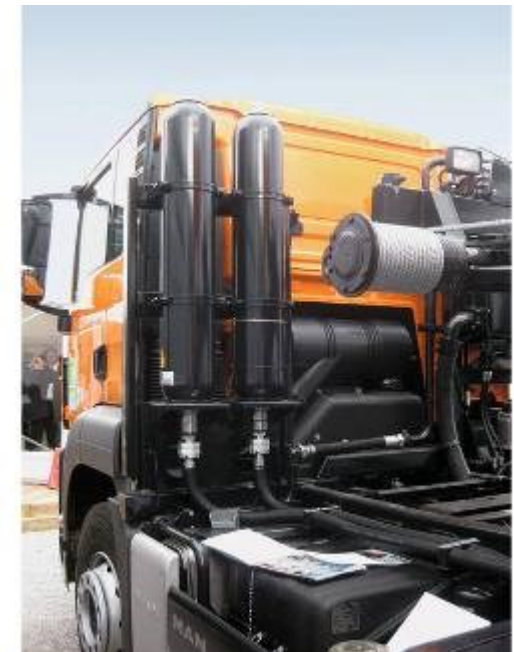
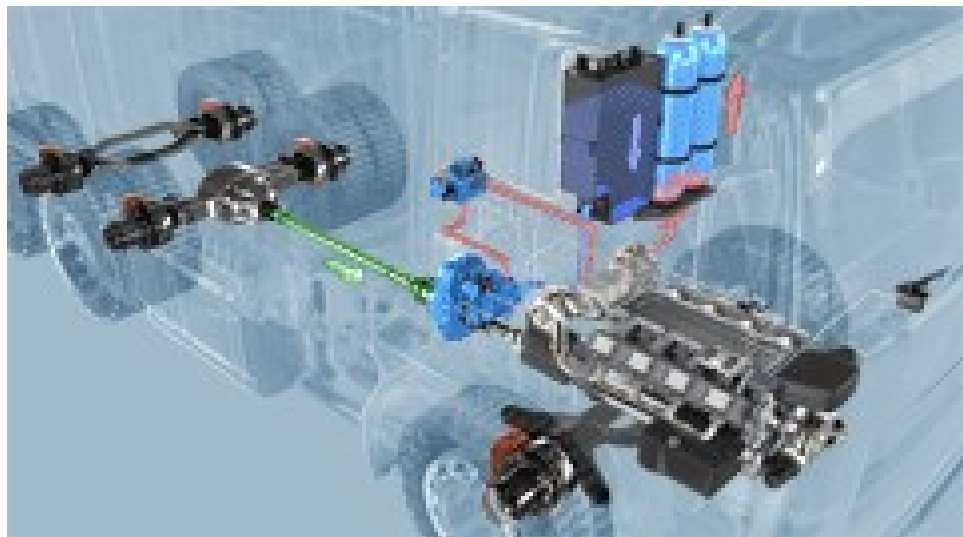
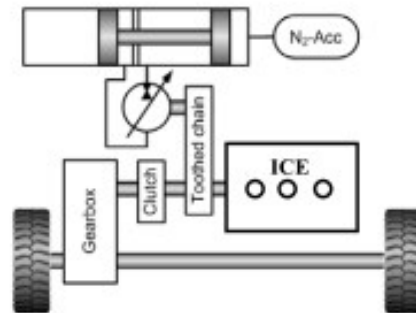
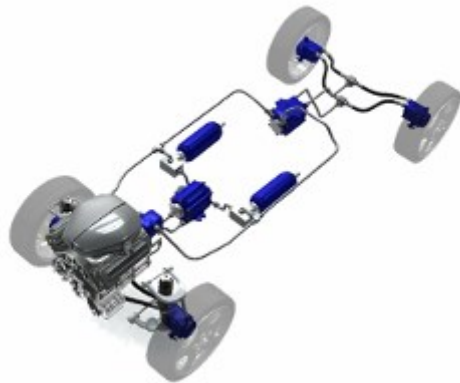


Nadzor stanja hidrauličkih sustava (Condition Monitoring)



Nova područja primjene

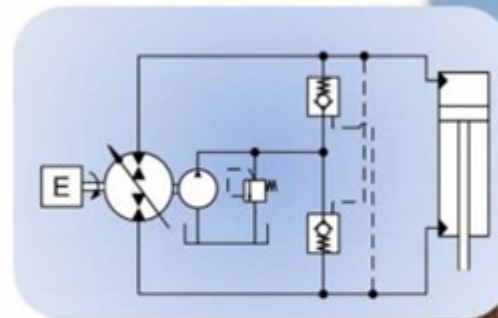
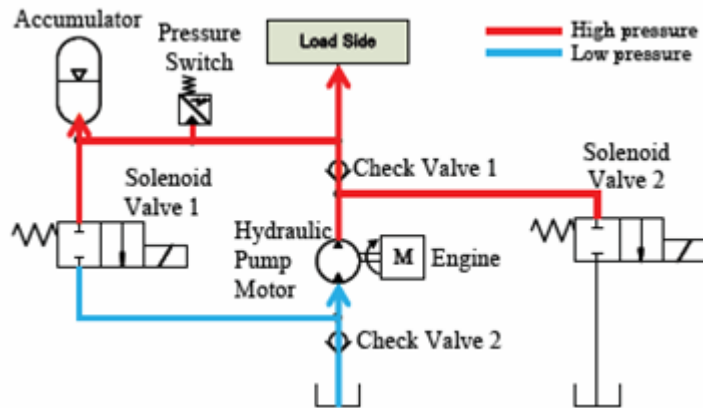
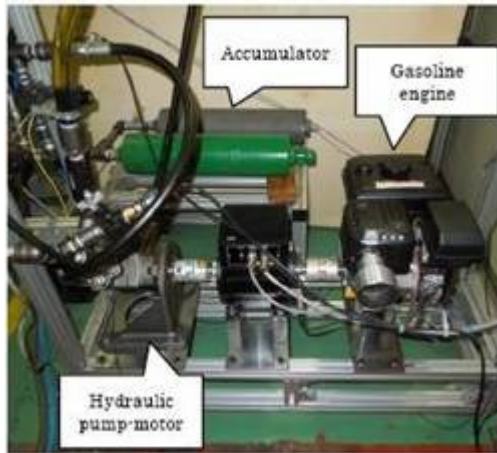
Hibridna vozila (smanjenje potrošnje goriva i povećanje energetske učinkovitosti)



Bosch Rexroth - Hydrostatic Regenerative Braking System HRB:
Sustav smanjuje potrošnju goriva kod komercijalnih vozila i do 25%.

Ušteda energije

- manja potrošnja goriva
- bolja energetska učinkovitost
- pohrana i ponovno korištenje energije



Displacement Controlled Excavator

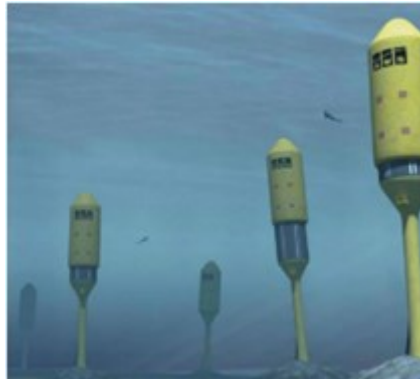
Nova područja primjene

OBNOVLJIVI IZVORI ENERGIJE

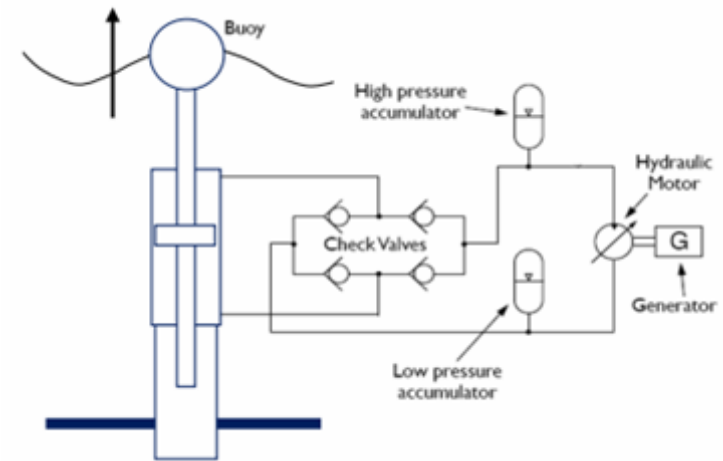
■ KORIŠTENJE ENERGIJE MORSKIH VALOVA

Klimatske promjene i povećanje udjela CO₂ u atmosferi usmjerava dobivanje el. energije iz obnovljivih izvora.

Početak istraživanja: od naftne krize 1970-tih



Point absorbers

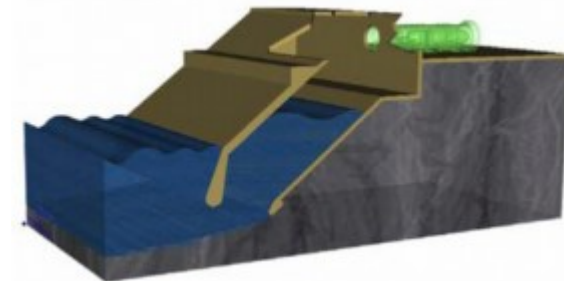


Attenuators (Pelamis)



Terminator (Oyster):

radni vijek: 25 g.
period održavanja: 5 g.



Oscillating water column

Nova područja primjene

OBNOVLJIVI IZVORI ENERGIJE

■ KORIŠTENJE ENERGIJE MORSKIH VALOVA

■ Prednosti:

Najveća gustoća energije među obnovljivim izvorima energije

Mali negativni utjecaj na okoliš

Valovi mogu generirati energiju i do 90 % vremena (vjetroelektrane i solarni izvori 20-30%)



■ Tehnički izazovi:

Konverzija sporog ($\cong 0.1$ Hz), neujednačenog, oscilatornog gibanja u prihvatljivo gibanje aktuatora za pogon generatora. → Potreban je SPREMNIK ENERGIJE

Osiguranje robustnosti i pouzdanosti unatoč ekstremnih uvjeta okoliša

Optimalan rad velikog broja pojedinačnih jedinki

Razvoj regulatora za automatsku adaptaciju trenutačnom stanju valova

■ Rješenje:

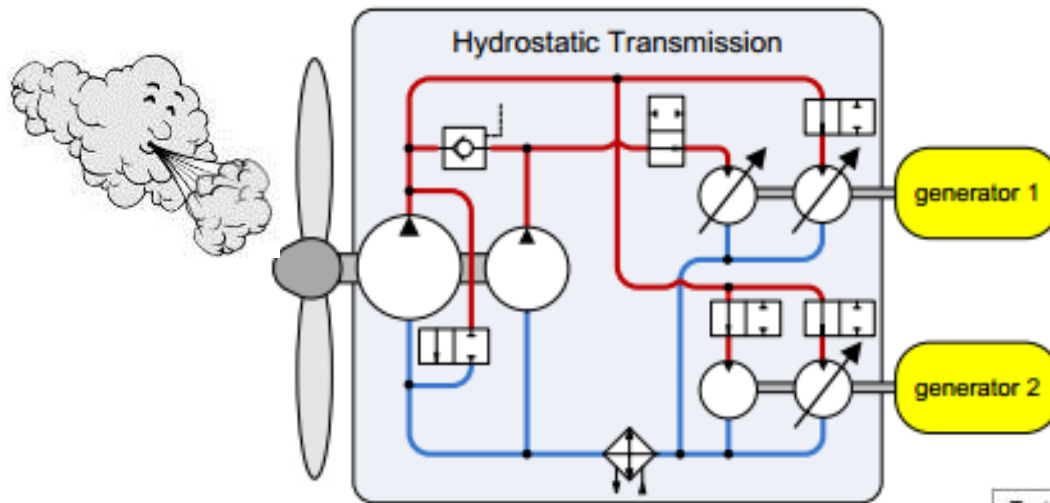
Primjena odgovarajućeg upravljanja da bi se maksimizirala energetska učinkovitost

Optimalna izvedba sustava

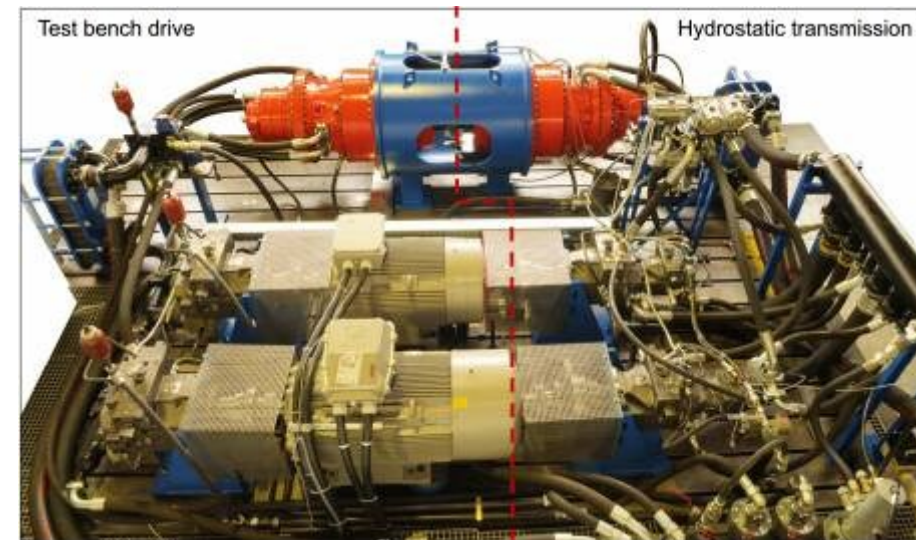
Nova područja primjene

OBNOVLJIVI IZVORI ENERGIJE

▪ KORIŠTENJE ENERGIJE VJETRA



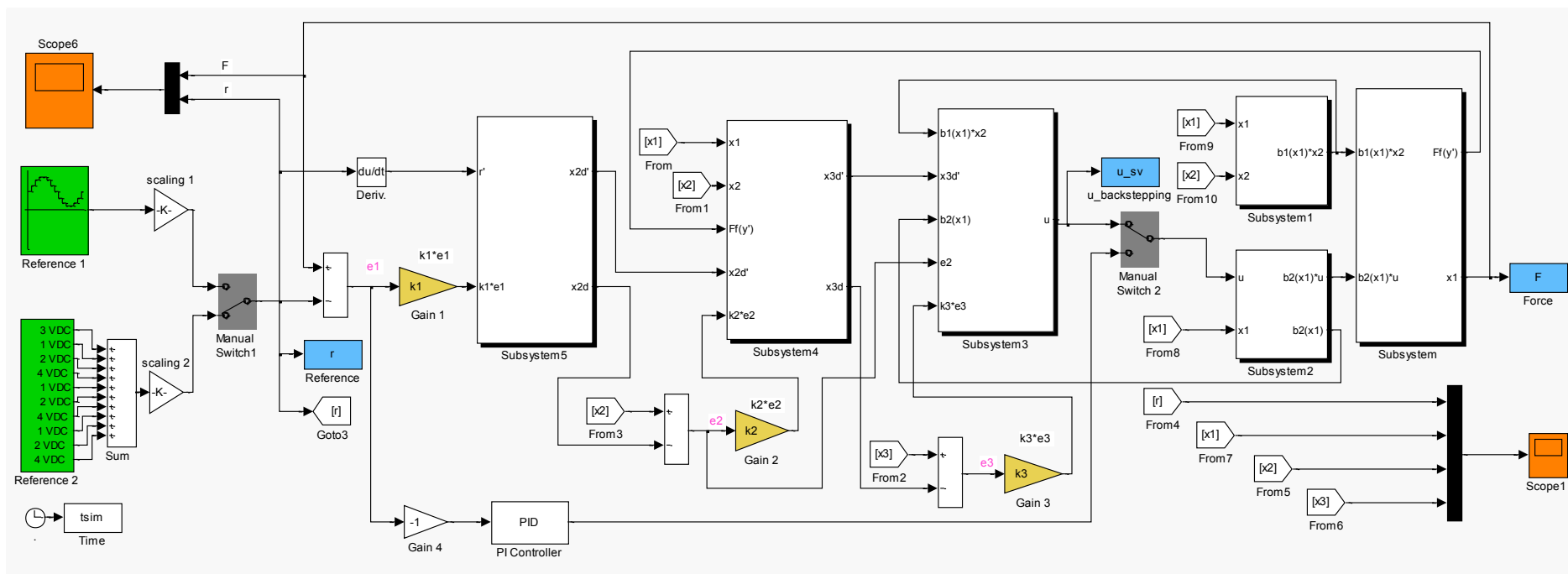
IFAS Institut für
fluidtechnische
Antriebe und
Steuerungen
Univ.-Prof. Dr.-Ing. H. Murrenhoff



Hydrostatic Drive Train in Wind Energy Plants

Primjena naprednih regulacijskih algoritama

- Adaptivno – robustno – optimalno... upravljanje
- Nelinearni regulatori
- Regulatori s varijabilnom strukturom
- Primjena umjetne inteligencije (neizrazita logika, umjetne neuronske mreže, genetički algoritmi)

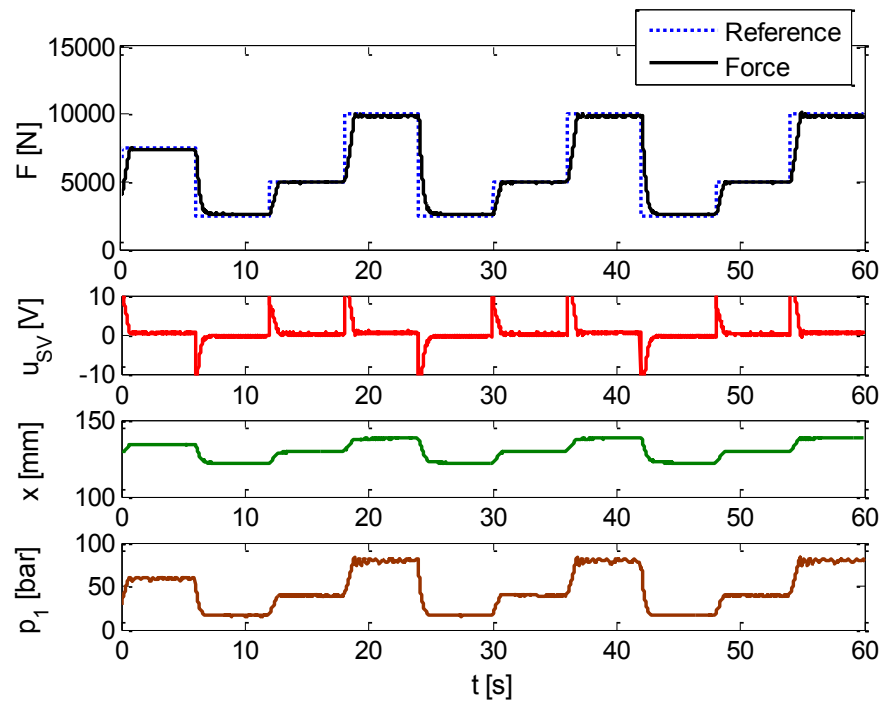


Simulacijski model s nelinearnim regulatorom (backstepping controller)

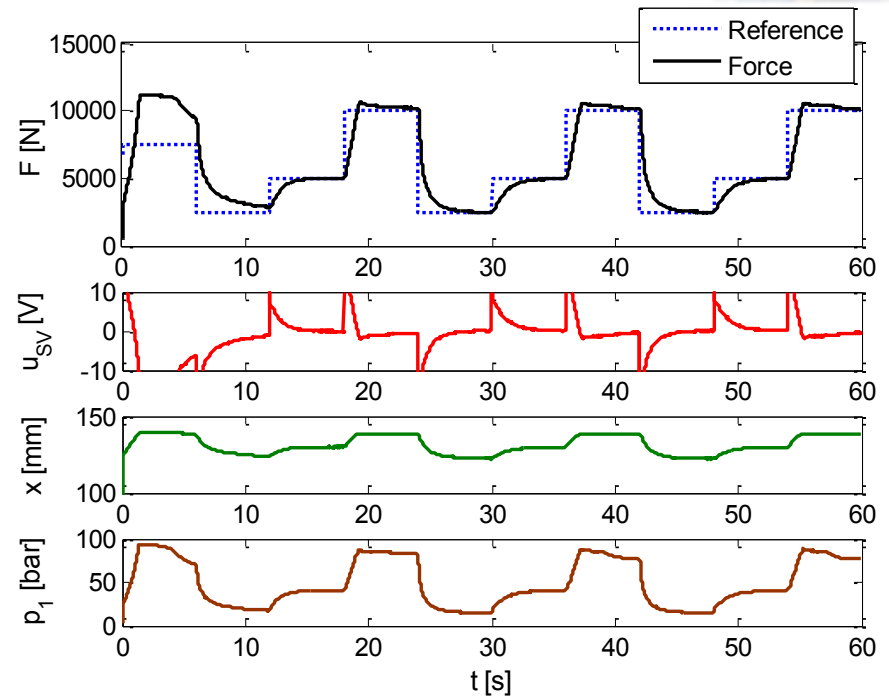
Primjena naprednih regulacijskih algoritama

Regulacija sile hidrauličke preše (eksperimentalni rezultati)

- step-reference signal



a) Backstepping controller



b) PI controller with anti-windup

Razvoj software-a (za industriju i za edukaciju)

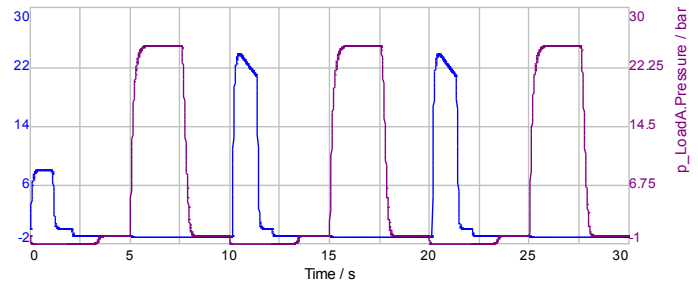
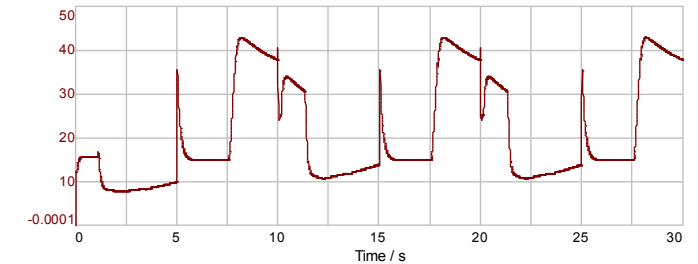
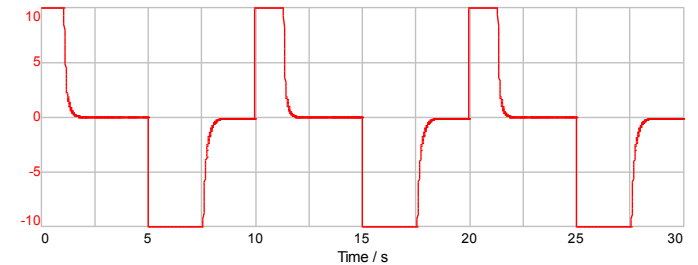
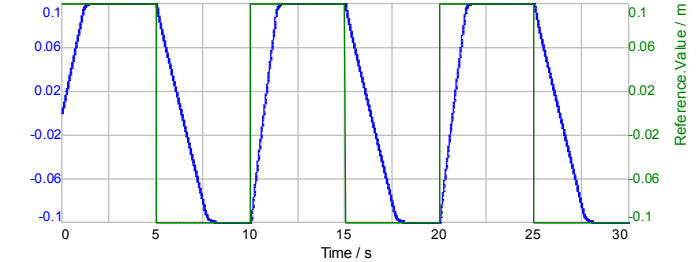
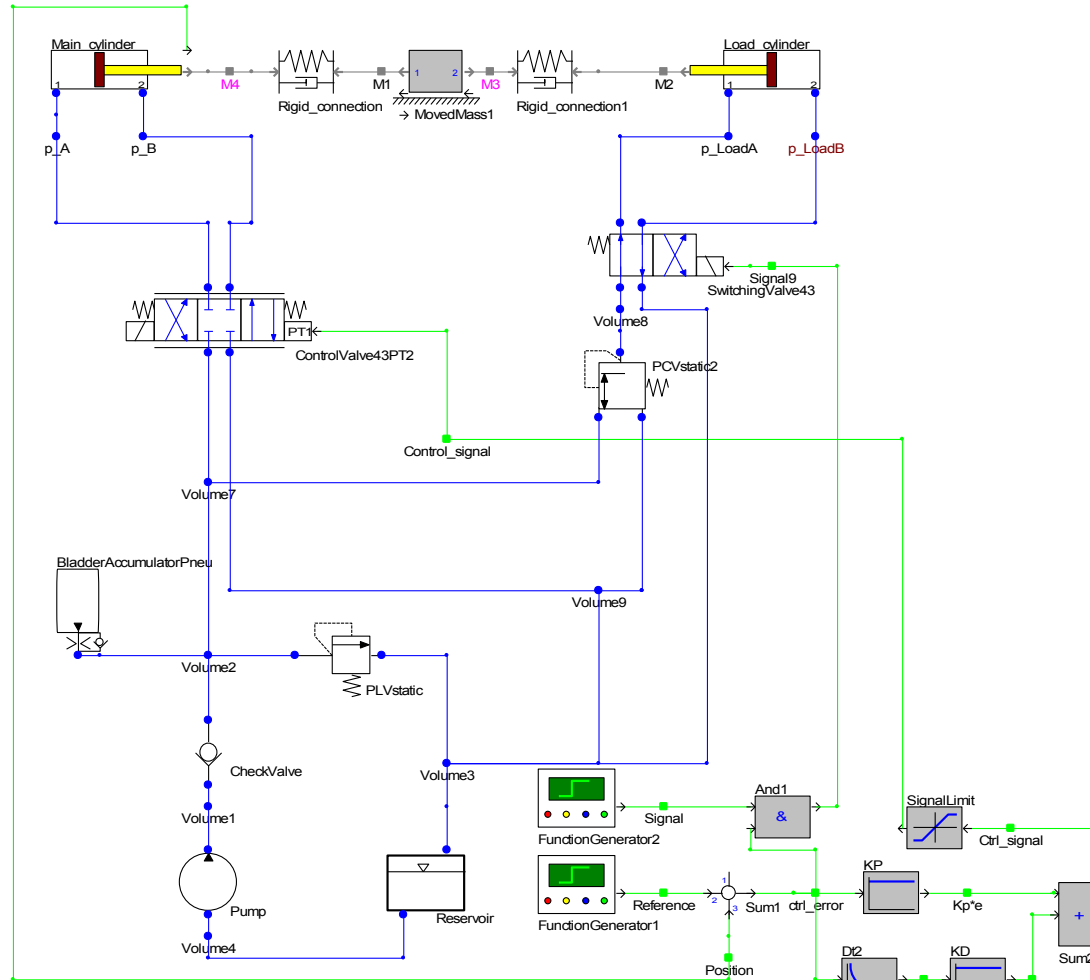
Simulation Software - Fluid Power

- ☐ Automation Studio - simulation for fluid power
- ☒ **FluidSIM – Festo (Germany)**
- ☐ CAMP - Bond Graph Modelling Software (USA)
- ☐ Visual Solutions - Vissim Sim. Software (USA)
- ☐ 20-Sim - Simulation software (Holland)
- ☐ Fluent - Computational Fluid Dynamics software
- ☐ Metamodelling - Bond Graphs and Dynamic System
- ☐ POG for modeling systems (Italy)
- ☐ ACSL simulation software (USA)
- ☐ Amesim simulation software (France)
- ☐ Bathfp simulation software (UK)
- ☒ **DSHplus simulation software (Germany)**
- ☐ Dymola (Sweden)
- ☐ EASY5 simulation software (USA)
- ☐ Flowmaster 2 (UK)
- ☐ HOPSAN (Sweden)
- ☐ Hydro Analyst simulation software (UK)
- ☐ HydroCAD simulation software (UK)
- ☐ HyPneu - hydraulic/pneumatic simulation software
- ☐ ITI-SIM Fluid Power Simulation Software
- ☐ Dynhax™ - dynamic simulation of hydraulic systems

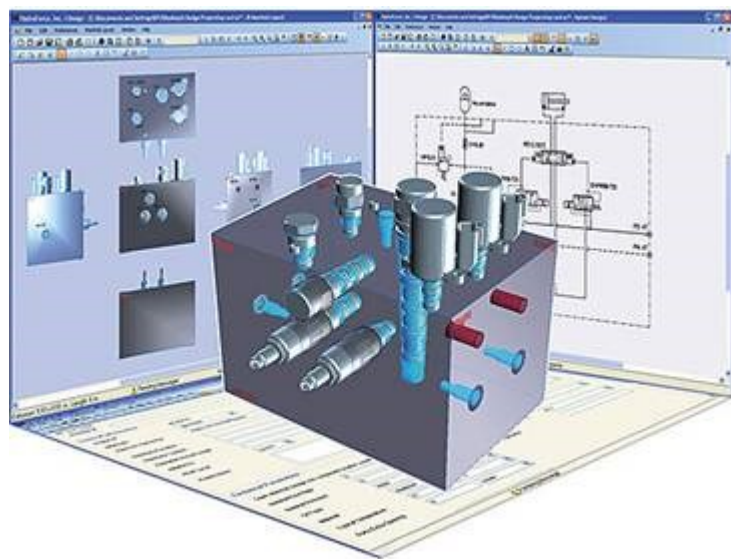
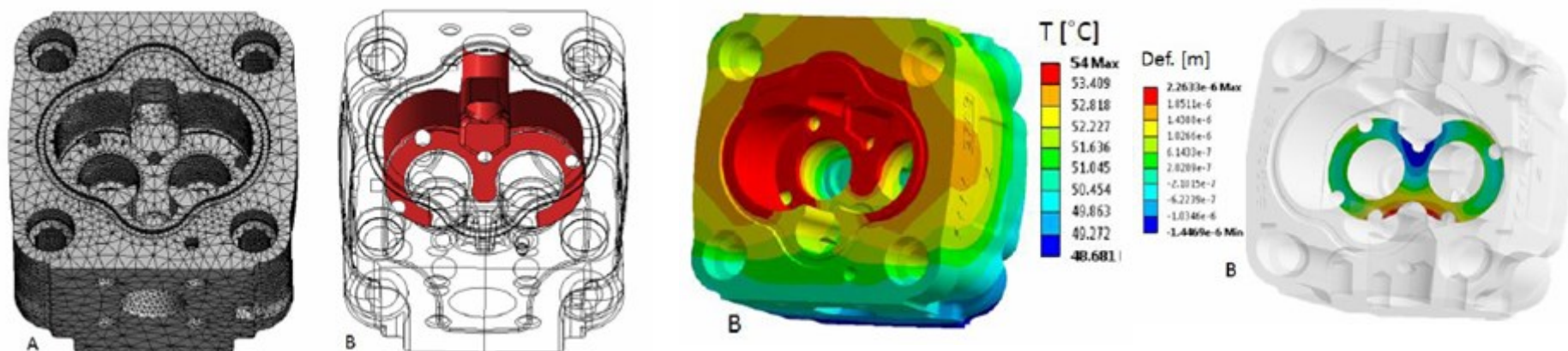
General purpose

- ☐ ACSL - Simulation Software
- ☐ AnyLogic - simulation modeling for business, eng. and science
- ☐ Berkeley Madonna - Dynamic Systems Modelling
- ☐ BuildSim (USA)
- ☐ (CSMA) COMPUTER SIMULATION
- ☐ Engineering Software Simulation and E-Solutions
- ☐ HyBrSim - Hybrid Bond Graph Simulator
- ☐ MathModelica simulation software (Sweden)
- ☐ MATRIXx (USA)
- ☐ MS1 from LorSim (Belgium)
- ☐ OMOLA/OMSIM modelling language (Sweden)
- ☐ PASION - Simulation System
- ☐ Simcar automotive simulation software
- ☐ SIMGAUSS general simulation software
- ☐ Simmon general simulation software (Sweden)
- ☒ **SIMULINK (Matlab based)**
- ☐ Vissim simulation software

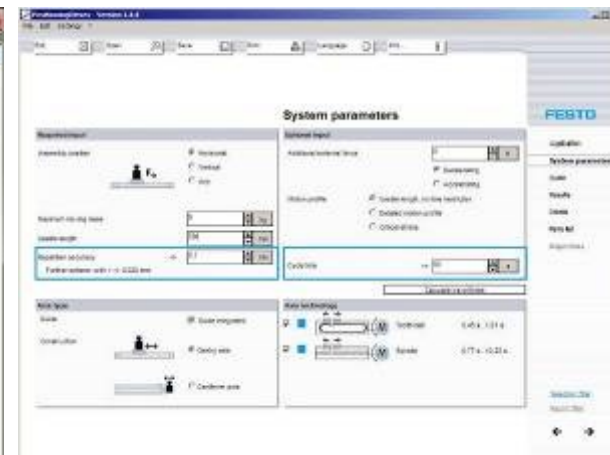
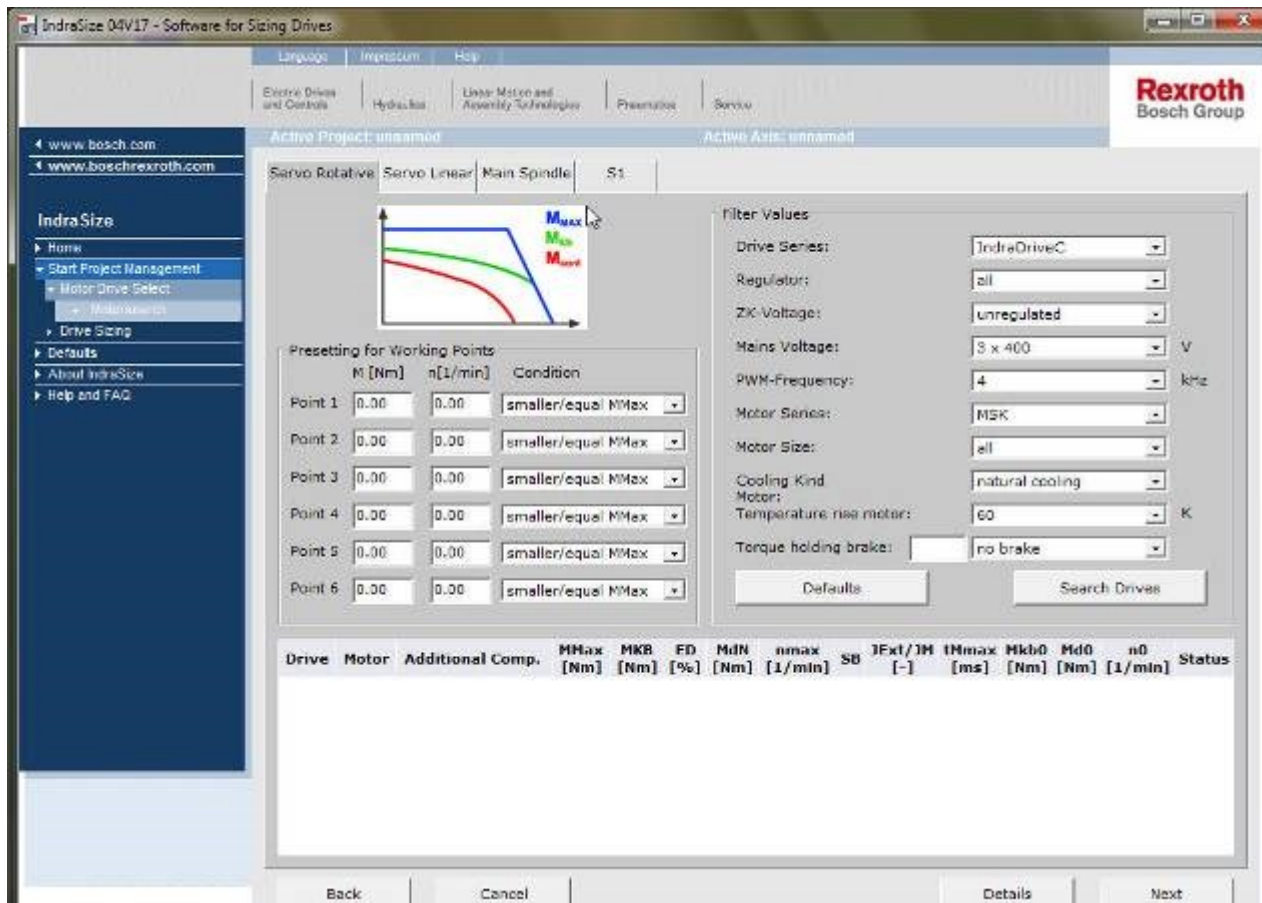
Simulation model - DSH_{plus}



Razvoj software-a (za industriju i za edukaciju)



Programski paketi za pravilan izbor komponenti

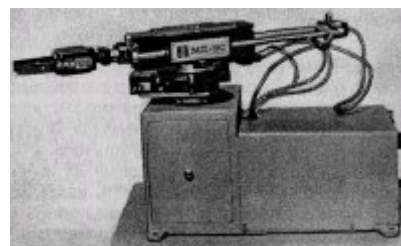


Specijalne primjene hidrauličkih sustava



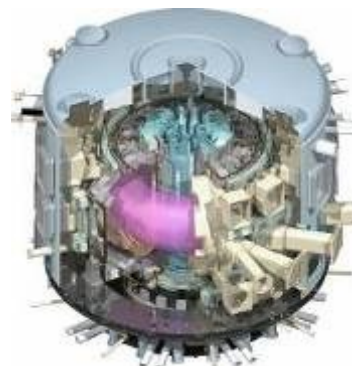
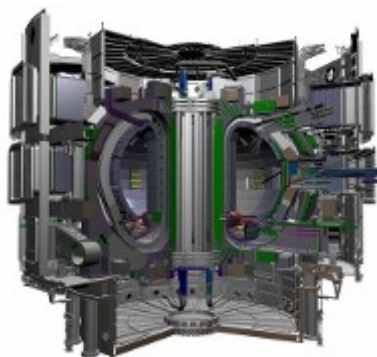
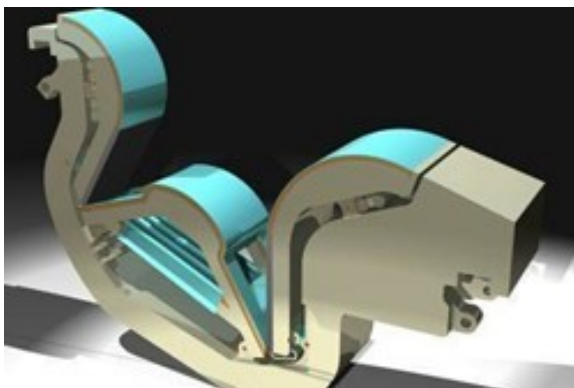
Od manipulatora do humanoidnih robota

Hidraulički robot



Pneumatski robot

Specijalne primjene hidrauličkih sustava



Water Hydraulic MANipulator
(WHMAN) for CMM



TAMPERE UNIVERSITY OF TECHNOLOGY
UTK - Department of Intelligent Hydraulics and Automation



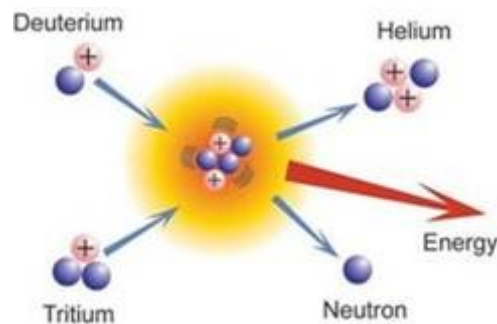
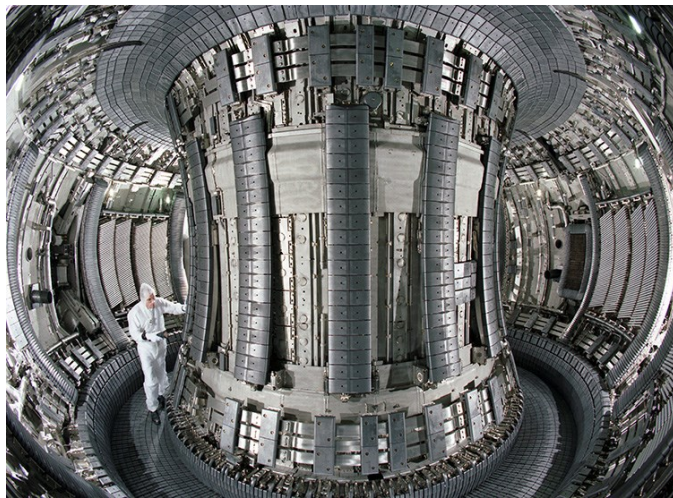
Association
Euratom-Tekes

Tokamak reaktor za nuklearnu fuziju

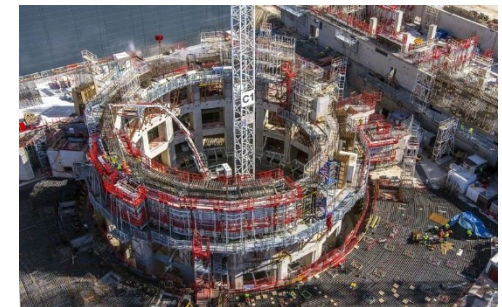
Specijalne primjene hidrauličkih sustava

ITER Project

- 13 mlrd Eur – 10-godišnji troškovi izrade reaktora
- 35 zemalja učestvuje u projektu
- 2010. - početak projekta, 2019. – završetak reaktora
- 23000 t – težina Tokamak reaktora
- 5000 zaposlenih na projektu
- 500 MW – izlazna snaga
- 150×10^6 °C – temperatura u reaktoru
- 73 m – visina postrojenja



Tokamak reaktor za nuklearnu fuziju



Cadarache – 60 km od Marseille

