FADROMA Development Sp. z o.o.

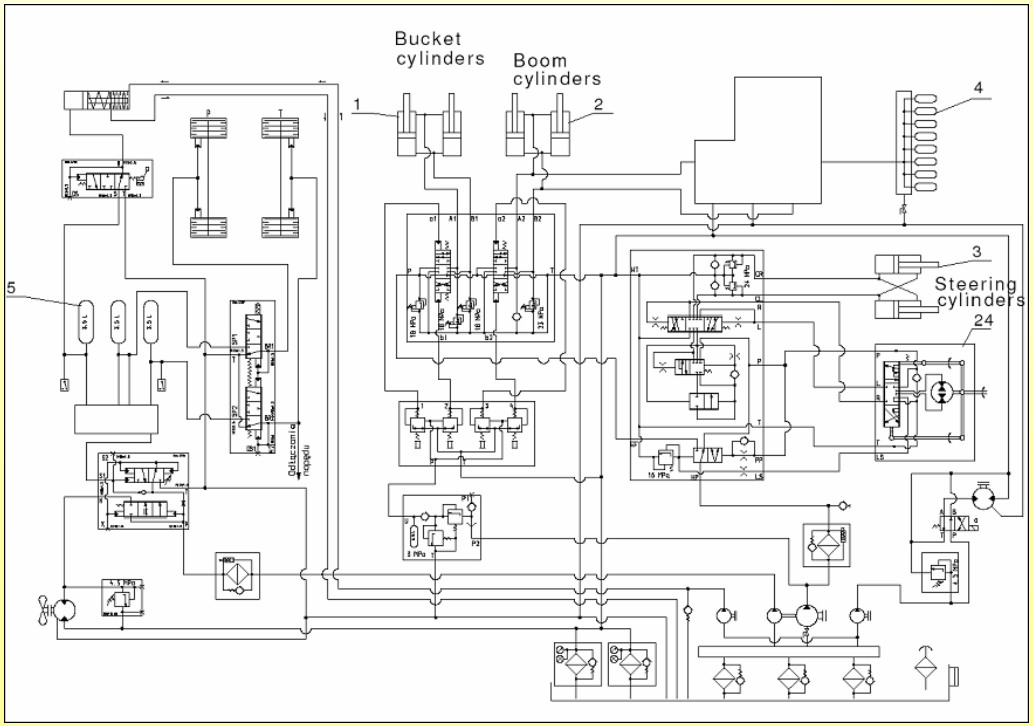
FADROMA

Work performed

- Specifications for 9 mining machines

- Specifications for hydraulic components used in those machines (cylinders and accumulators)

- Hydraulic systems diagrams for all machines

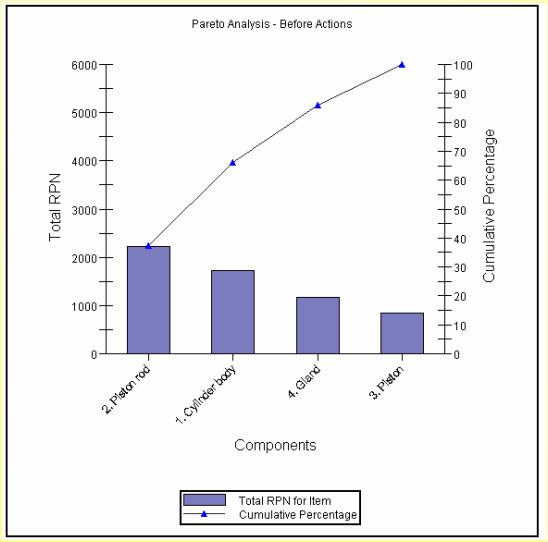


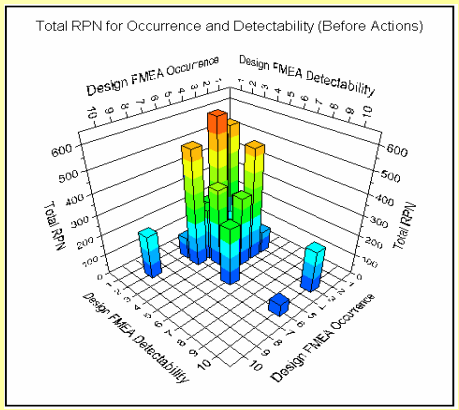
Work performed

- Analysis of cylinder failures
- Probability risk assessment (Fault-tree, Master Logic Diagram, FMEA)
- Hydraulic cylinders categories (Rainflow counting analysis)

FADROMA FMEA results:

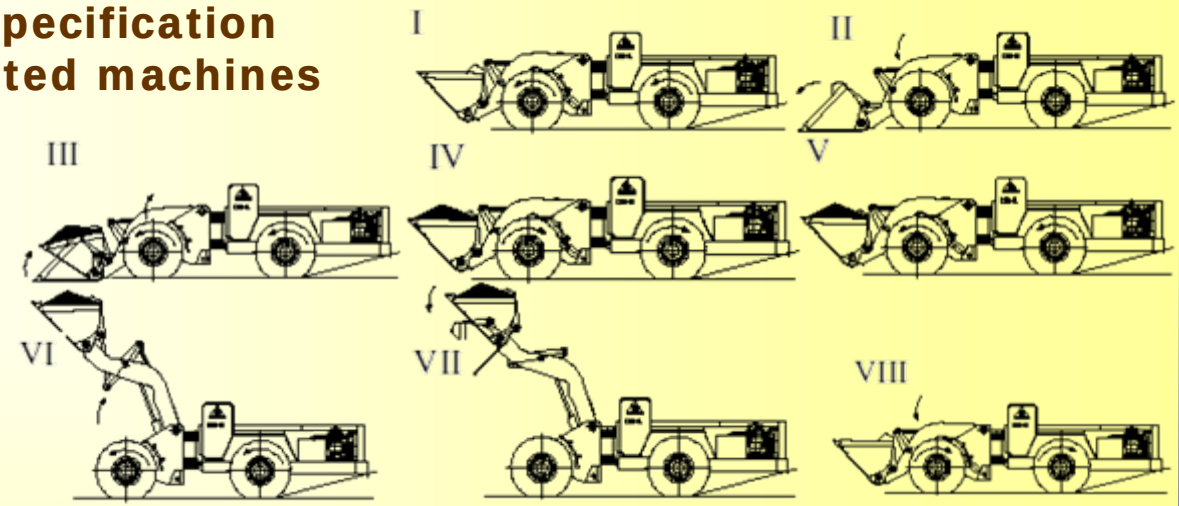
- New standardized FMEA analysis methodology for hydraulic cylinders
- Extension of failure modes, effects and causes lists – FADROMA proposal
- Increased knowledge about problems with cylinders and their significance
- Improvements in cylinders design in the area of
  - gland sealing
  - protective layer on cylinder piston rods
- Possibility of increasing rated loads for new mining loaders





Work performed

- Measurement equipment specification and implementation on tested machines
- Field testing methodology
- Field testing experiments



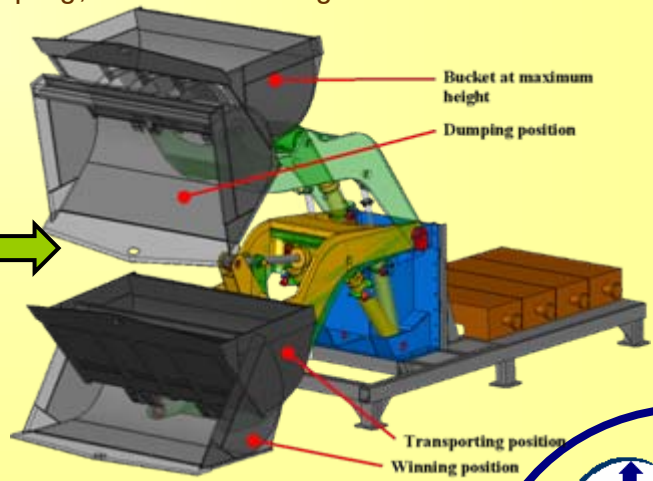
Basic motions of mining loader duty cycle

I – driving to the winning, II – boom lowering, III – winning,
IV, V – moving to the dumping site, I – boom lifting,
VII – dumping, VIII - retracting

Testing in underground mine

Testing in test field

Testing in test field with rated load



Laboratory testing

Entire project (months 1-48)

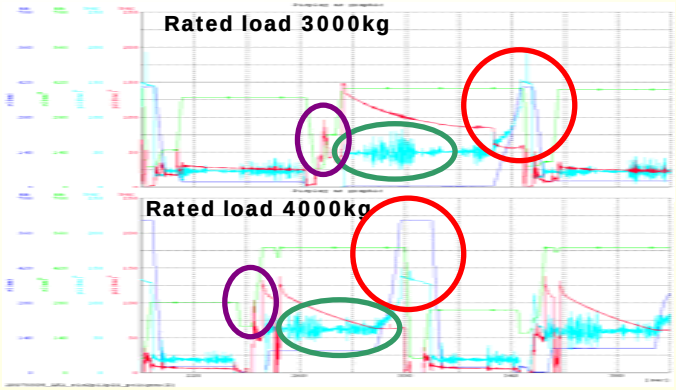
Work performed

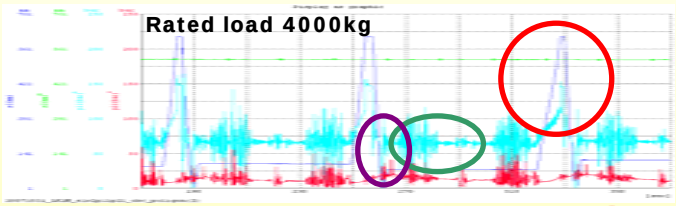
Tested mining loaders	Testing scenarios
LK07 – weight 10.8 [t], bucket 1.9 [m³], load 3.2 [t] LK1 – weight 13.5 [t], bucket 2 [m³], load 4 [t] LK1N – (prototype) weight 12 [t], bucket 2 [m³], load 4 [t] LK2AC – weight 18.7 [t], bucket 3.2 [m³], load 6.5 [t] LK2ACDW – (prototype) weight 23 [t], bucket 3.5 [m³], load 7.2 [t] LK4C – (prototype) weight 29.3 [t], bucket 4.7 [m³], load 10 [t]	- Thrusting - Load extracting - Lifting of real load - Long lasting real work (underground mine and testing ground) - Lifting of rated load (counterweights) - Driving with rated load and lifting of rated load - Lifting of rated load increased by 1350 kg – stability testing - Driving and lifting of rated load increased by 1350 kg – stability testing - Lifting of rated load increased by 2700 kg – stability testing - Driving and lifting of rated load increased by 2700 kg – stability testing

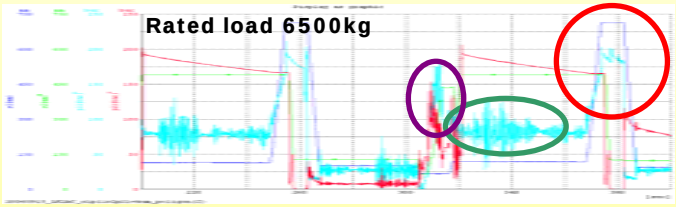
- In total of 183 field testing experiments and corresponding field testing results reports
- Field testing results database (load and displacement spectra)
- Comparative analysis of field testing results and some conclusions

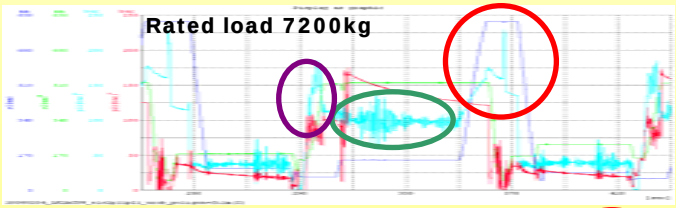
FILM

Work performed – Analysis of field testing results









MAIN CONCLUSIONS:

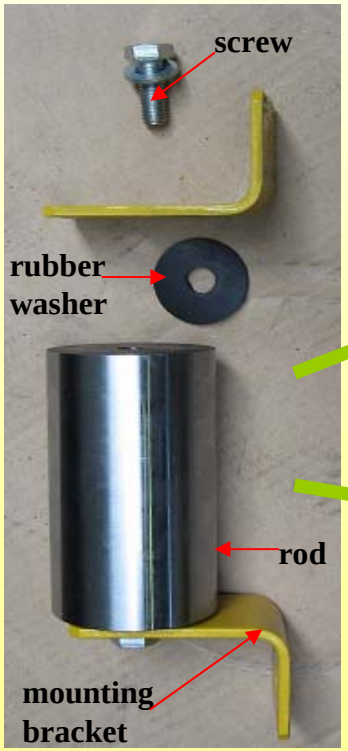
Results for all tested machines follow the same pressure patterns and only pressure values are different due to the difference in machines' size and rated loads

The most crucial are investigations of pressures in piston chambers of boom and bucket cylinders measured during normal work.

Introduced wooden bars caused increased dynamic loads in operating system allowing for good convergence to results from tests in underground mine.

Work performed

- Test samples from FADROMA (chrome plated) and Roquet (chrome plated and oxynitrocarburised)
- Test samples were placed on the machines working in underground mines
- Information about surface condition were periodically gathered to show how humidity, salinity, falling rocks etc. influence rod surface.
- In underground mines corrosion on rods appears generally beyond the stroke or during longer shutdown



After 11 months

After 11 months

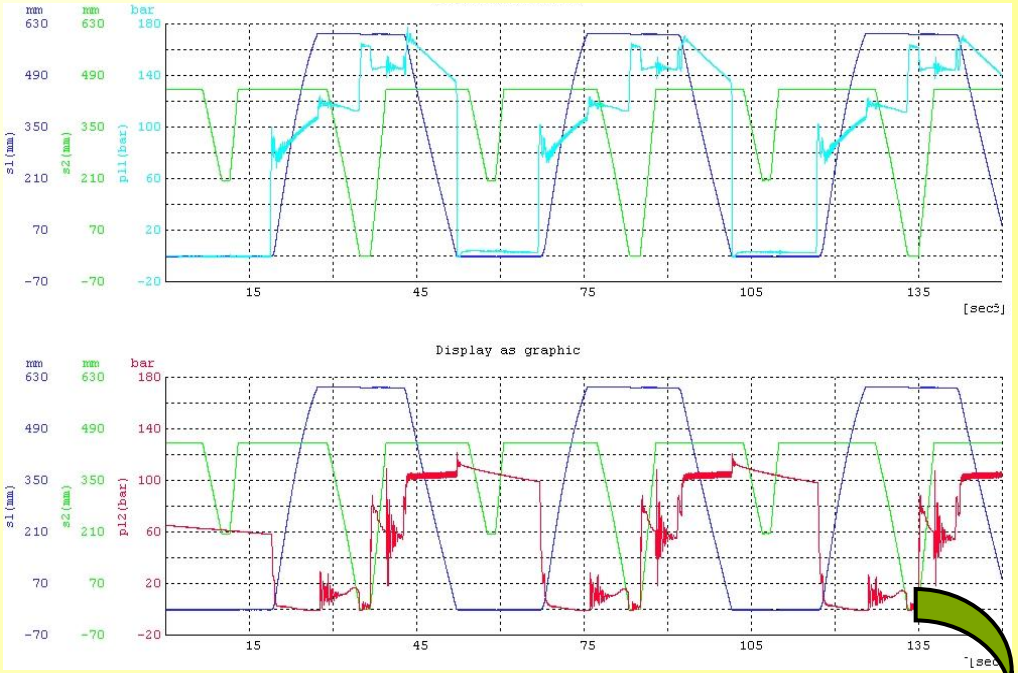
Work performed

- Final laboratory testing methodology
- Loader operating system test bench start-up and laboratory testing

Main view

Control system

Power system Measurement system

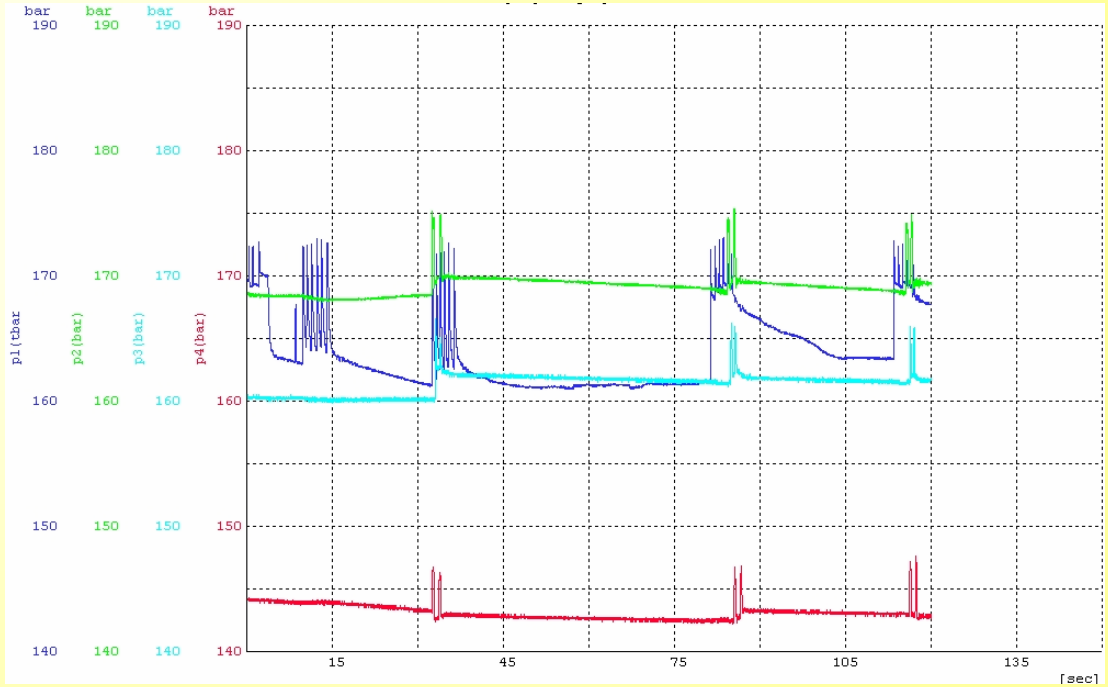


1	3,042349909	3,042349909	0	202	14	4	12	1	0	0
2	10,03904973	10,03904973	0	0	58	4	1	0	0	0
3	17,03574954	17,03574954	0	8	0	144	36	1	0	
4	24,03244936	24,03244936	0	2	9	0	141	4	1	
5	31,02914918	31,02914918	0	0	4	4	0	32	2	
6	38,025849	38,025849	0	0	0	1	2	0	38	
7	45,02254881	45,02254881	0	0	0	0	2	3	0	44
8	52,01924863	52,01924863	0	0	0	0	0	1	5	0
9	59,01594845	59,01594845	0	0	0	0	0	0	0	4
10	66,01264827	66,01264827	0	0	0	0	0	0	0	0
11	73,00934808	73,00934808	0	0	0	0	1	0	0	1

Entire project (months 1-48)

Work performed

- Loader stability test bench design, start-up and laboratory testing
- Loader stability testing at testing ground - machine driving with increased loads



Entire project (months 1-48)

Work performed

BEST PRACTICE RULES:

- Hydraulic cylinder test protocols and design rules
- Hydraulic components assembly on the machine and hydraulic system start up
- Hydraulic cylinder maintenance
- Hydraulic cylinders removal and end life treatment

SAFETY RULES:

- Mining equipment safety standards
- Operator's cabin safety standards
- General safety rules related to mobile underground mining machinery
- Local regulations:
  - FOPS – falling object protective structure
  - ROPS – roll over protective structure
  - RSPS – rock slide protective structure
  - Additional emergency exit for operator
  - Increased requirements for electrical systems

Work performed

1. World's resources and mining technologies
- Minerals of the world
- Mining methods
- Mining technology
- Possible ore lay outs
- Deep drilling
- Open-pit mining
- Transporting systems

2. Underground mining methods
- Mineral prospecting
- Infrastructure of underground mines
- Mining systems
- Room and pillar mining
- Cut and fill mining
- Longwall mining

3. Main underground mining machines
- Wheel loaders (LHD)
- Hauling vehicles
- Drilling jumbos

4. Underground utility vehicles
- Personnel carriers
- Fuel and oil carriers
- Explosives carriers
- Explosives charging vehicles
- Inspection vehicles
- Repair works vehicles
- Wheel changing vehicles

Entire project (months 1-48)

Exploitable results list

1. Methodology and field testing results for hydraulic systems of underground mining machines: - Data acquisition system and its implementation into machines - Testing scenarios (in mine and at testing ground) - Results analysis methods - Results database	**2. Methodology and laboratory testing results for hydraulic systems of underground mining machines:** - Test benches design - Data acquisition system and its implementation into test benches - Testing scenarios - Results analysis methods - Results database
3. Risk analysis of hydraulic systems of mobile underground mining machines: - Fault-tree analysis - Cylinder failure modes - Master logic diagram - FMEA methodology and results	**4. Best practice and safety rules for:** - Hydraulic components for mining machines selection and implementation - Activating, exploitation and recycling of hydraulic components used in underground mining machines - General and safety regulations for underground mining machines