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DEVELOPMENT OF MAGNETORHEOLOGICAL FLUID FOR RUNNING SHOES WITH AN ACTIVE DAMPING SYSTEM

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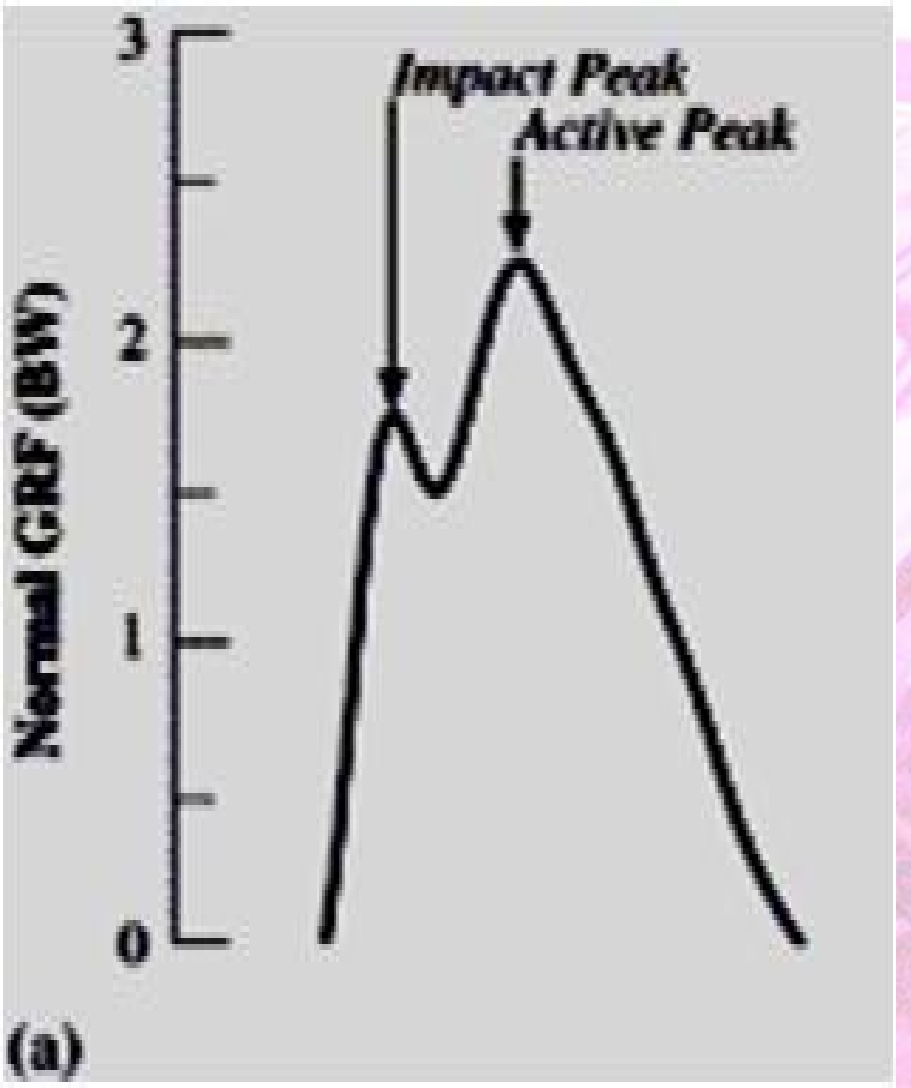
Impact Force During Running



Reduce impact force peaks

- **Joint and muscular injuries**

I impact peak

- **Horizontal force**

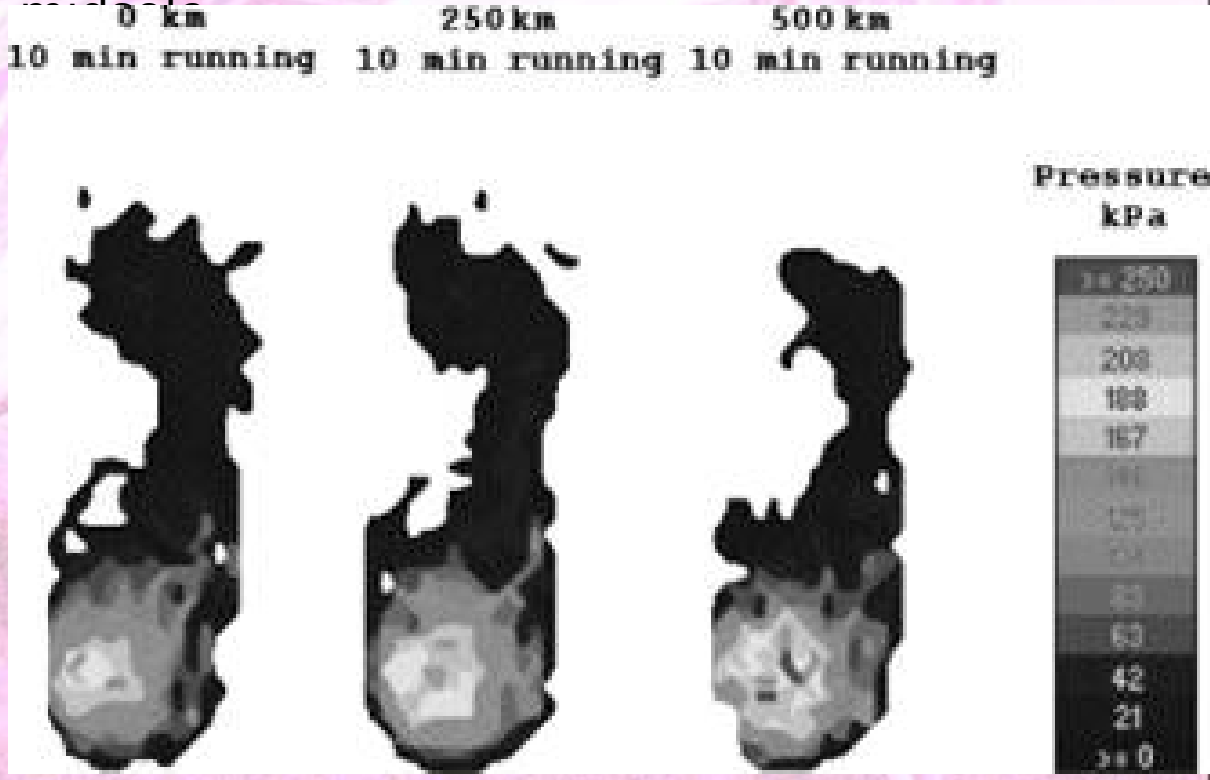
II active peak

- **Vertical force due by muscle activity**

Damping in the sport shoes

- EVA (copolymeric rubber: Ethyl Vinyl Acetate) More soft and most used
- PU (puliuretan) or TPU More elastic

Pressures exchanged between heel pad and midsole



EVA duration

- after 100 km pressure peak raising of 100%

Other cushioning systems

Passive systems

- Air cushioning (Nike Air, DMX Reebok)
- Silicone gel (Asics, Diadora)

Active system

- 2005 Adidas “1”

-20 Mhz processor

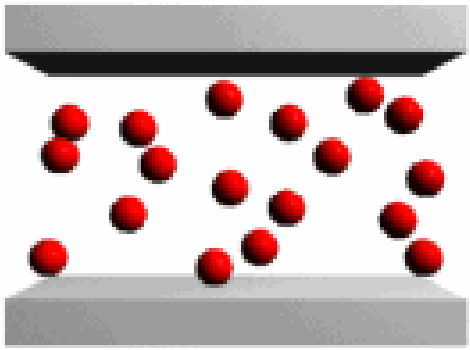
-effect hall sensor (precision 0,1 m)

-stiffness range 150%

Semi-active damping system using magnetorheological fluid

MRF change the apparent viscosity if exposed to a magnetic field

semi-active damping system



Main components of the MR fluids

Approximately to obtain 100 ml of MRF:

- **50 g synthetic oil (23,8%)**
- **10 g lithium white grease (4,76%)**
- **150 g iron powder (71,54%)**

Density = 2,1 kg/liter

Rheometer description tests

- **STRAIN SWEEP at 25° C, frequency 1 Hz**
- **ISOTHERM at 25° C: frequency 1Hz, strain 1,5 and total time 3 minutes**
- **DYNAMIC from 25 °C to 70 °C, speed step 2°C/minute, frequency 1 Hz,**

a)

b)

Oils Brooksfield rheometer

Grease and MR fluid Ares rheometer

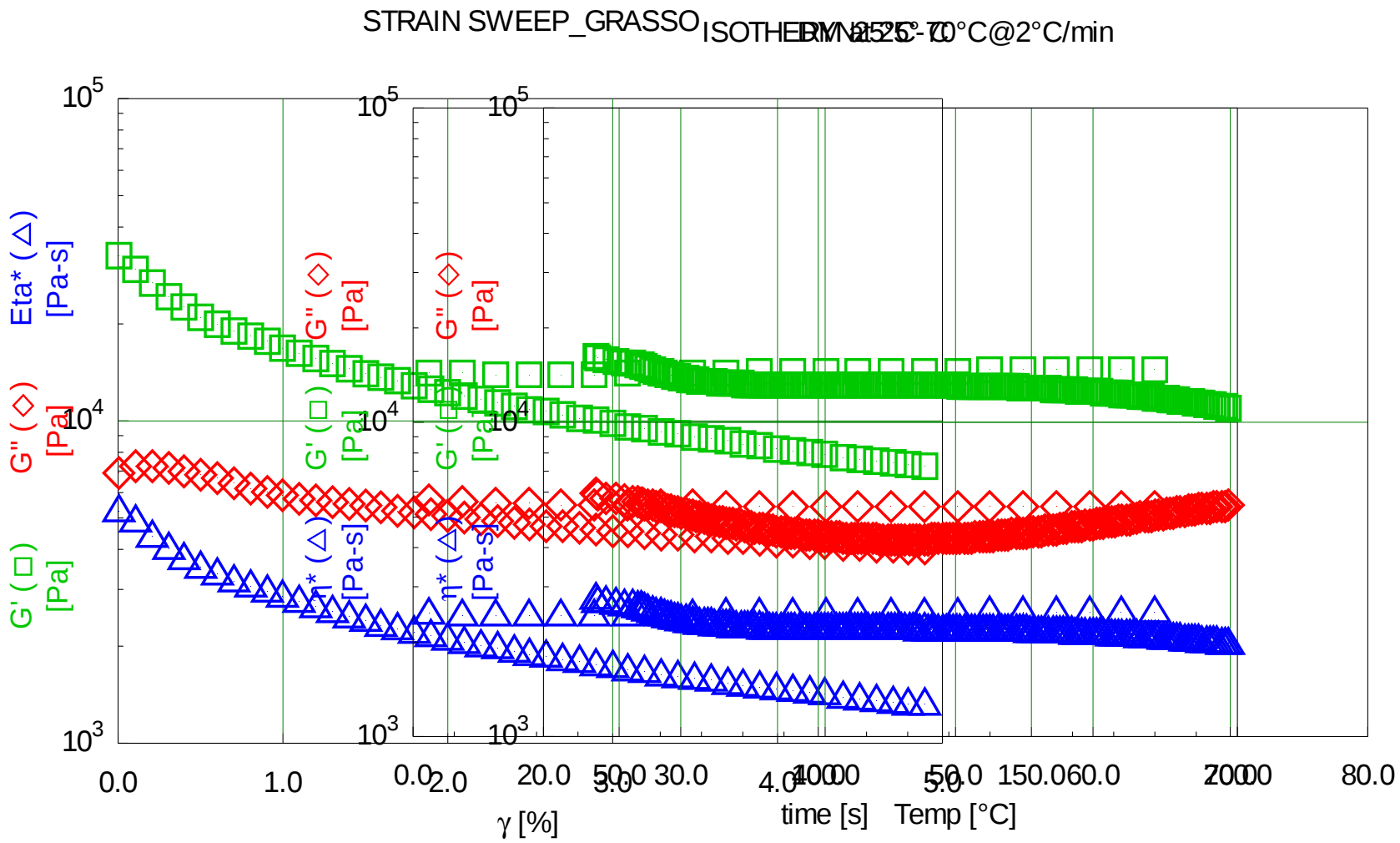
Oils

- **Shell Helix Plus 5W-40** **154,1 mPa*sec**
- **Ford 75W-90 BO** **130, 2 mPa*sec**
- **Castrol ForkOil SAE 20W** **132,8 mPa*sec**
- **Castrol ForkOil SAE 10W** **26,04 mPa*sec**
- **LubroFluid 18** **23,04 mPa*sec**
- **WD 40** **4,50 mPa*sec**

Viscosity measured with Brookfield rheometer.

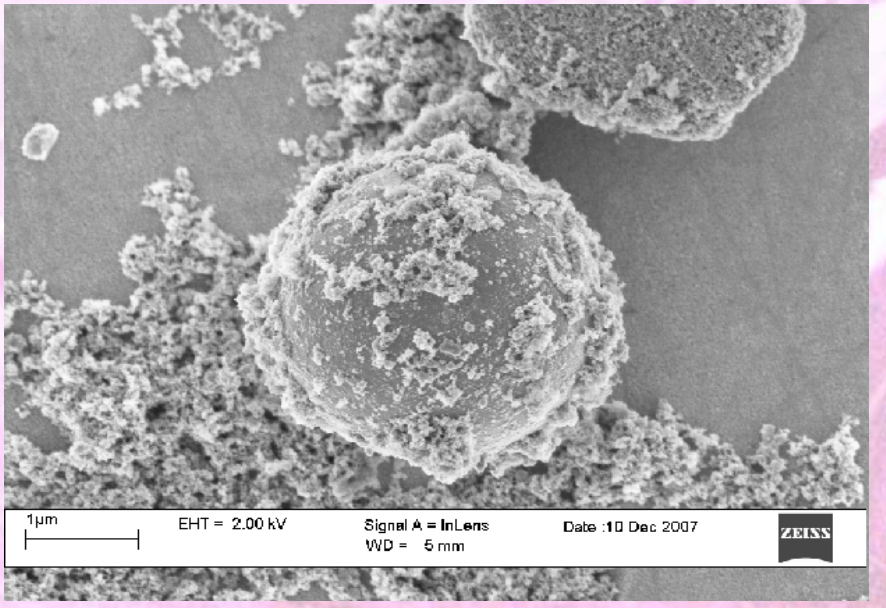
Conditons: 700 ml a 25° C (regulation) rotor 1

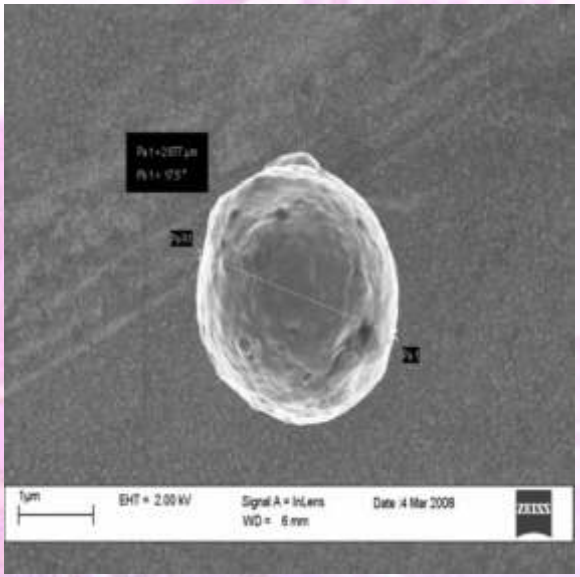
Lithium white



Carbonyl Iron Powder

- Datasheet:
  - Mesh (diameter) 6-9 micron
  - Effective density 7,5 g/ccm
  - Apparent density 1,7-2,7 g/ccm

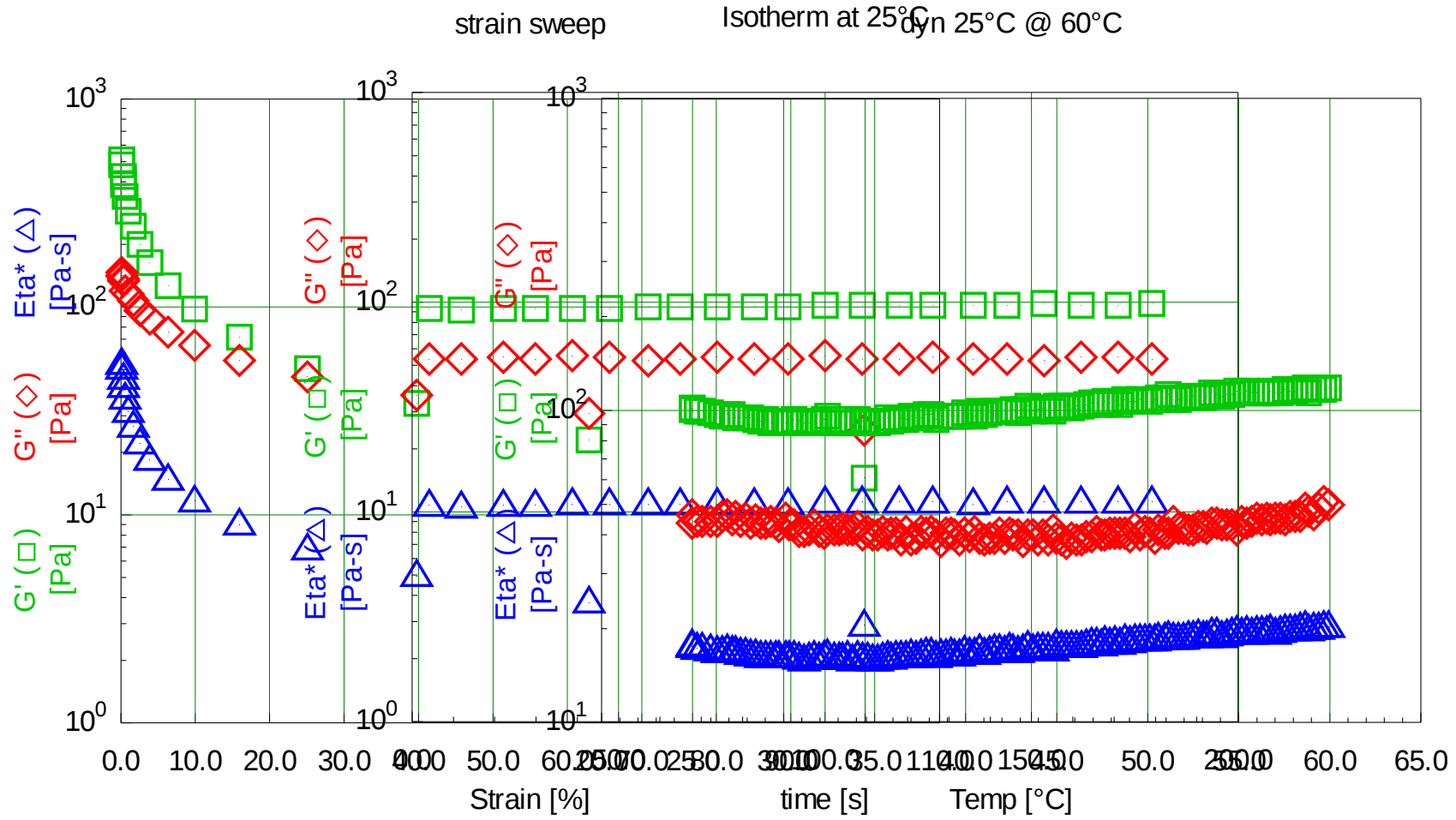




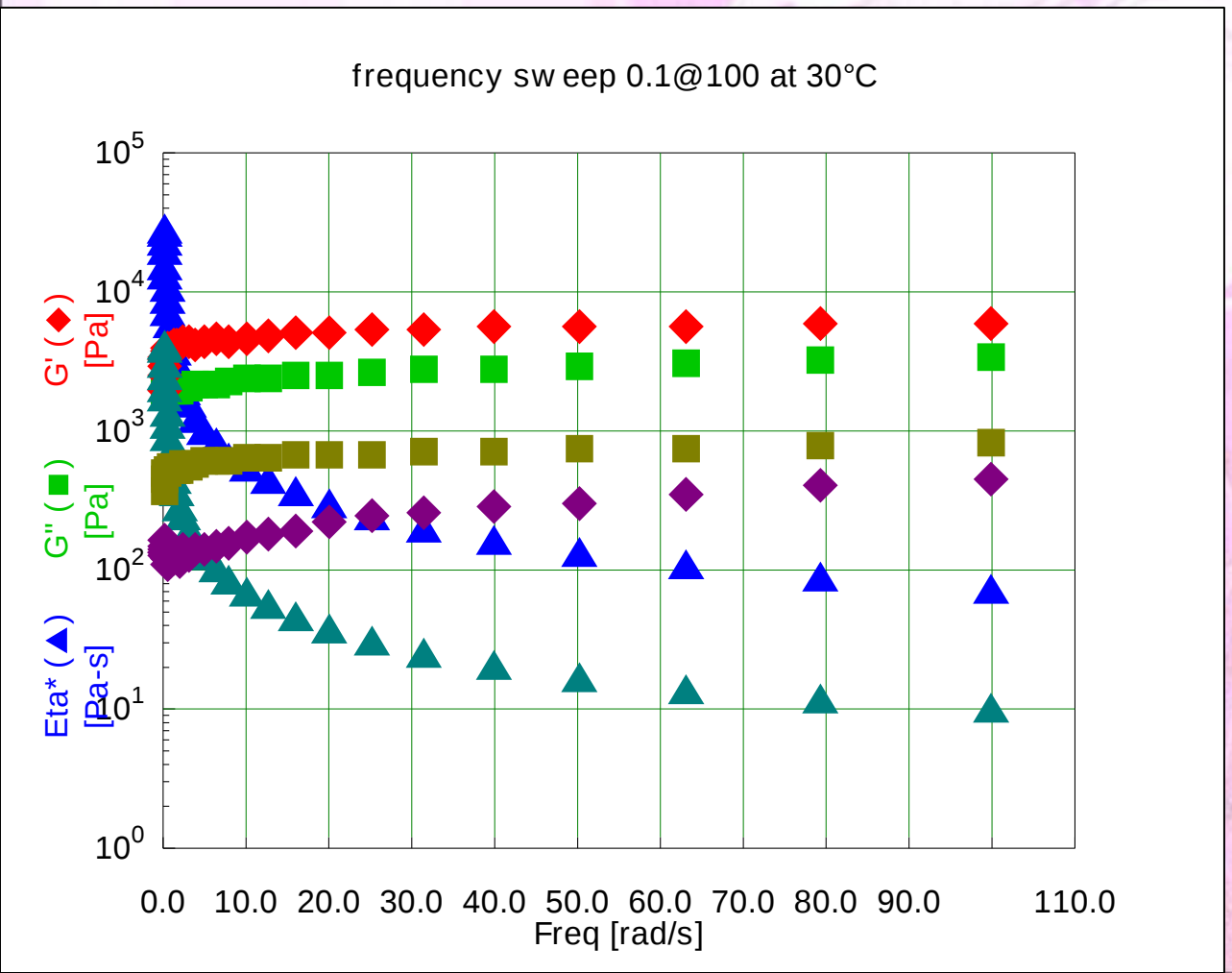
On the left we can see iron powder oxidized, on the right Carbonyl iron

FMR ford 50+10

- Ford oil (BO 75W-90)
- 10 g of White Lithium Grease
- 150 g of powder Carbonyl



Energy storage modulus G', energy loss modulus G'' and viscosity Eta* in function of frequency with two different currents I=0 A and I=0,1 A



FMR-Ford 50+10

	I=0 A	I=0,1 A
G'	■	■
G''	◆	◆
Eta*	▲	▲

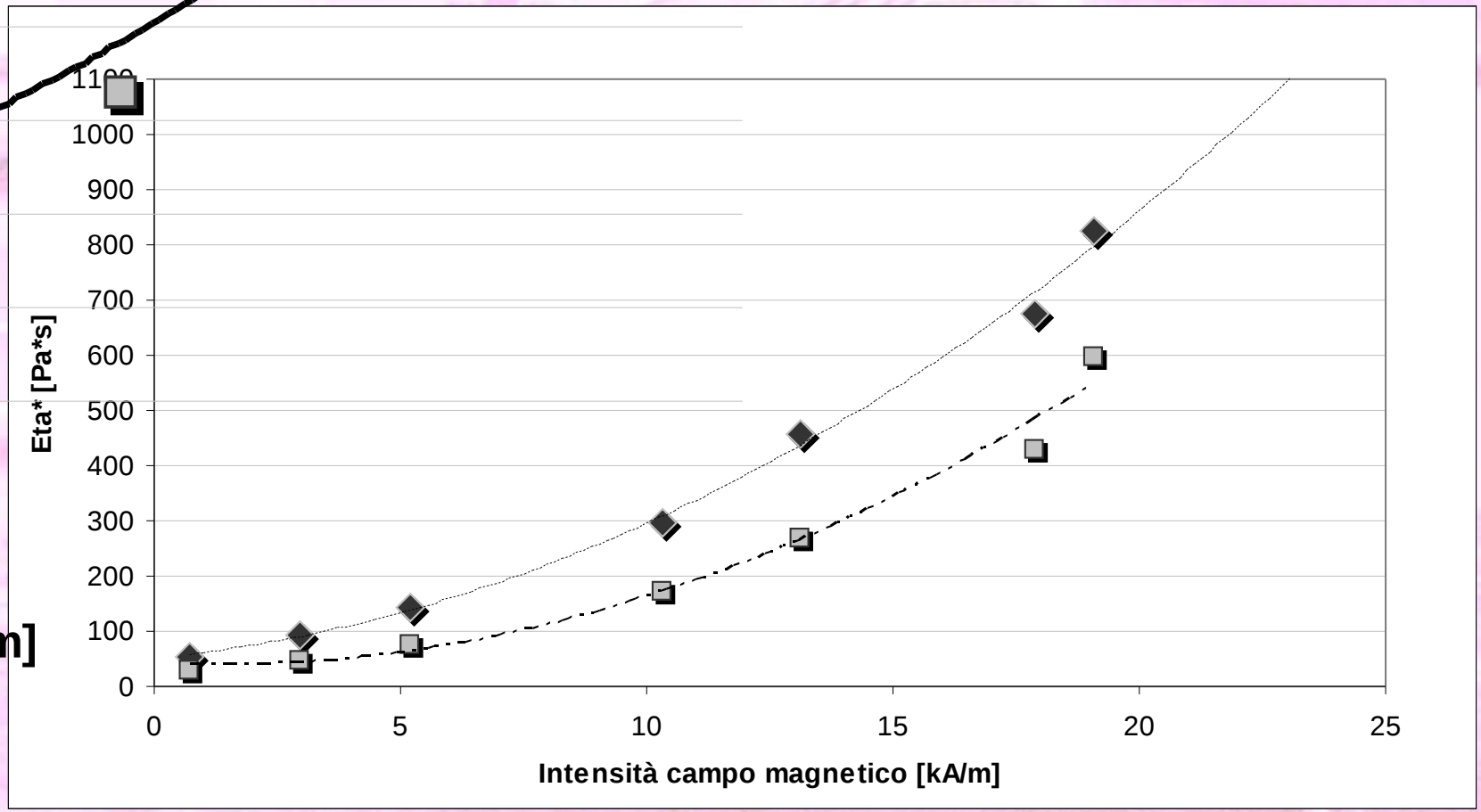
Ratio Magnetic field/Viscosity

Current A	Magnetic field KA/m	Viscosity Pa·s
0	0.745*	49,5
0.1	10.4	112.2
0.2	18.1	347

ETA* rises from 49.5 to 347 Pa·s (7 times) with only 0.2 A step

***residual magnetization**

Comparison between Ford 50+ 0 ( )and commercial MR lord ( )

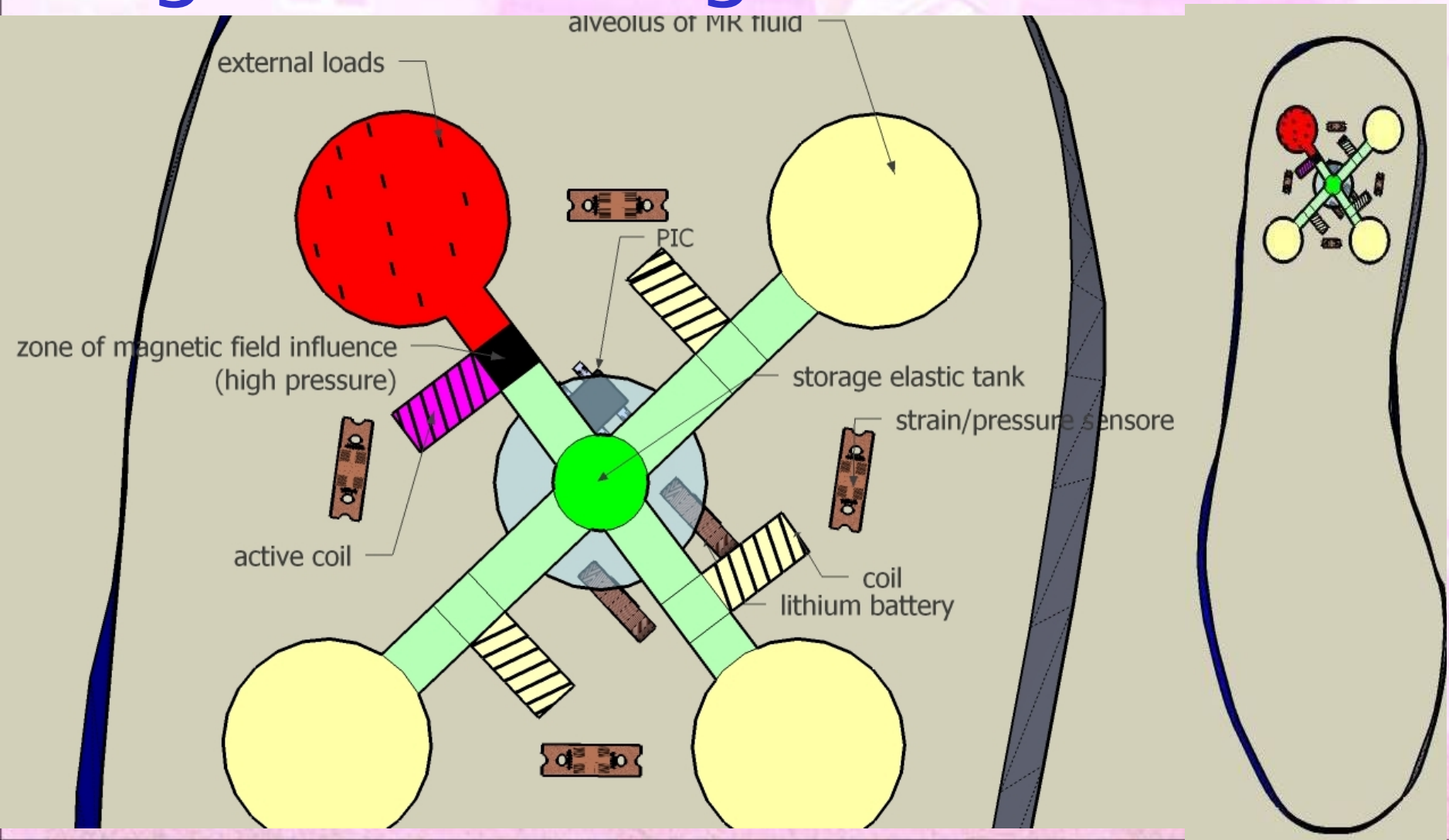


[kA/m]

Main MR shoes components

Algorithm	Strain based (displacement, derivative)
Unit logic	40 Mhz Programmable PIC
MR fluid	4 pistons connected with pipes
Input	4 effect hall sensors
	4 Magnetic Micro coils
Outp ut	
Power system	Lithium battery 5V

Basic layout of the Magnetorheological shoes



Possible applications

- Sport (running, basket, jump, etc..)
- Medical (shoes for diabetic, pronation, supination)
- Military
- Work Safety (low frequency attenuator)

Future Tasks

Short term

- Cushioning test
- Power system
- Control algorithms

Medium term

- Mathematical model of the shoes
- Fem Model of the shoes

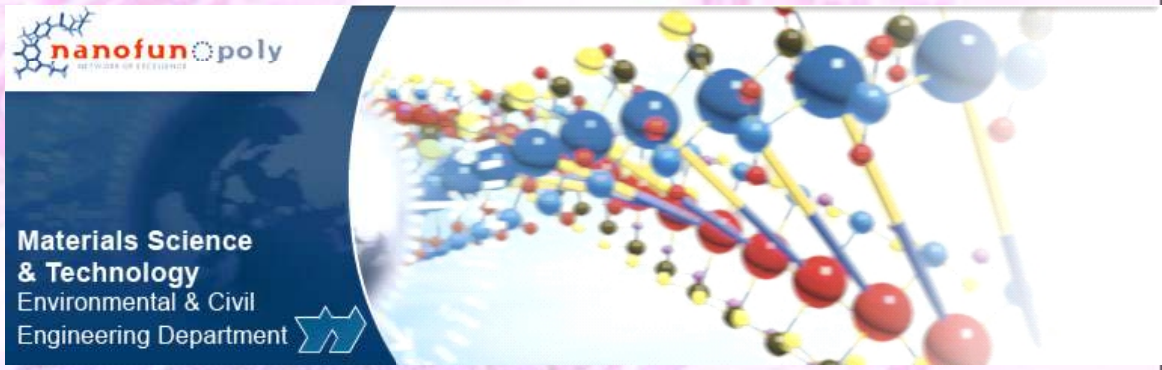
Long term

- Prototype

Aknowledgements

•Industrial Engineering Department, University of Perugia, Perugia (Italy)

•European Center of Nanostructured Polymers (ECNP), Material Science Department, University of Perugia, Terni (Italy)



•Grado Zero Espace s.r.l., Empoli (Italy)