



UNIVERSITÄT PADERBORN
Die Universität der Informationsgesellschaft

PIBRAC - Piezoelectrical Brake Actuator

Dr.-Ing. Norbert Fröhleke



SIXTH FRAMEWORK
PROGRAMME

EU-Projekt PIBRAC

Piezoelectric **BR**ake **AC**tuator



PIBRAC – Piezoelectric Brake Actator

- Motivation for actuator enabling direct drive braking
- Functional principle of multi-mass ultrasonic
- Power supply and control development

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Projektleitung,
Motorentwicklung



Teilprojektleitung,
Spezifikation, Tests

AIRBUS



Teilprojektleitung, Brems-
systeme, Spezifikation, Tests



Teilprojektleitung,
Reibschichtentwicklung



Entwicklung Leistungselektronik,
Modellierung und Regelung



Herstellen Piezokeramiken



Materialtests,
Ermüdungsuntersuchungen



FEA-Modellierung für
Validierung und Design



Produktion mechanischer
Teile, Prototypenbau

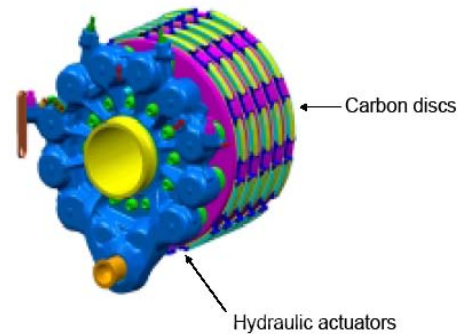
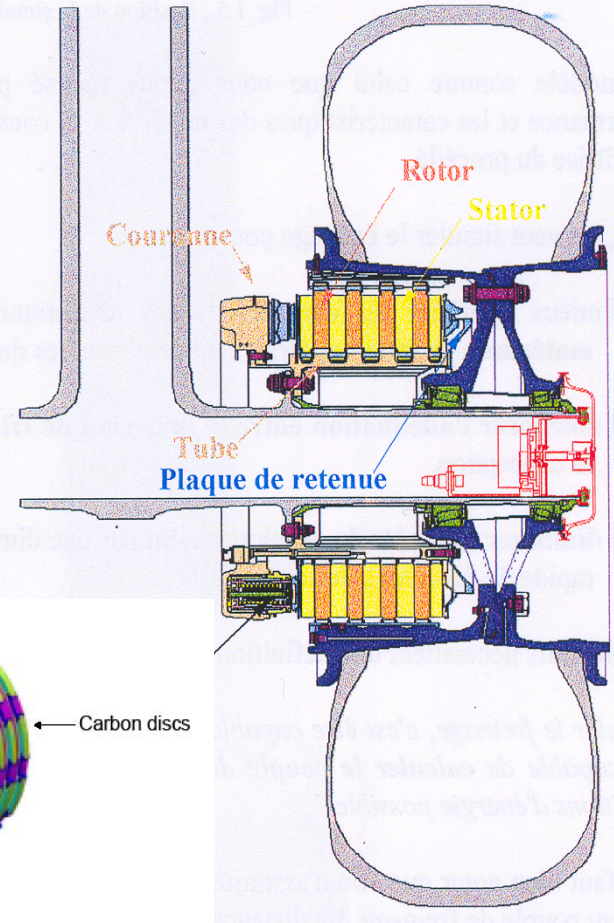


Materialtests, Simulation,
Prototypintegration

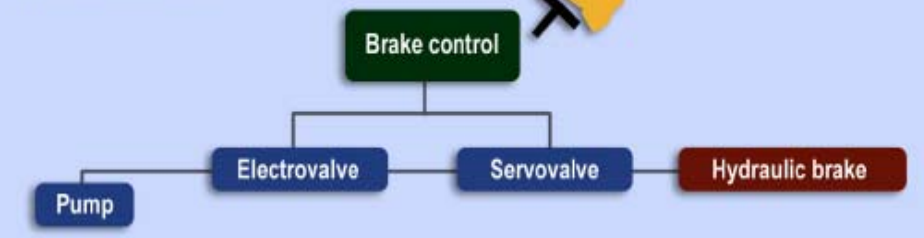


Beschichten der Reibschicht

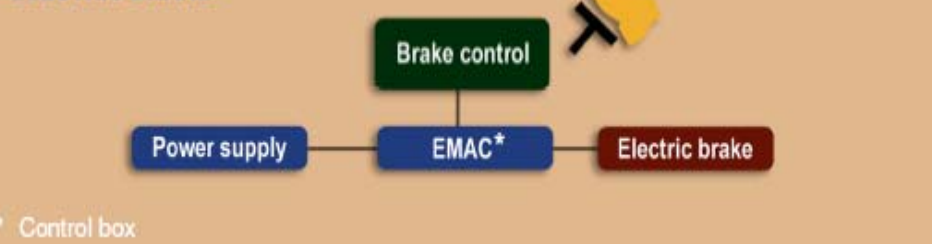
Current Aircraft Brake Actuator



HYDRAULIC BRAKE



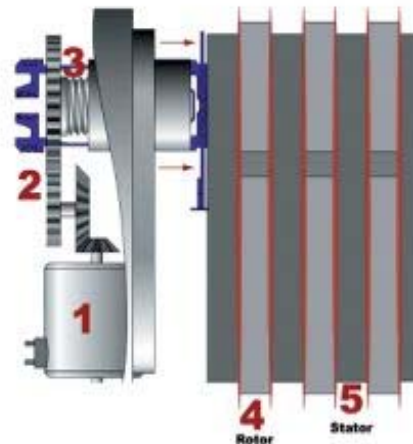
ELECTRIC BRAKE

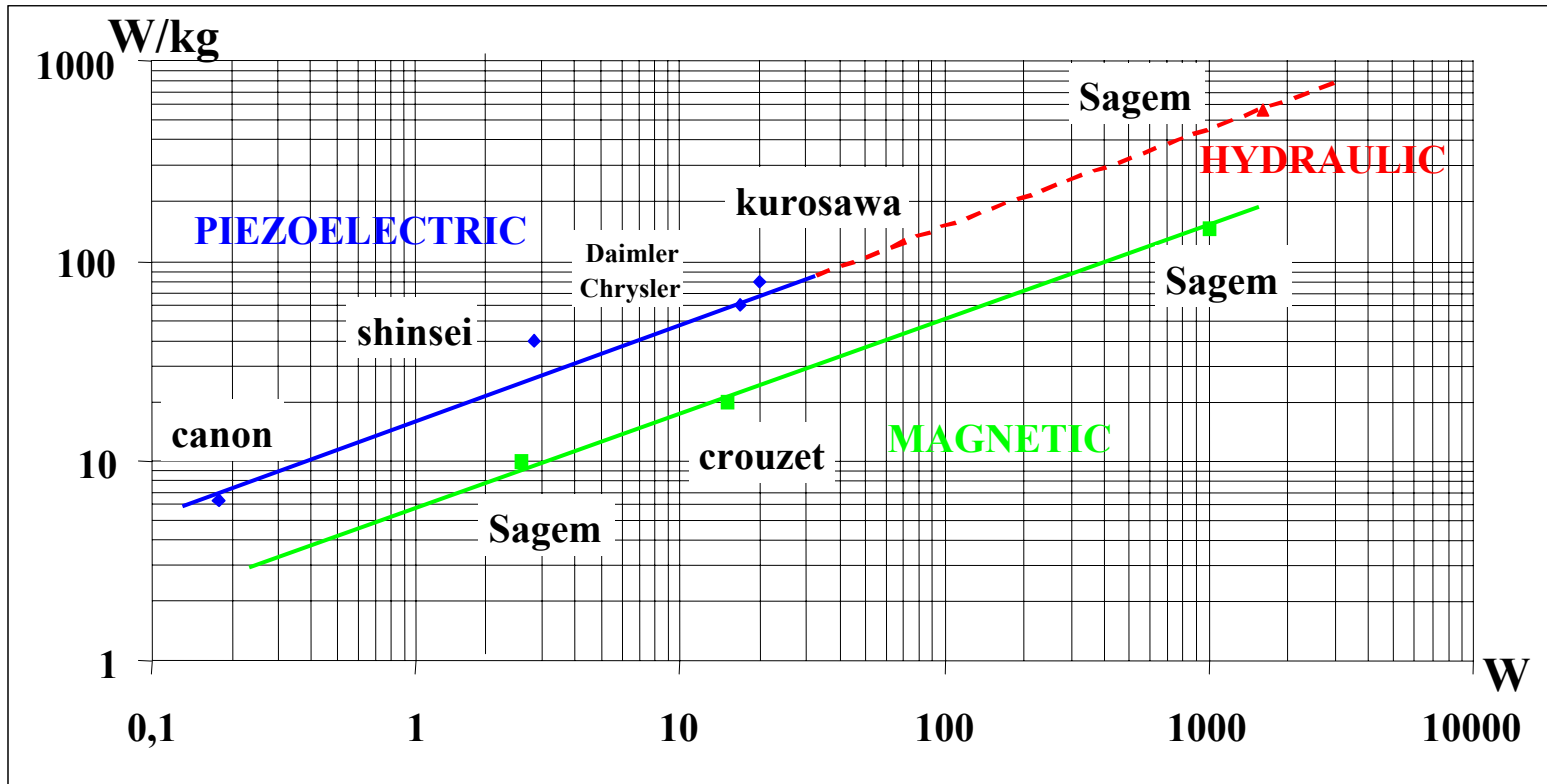

















Advantages by „full electrical” aircraft:

- Reduction in volume and weight
- Increase in reliability and operating safety
- Reduction costs for operation and maintenance

1. Electric motor
2. Transmission
3. Bullet thread
4. Rotor disc from carbon
5. Stator disc from carbon

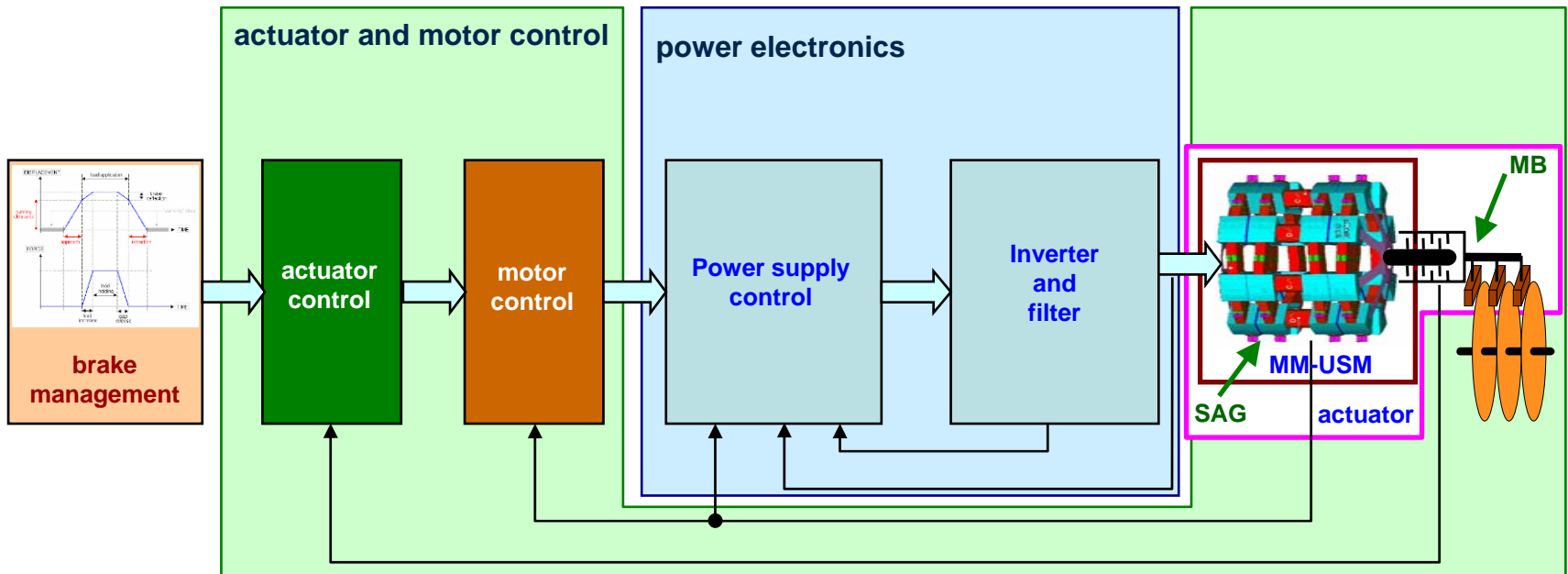
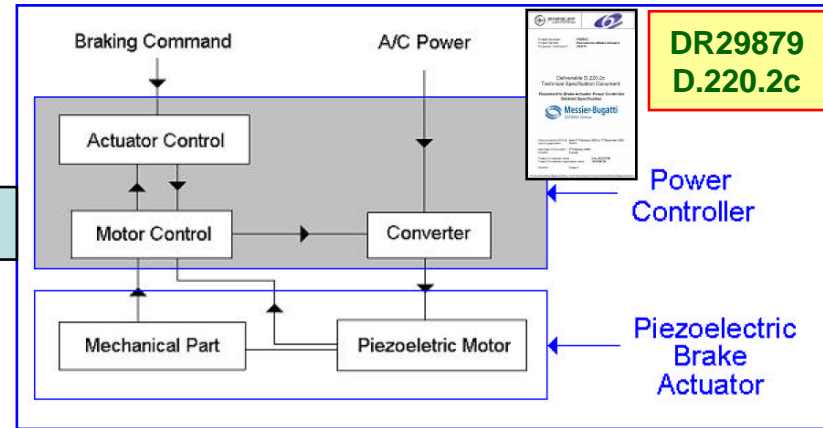




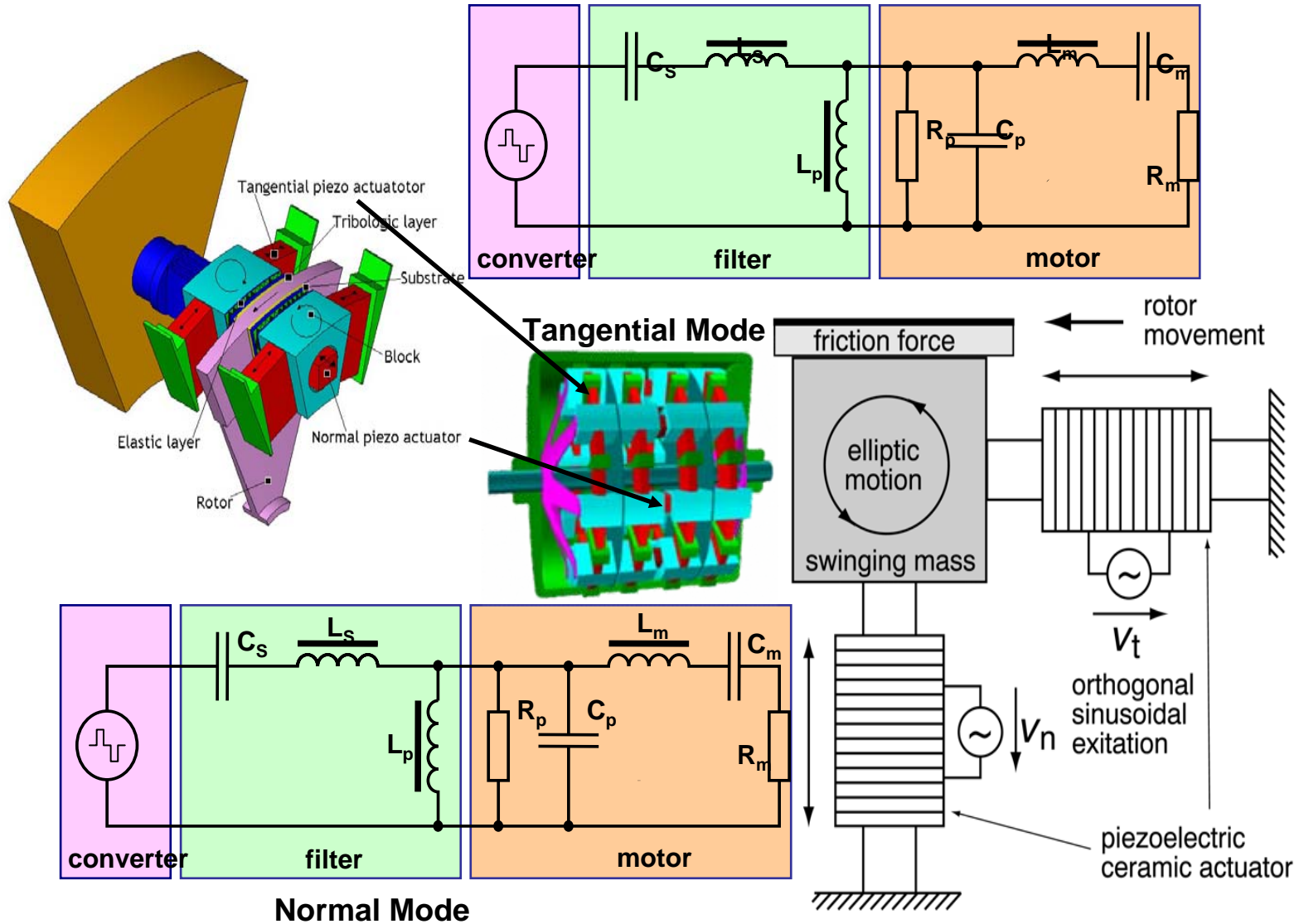
	Hydraulic	Electromagnetic	Piezoelectric (Expected)
Masse			
Inertia			
Peak power demand			
Maintenance			
Environment & Fire risk			

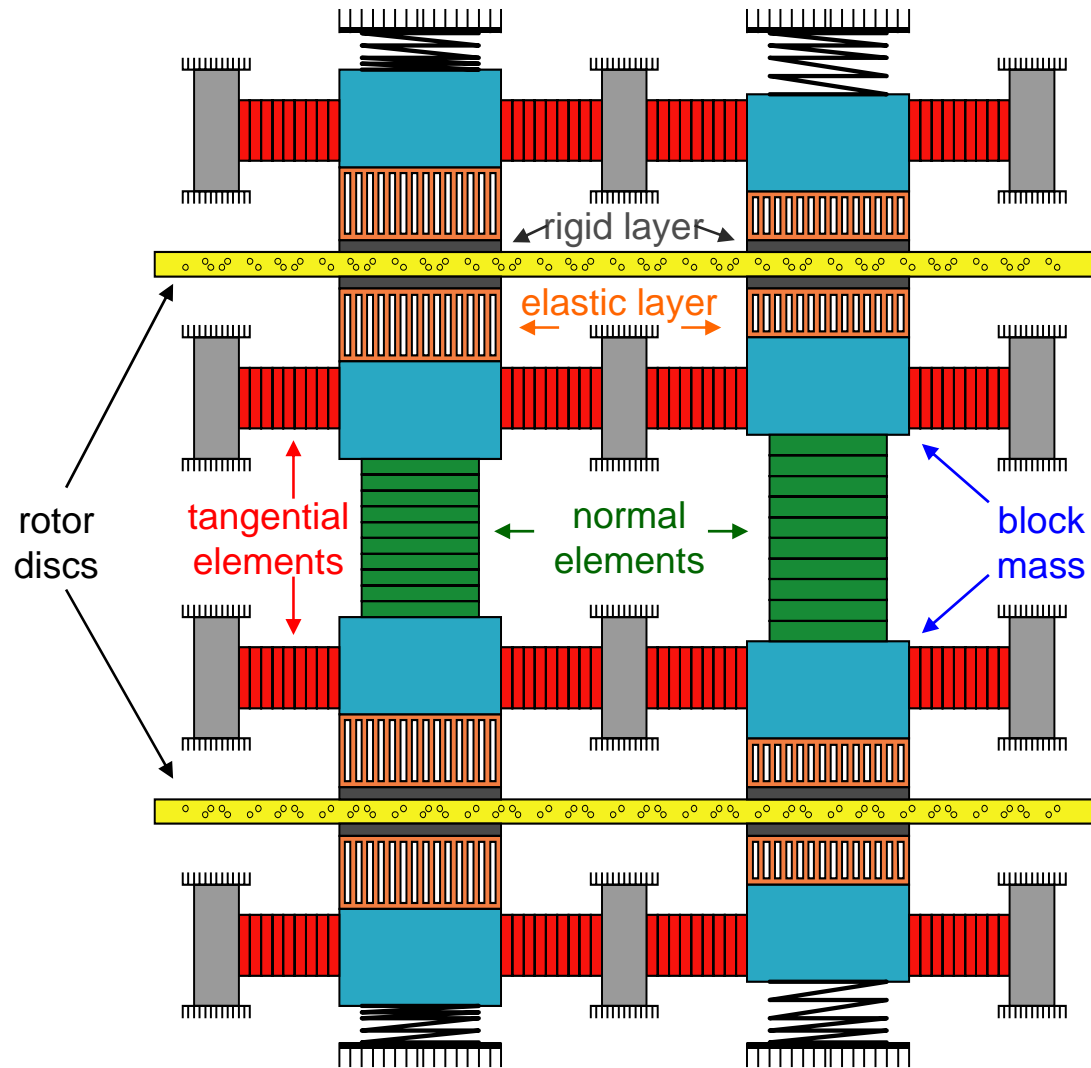
Objectives:

Development of power supply and control architecture for Piezo Brake Actuator with a multi mass ultrasonic motor (MM-USM)

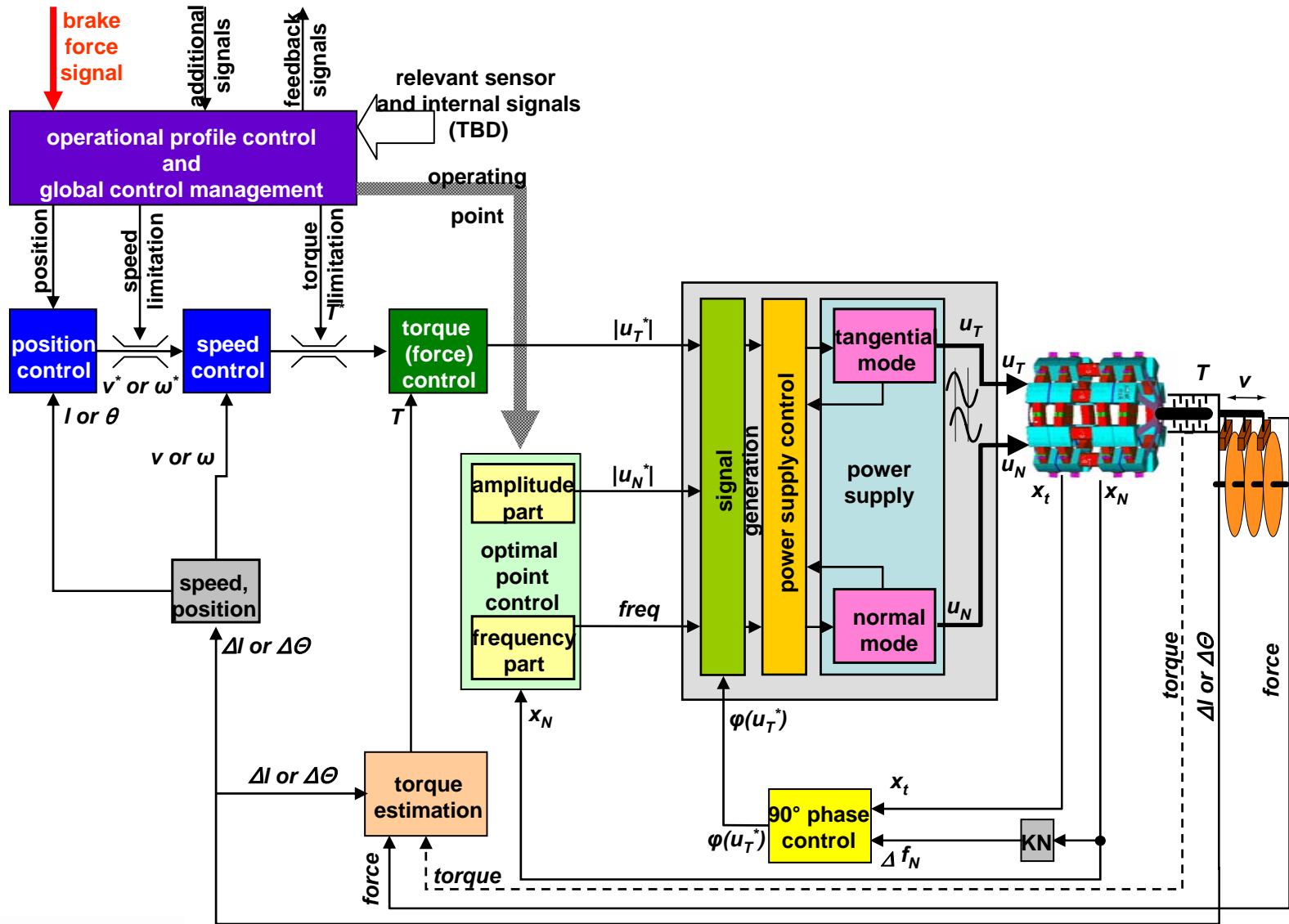


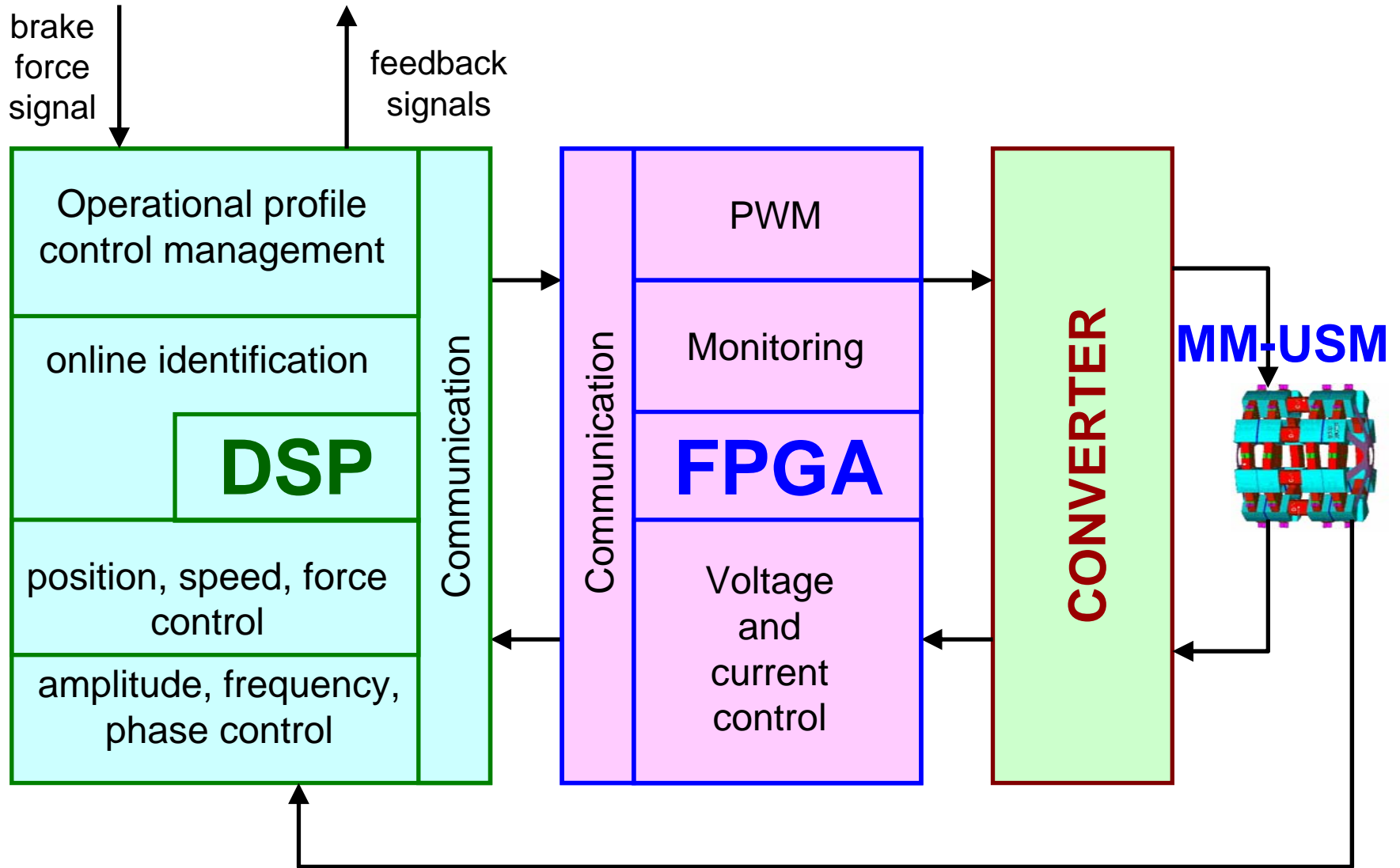
Operating Principle of MM-USM

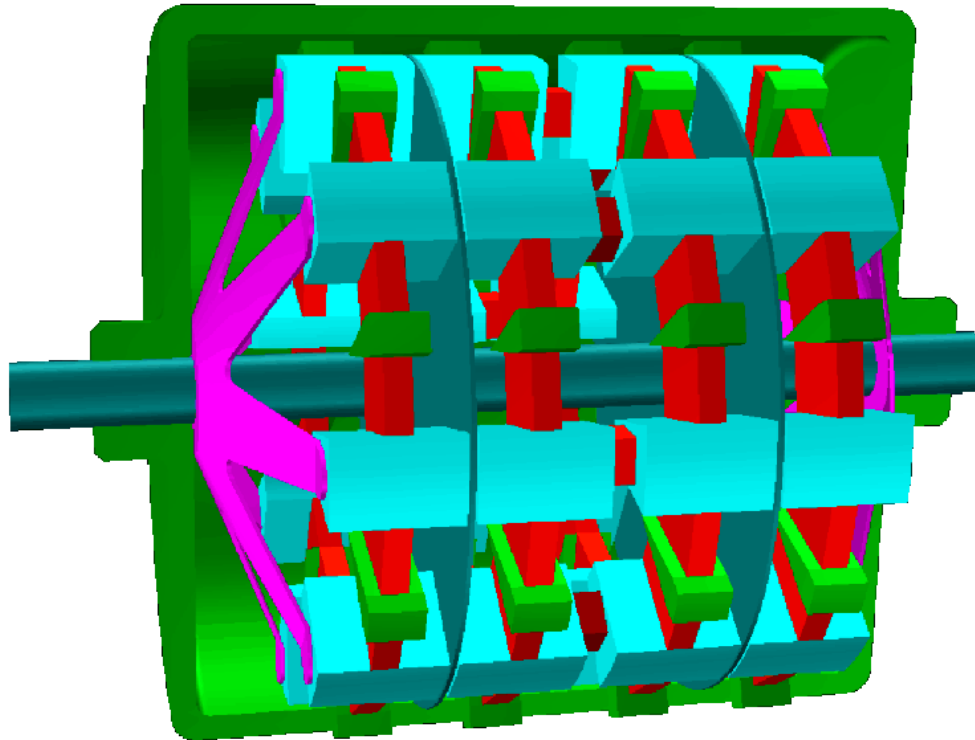


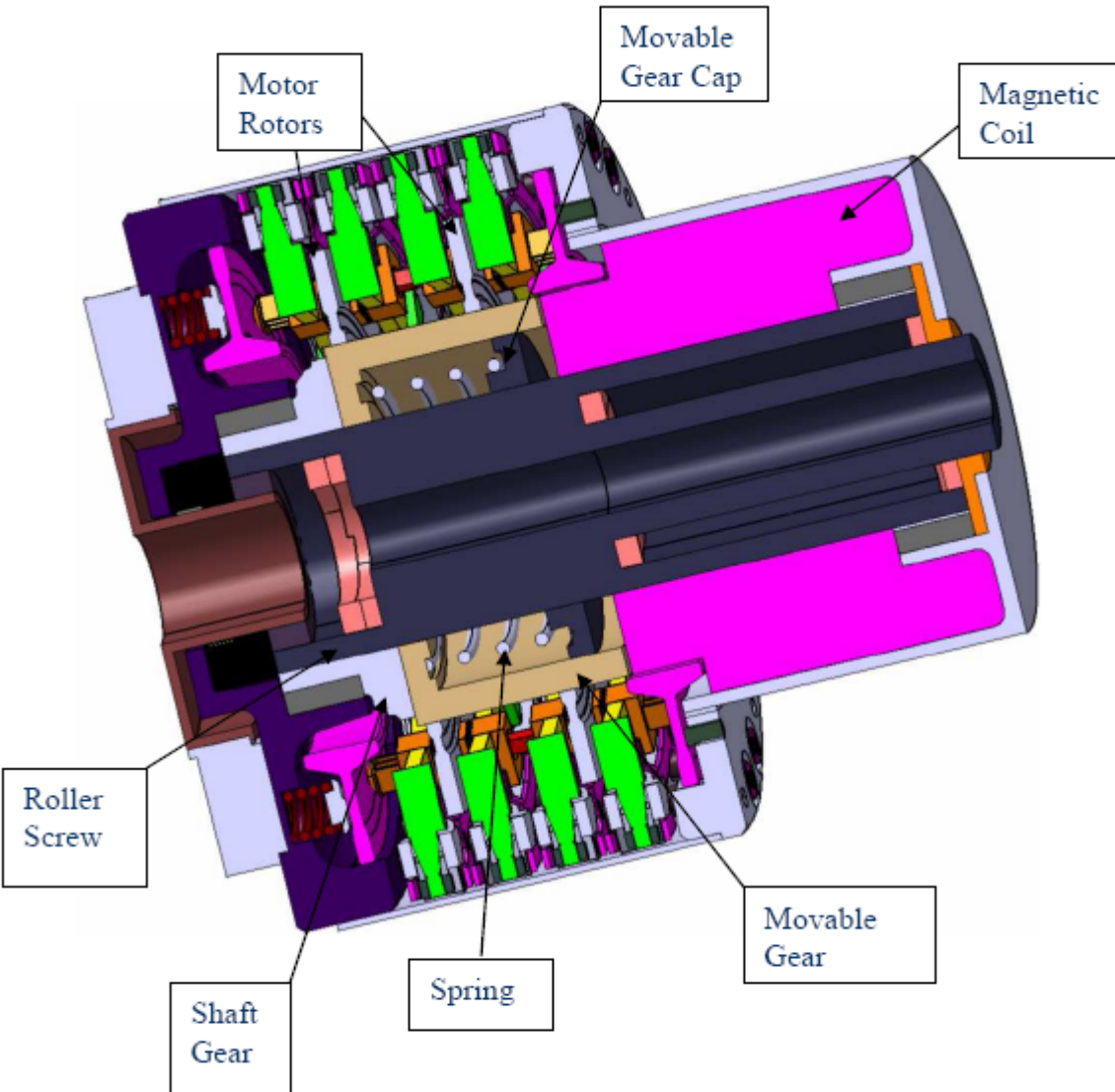


Proposed Control Strategy for PIBRAC Motor



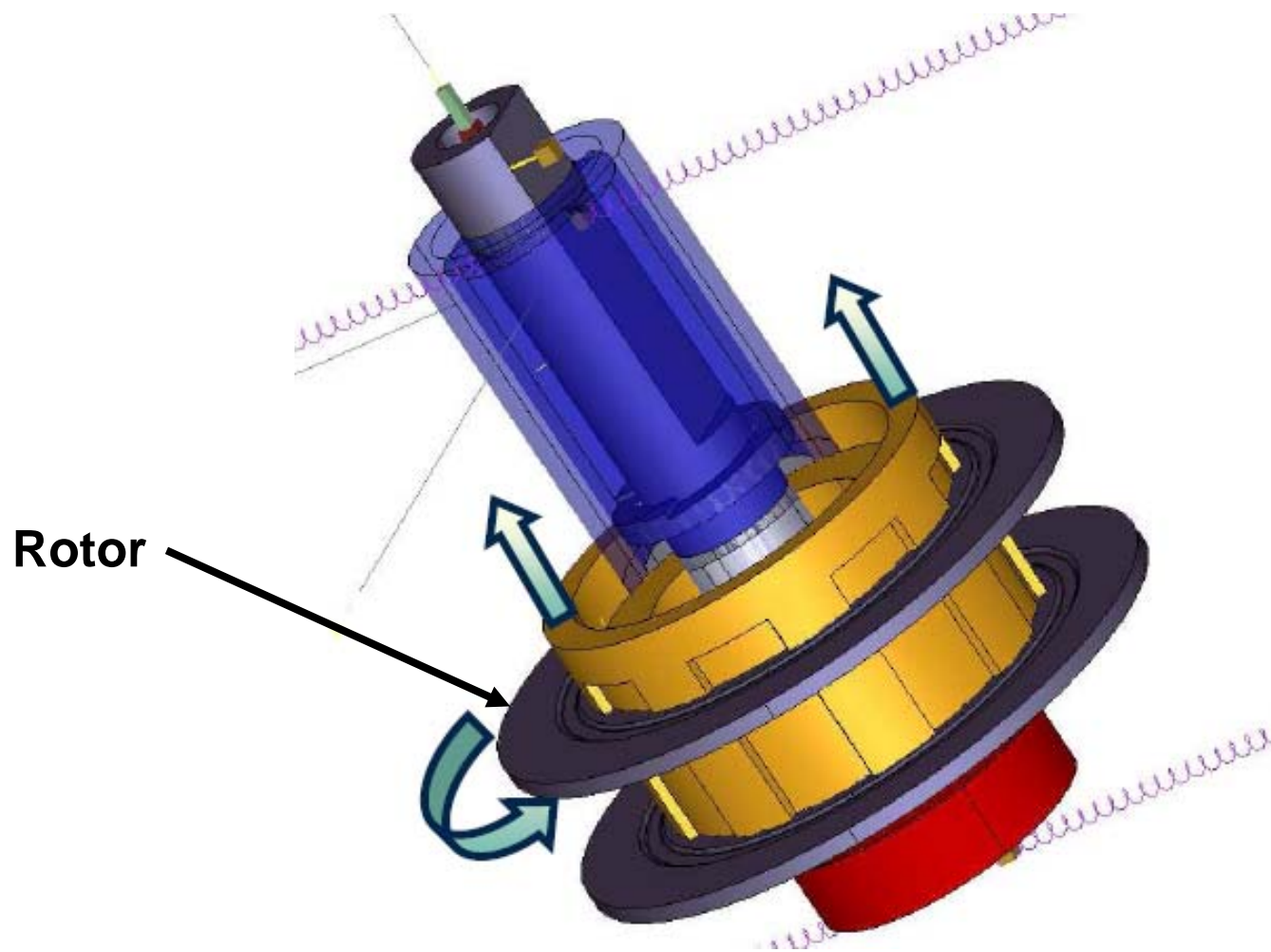




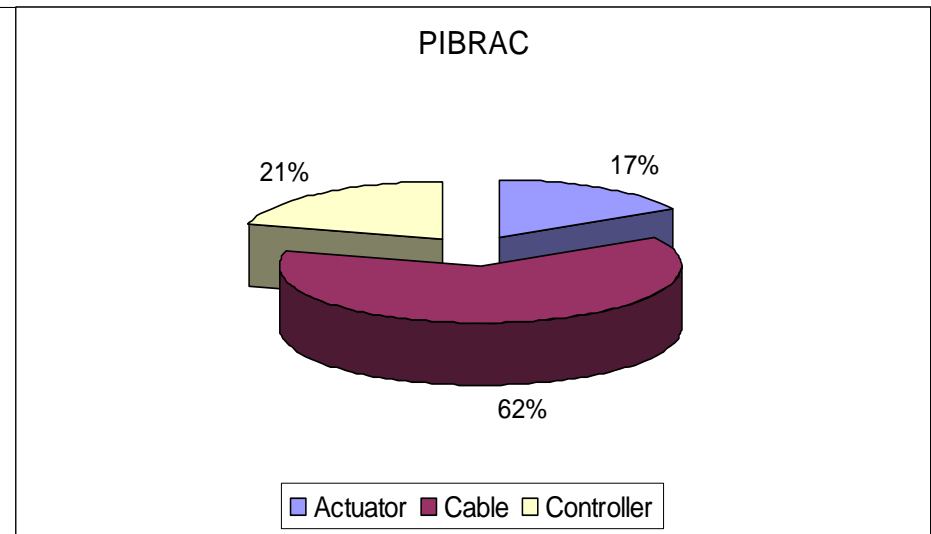
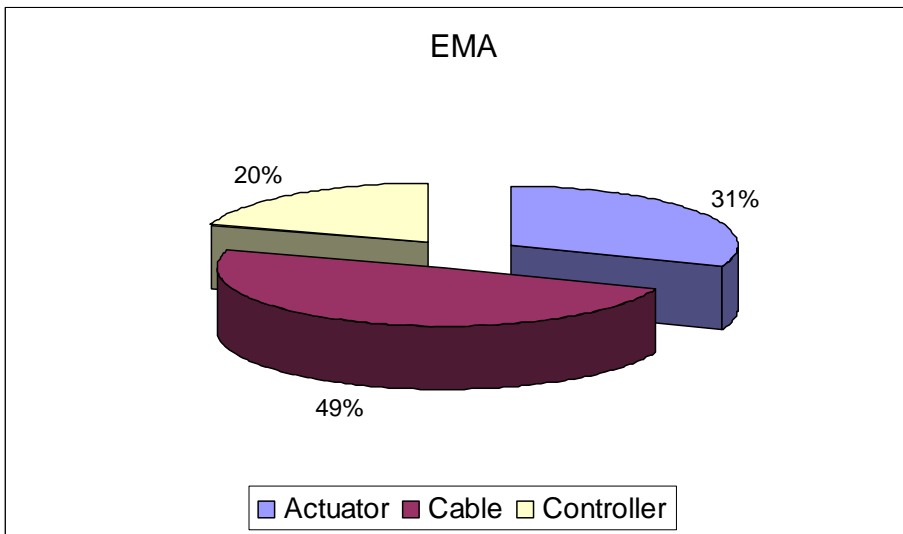


Motor (including ist housing)	800g
Roller screw	372g
Thrust bearing	37g
Needle bearings (x2)	139g
Actuator Housing	400g
Clutch	279g
TOTAL	2027g

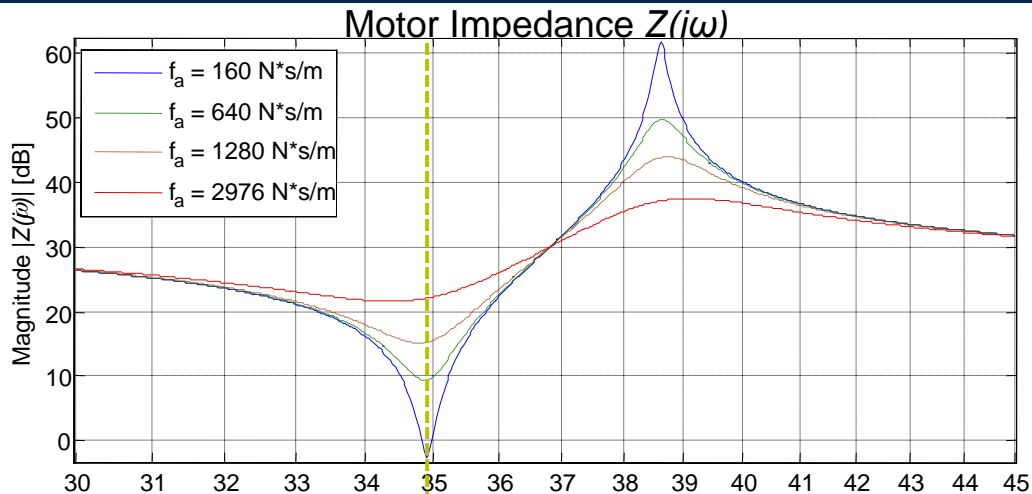
Max. diameter	113mm
Motor min. diameter	74mm
Length	123mm



Component	EMA			PIBRAC		
	Weight	Quality	Total weight	Weight	Quality	Total weight
Actuator	4kg	16	64Kg	2,1kg	16	33,6kg
Cable	100kg	1	100kg	126kg	1	126kg
Controller	10,5kg	4	42kg	10,5kg	4	42kg
Total			206kg			202kg

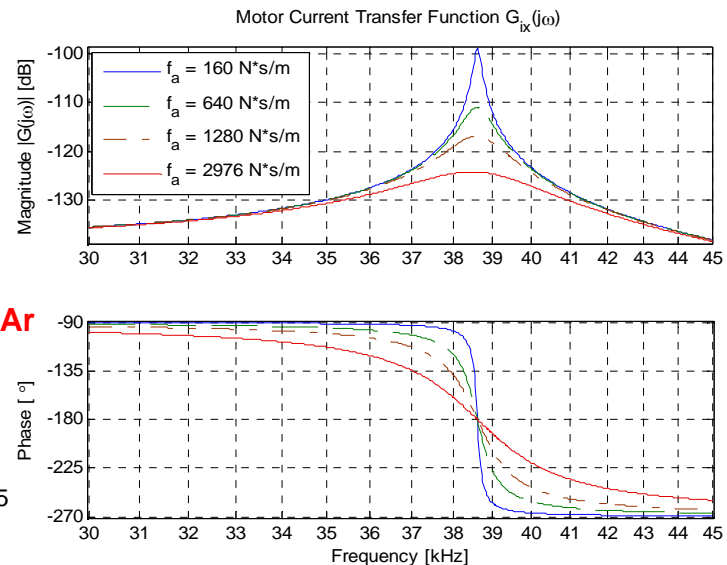
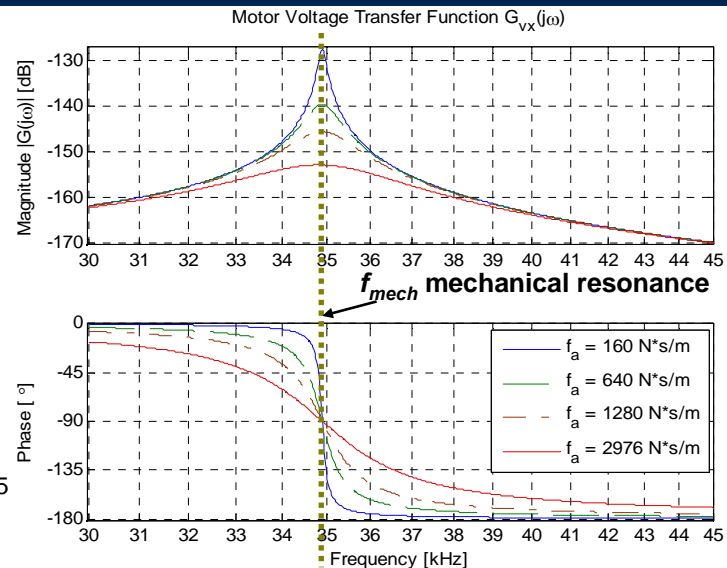
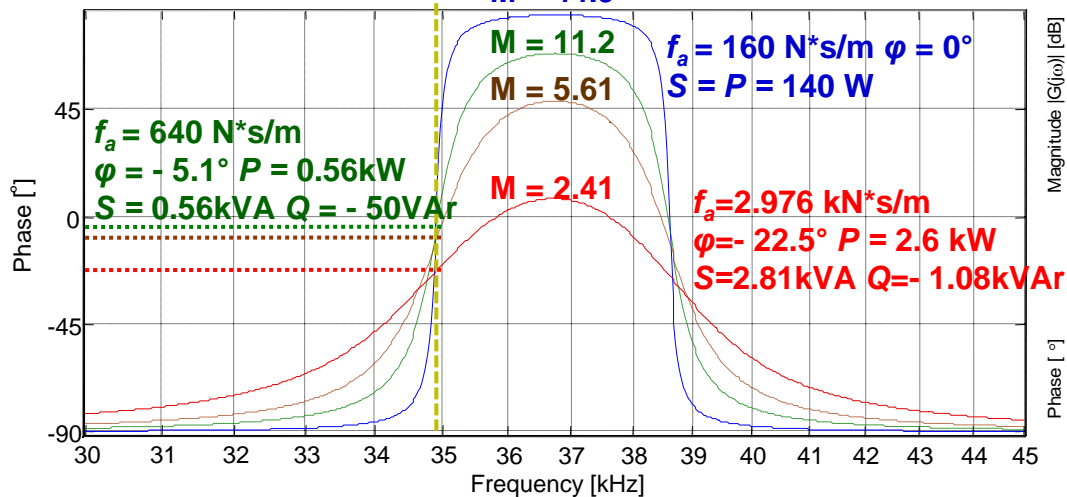


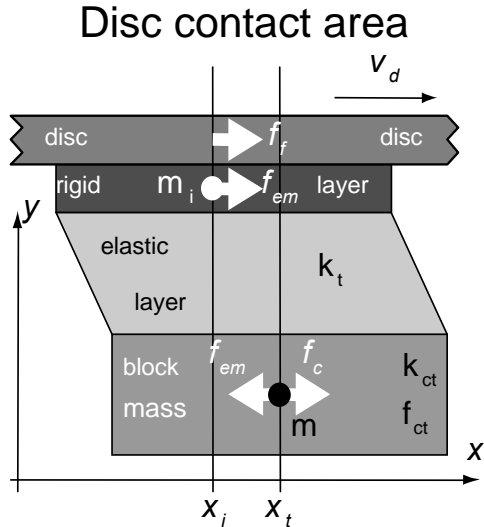
Load Variation for MM-USM



$f_a = 1.28 \text{ kN*s/m}$
 $\varphi = -10.1^\circ$ $P = 1.12 \text{ kW}$
 $S = 1.14 \text{ kVA}$ $Q = -199 \text{ VAR}$

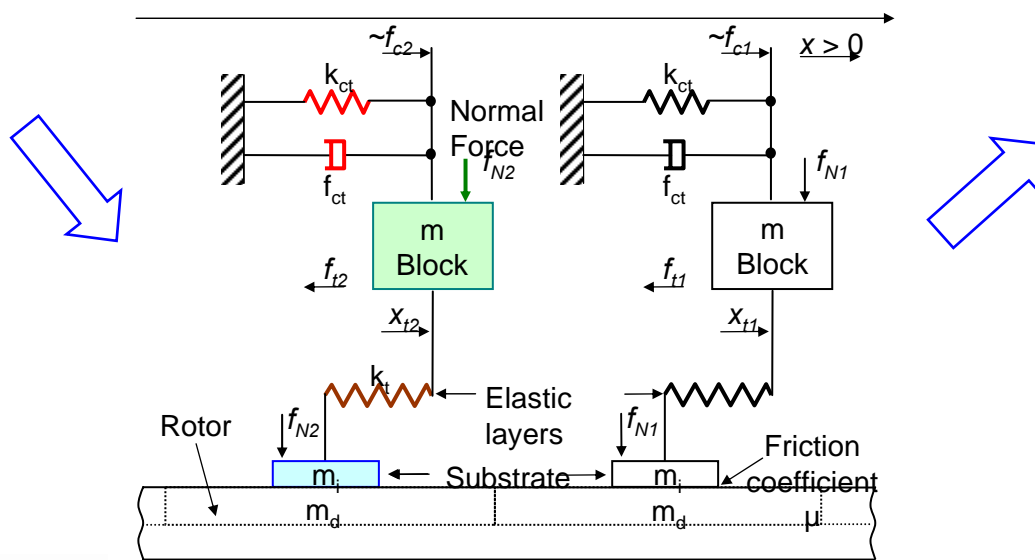
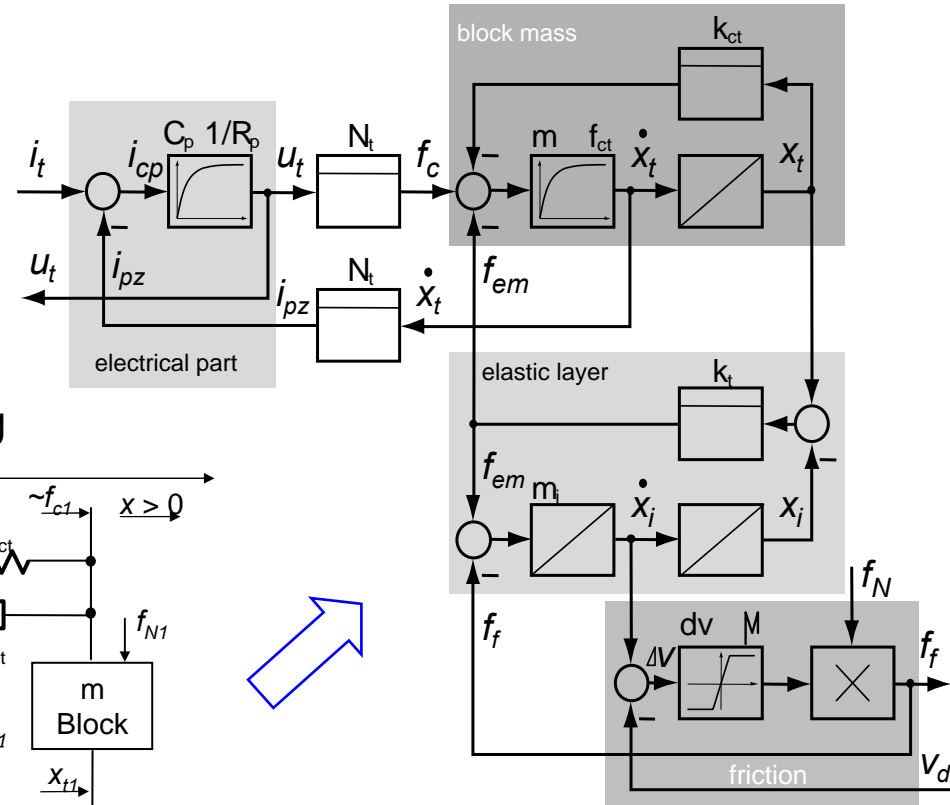
f_{mech} mechanical resonance
 $M = 44.9$





Mechanical Modelling

Generalized motor model



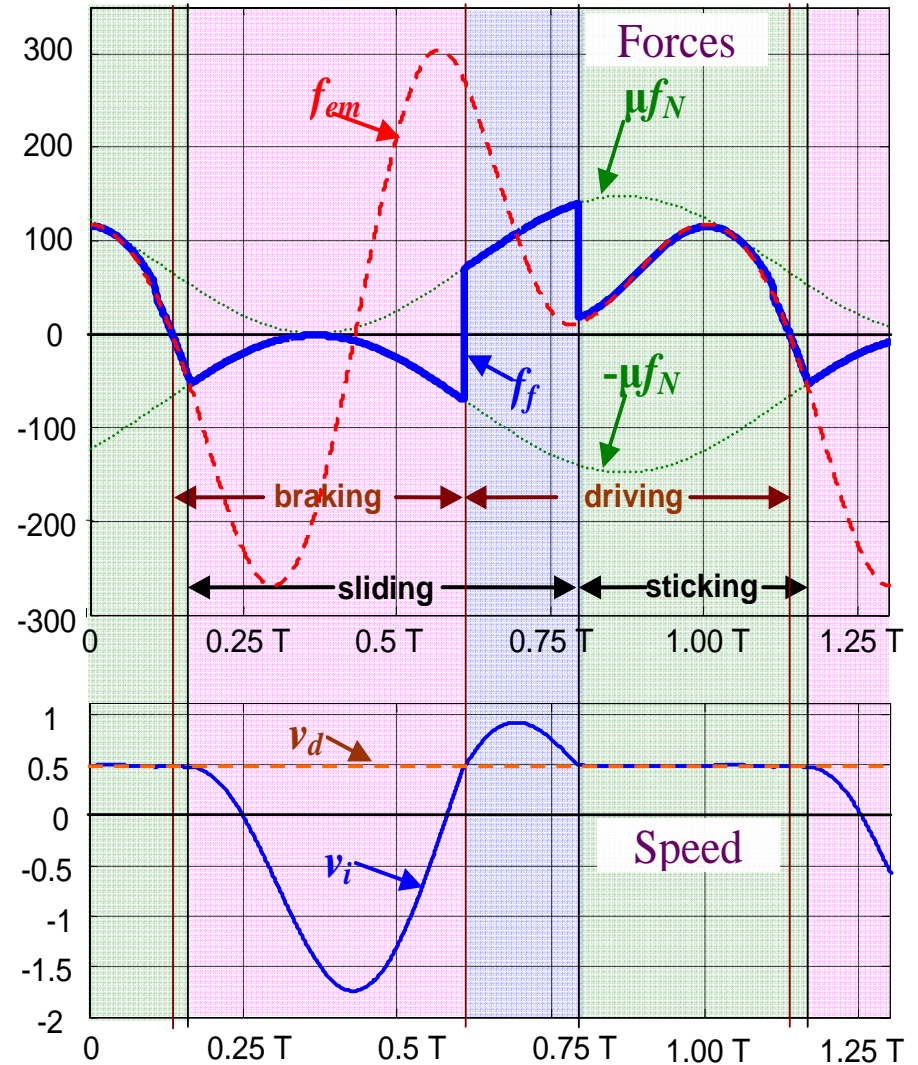
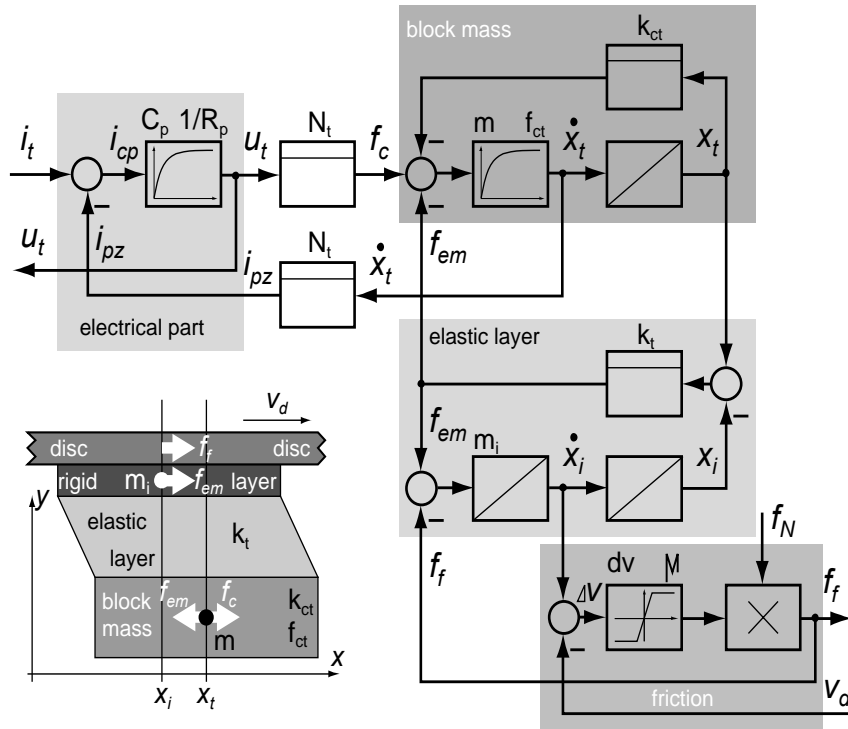
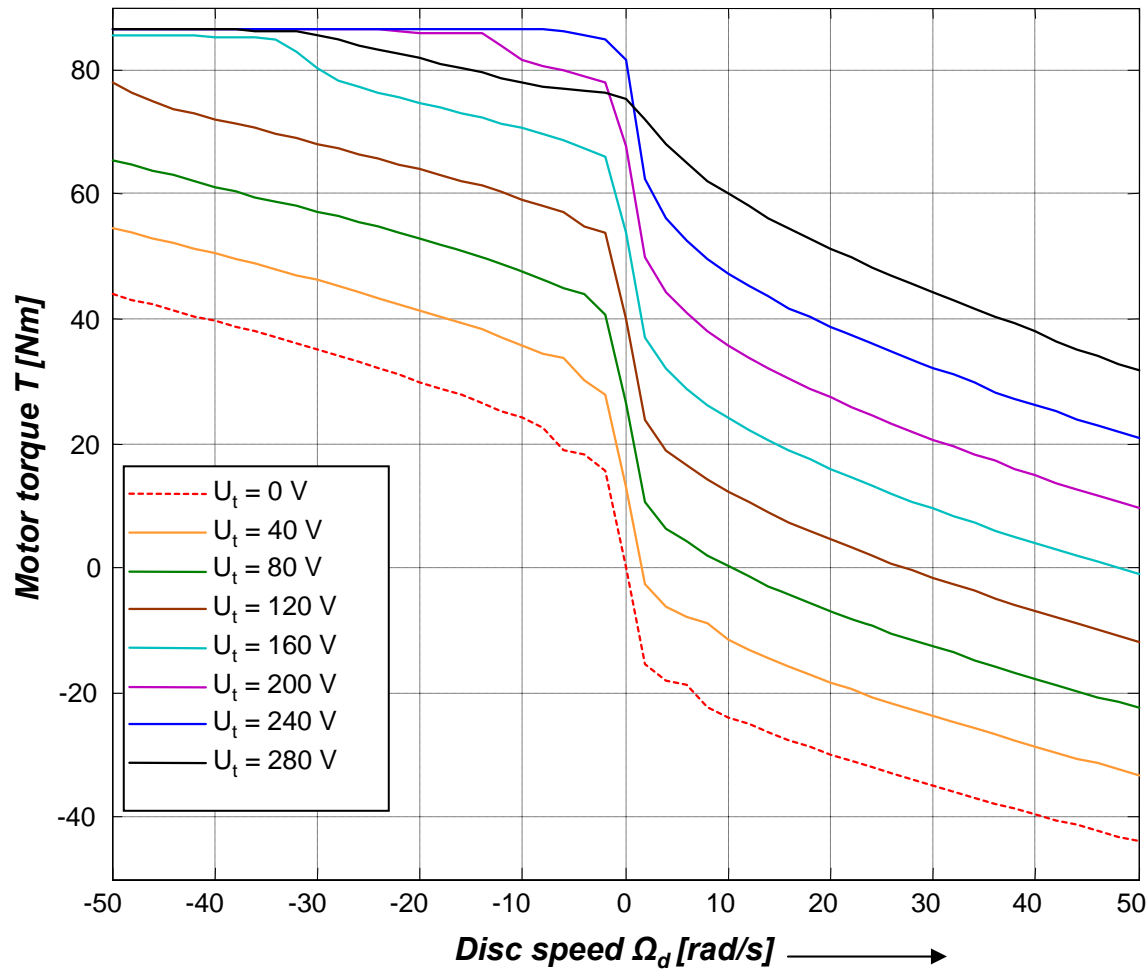
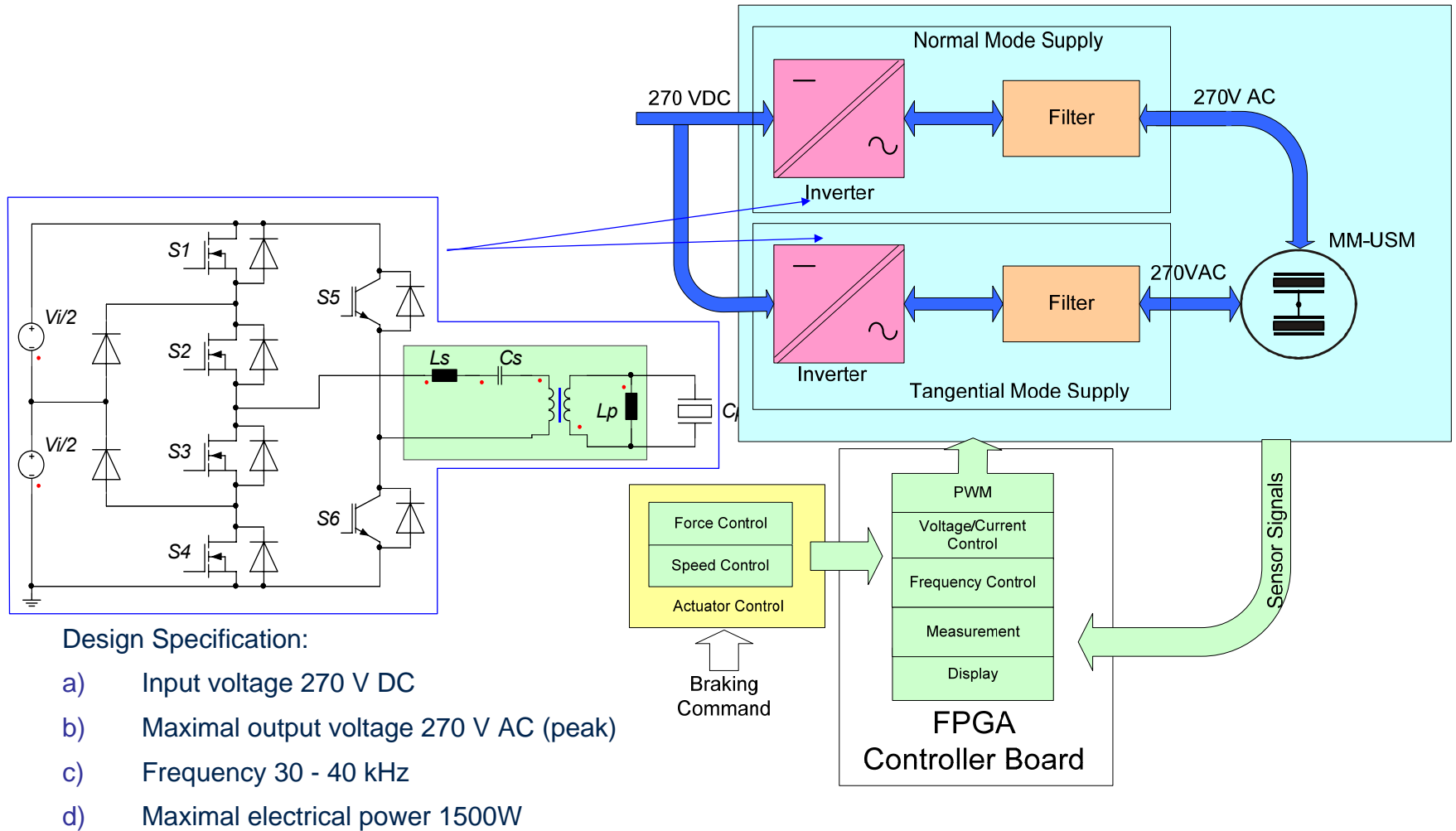
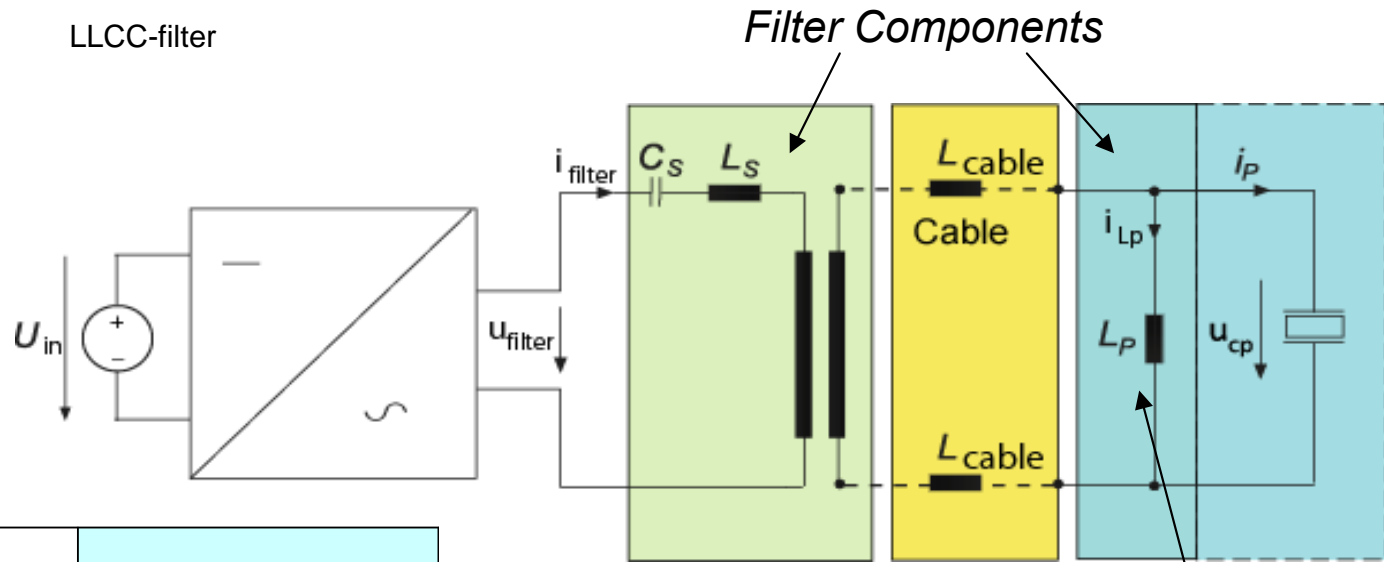


Fig. 1 MM-USM friction modes



Power Electronics and Control



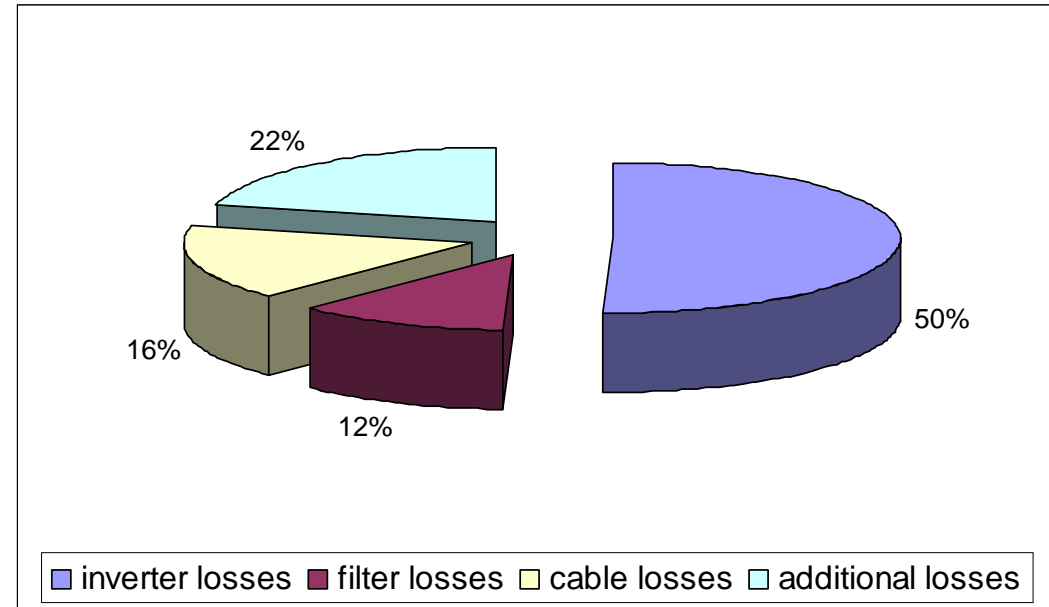


Components of power supply	Parameters
Inverter	So = 9.4 kVA Po = 9 kW
	Efficiency: 97.5%
	Weight : 4 kg
Filter	Weight : 5 kg
Case	Weight: 1.5 kg
Sum	Weight: 10.5 kg

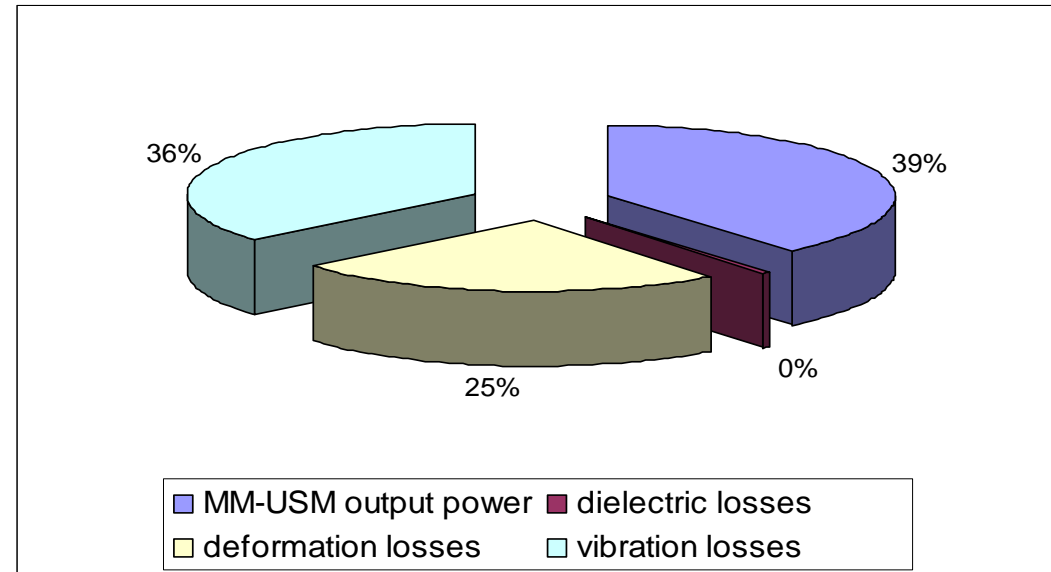
L_p Integrated in Actuator

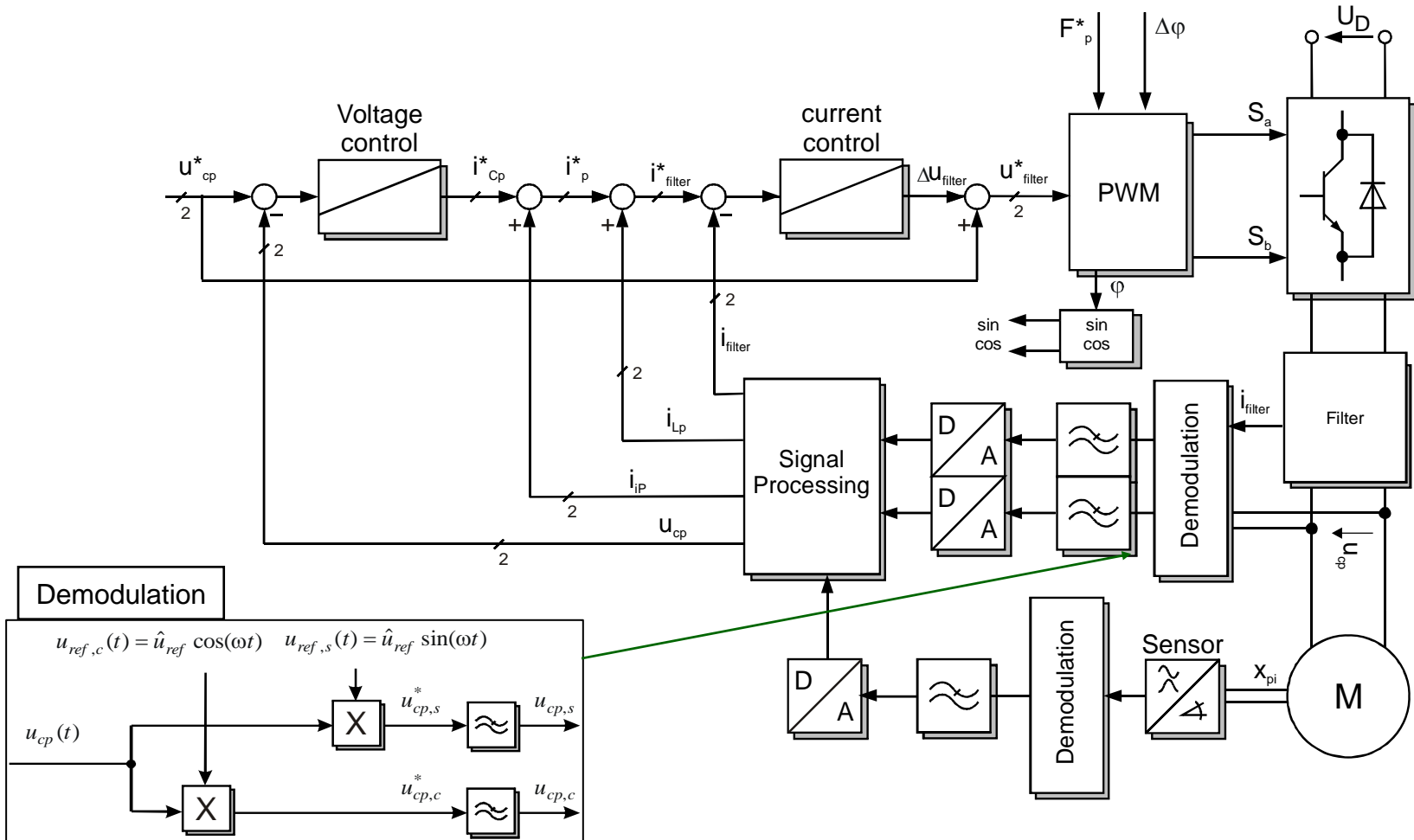
Parameters of L_p per 1 actuator
 172 μH
 Dim.: 42*21*15 mm³
 weight: 250 g
 Losses: 3 W

Power supply output power at full load	1500W
Losses	
Inverter losses	47W
Filter losses	11W
Cable losses	15W
Additional losses	20W
Total power supply losses	93W
Efficiency	93,8%

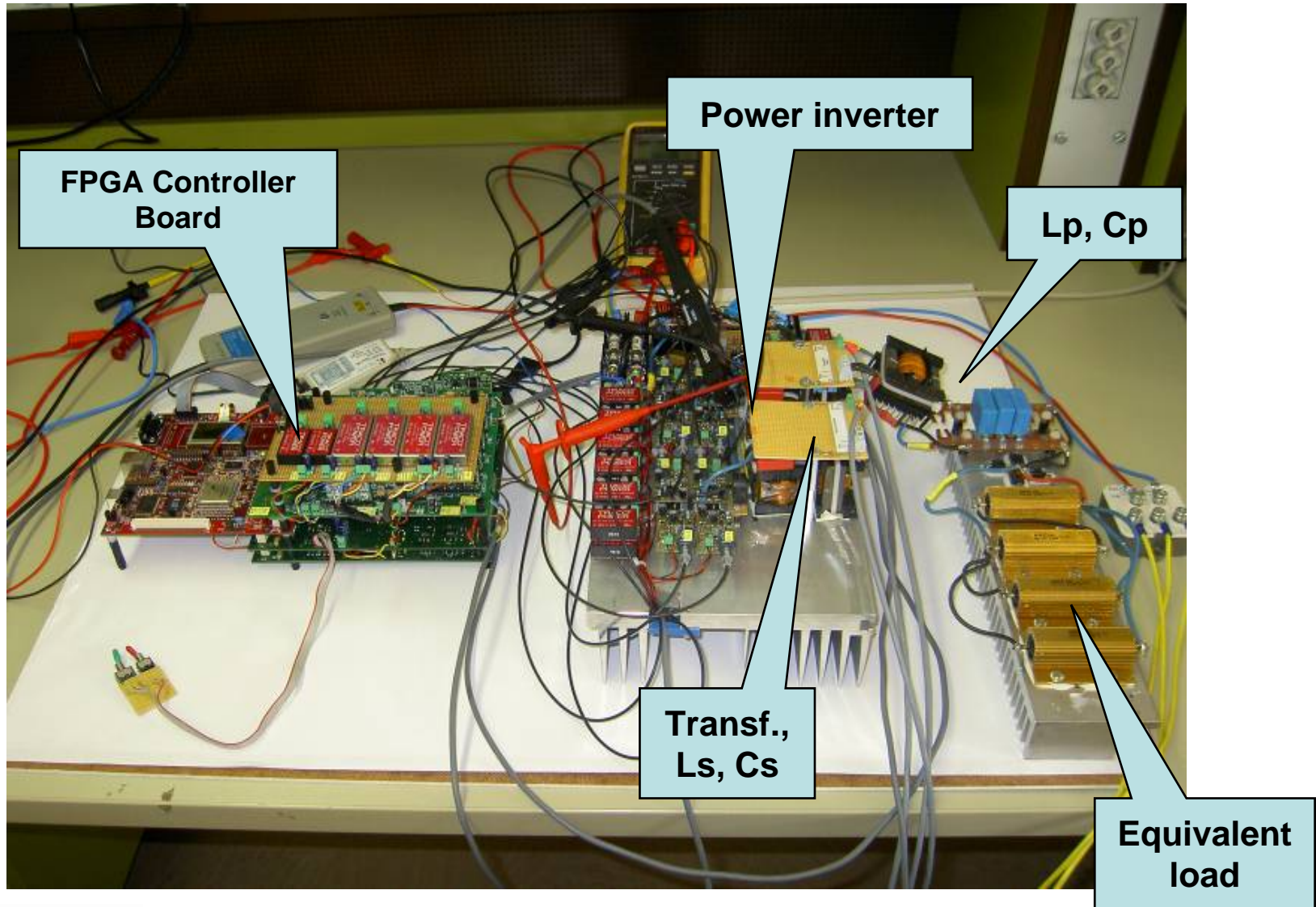


MM-USM output power	550W
Losses	
Dielectric losses	5W
Deformation losses	347W
Vibration losses	508W
Total power supply losses	860W
Required electrical power	1410W
Efficiency	39,0%





Cascade Voltage and Current Control Scheme



	EMA	PIBRAC
Steady-State Section		
Converter efficiency	0	0
Motor efficiency	+	-
Mechanical efficiency	0	0
Dynamic Section		
Inertia	-	+
Ways of improvement section		
No lubricant	-	+
Conclusion		
	???	???

Thank you for your attention !