Th. Rödig, A. Schönecker, L. Seffner,

W.-G. Drossel, H.-J. Roscher, Kunze, H.

New modular piezo actuator with built-in stress-strain transformation

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IC MecPro

Innovation Cluster Mechatronic Machine Systems Chemnitz

Partners: **Fraunhofer Institutes**

for Machine Tools and Forming Technology **IWU**, Chemnitz/Dresden

for Ceramic Technologies and Systems **IKTS**, Dresden

Goal: Combining competences of 2 Fraunhofer Institutes
Sheet metal forming
Piezoceramics

ACKNOWLEDGEMENTS The work was supported by the Fraunhofer Gesellschaft

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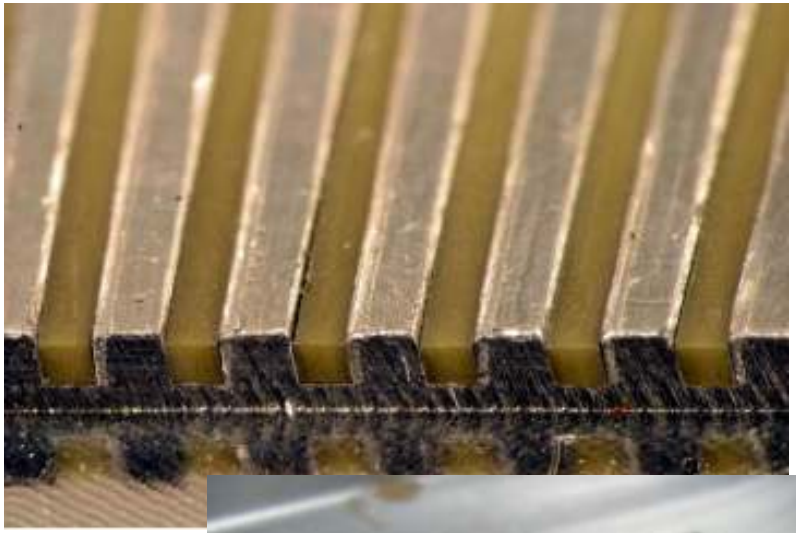
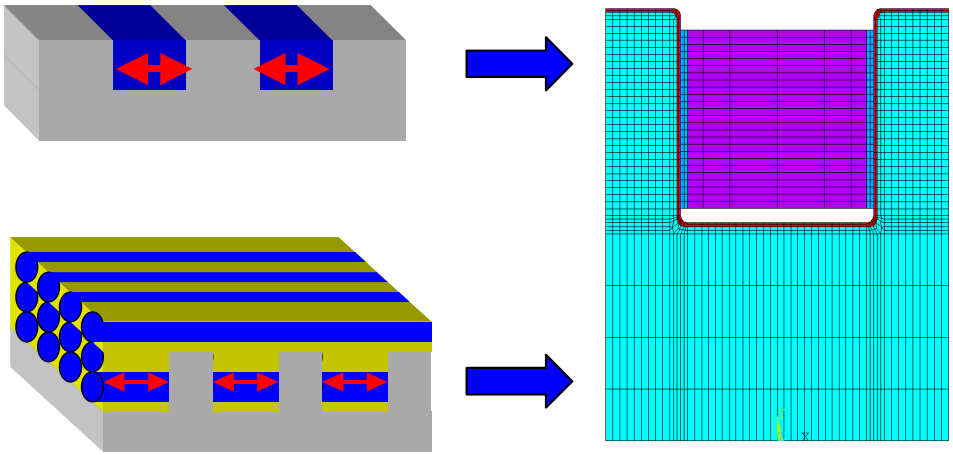
New modular piezo actuator with built-in stress-strain transformation

Transregional Collaborative Research Centre 39 PT-PIESA

"**P**roduction **T**echnologies
for light metal and fiber
reinforced composite based components
with integrated **PIE**zoceramic **S**ensors
and **A**ctuators"





New modular piezo actuator with built-in stress-strain transformation

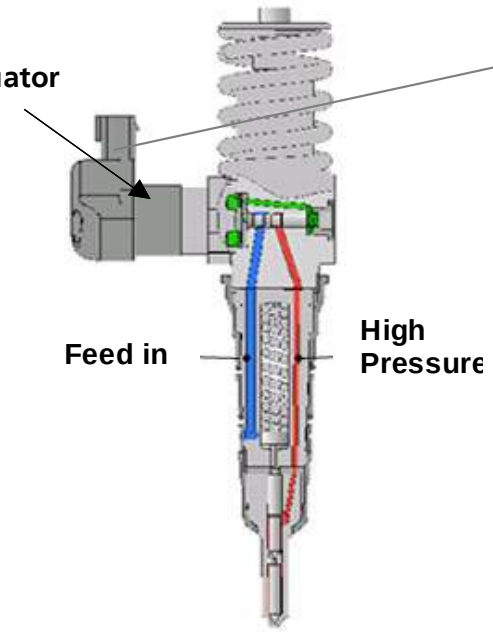
Content

1. Motivation
2. Design and preparation of actuators
3. Construction of a modular actuator system
4. Summary and Outlook

Motivation

Pump-Injector-System

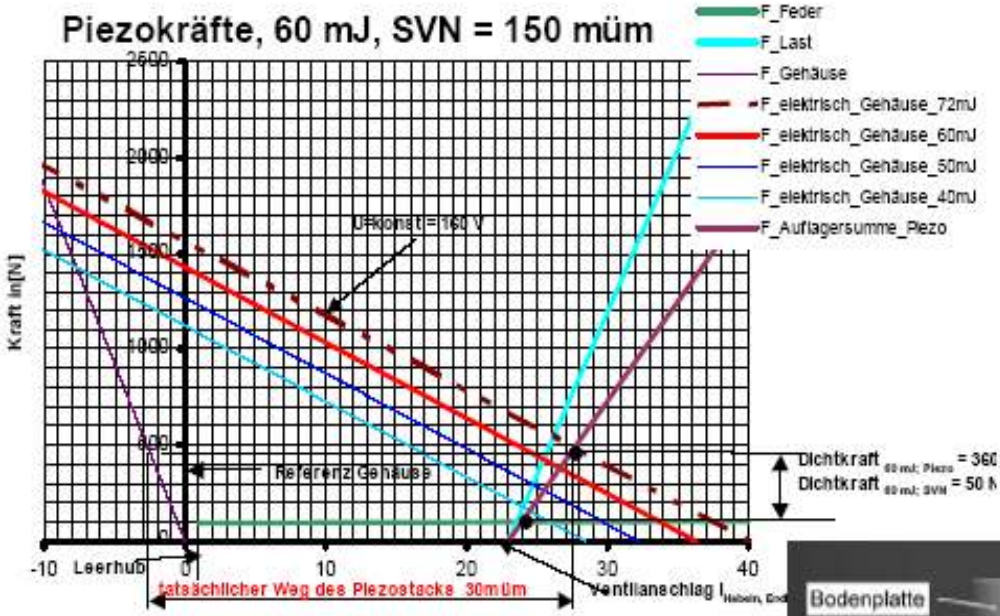
•direct injection into the cylinder,
•high injection pressures,
•low consumption,
•a lot of noise



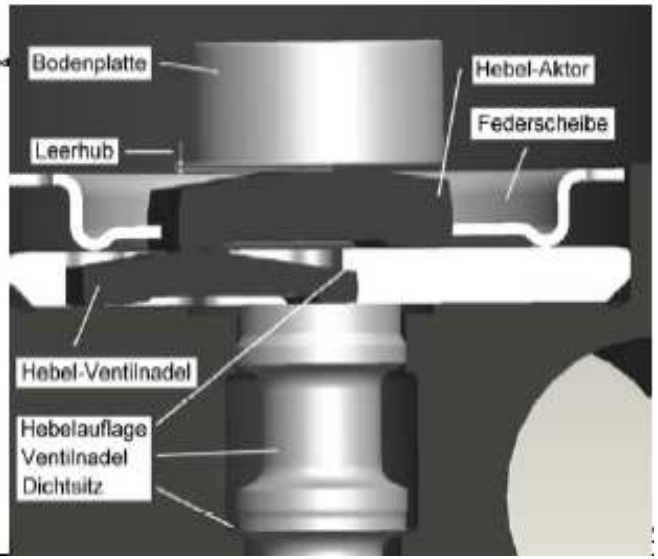
Piezo-pump-injector-technology
with mechanical leverage of stroke

Piezo stack actuator for
Piezo-pump-injector-technology

Source: Volkswagen-Mechatronic

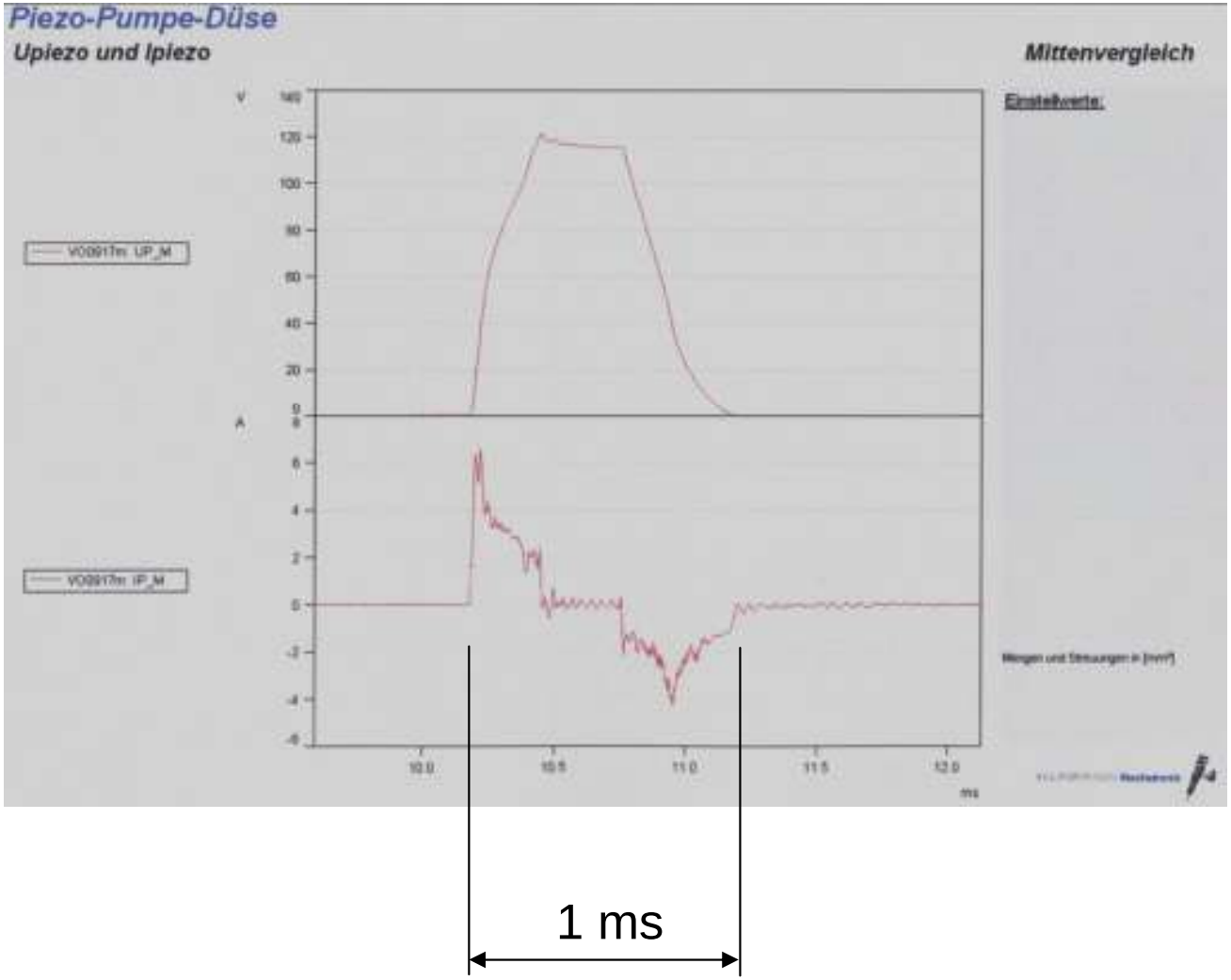


Source: Volkswagen-Mechatronic



values for leverage : ü =1/6,8

Source: Volkswagen-Mechatronic



New modular piezo actuator with built-in stress-strain transformation

Requirements

- small number of component parts
- light weight
- simple producibility
- low costs

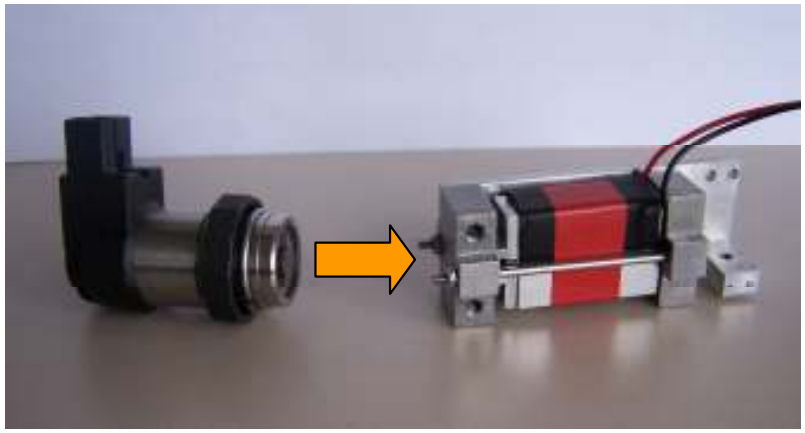
$h_{max} = 200\ \mu m$
$F_{max} = 200\ N$

$t_P < 1\ ms$

max.
scale: 20x20x30 mm³

Modular System

Idea:



Actuator system with built in stress-strain transformation

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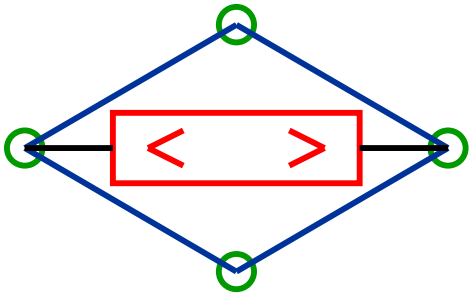
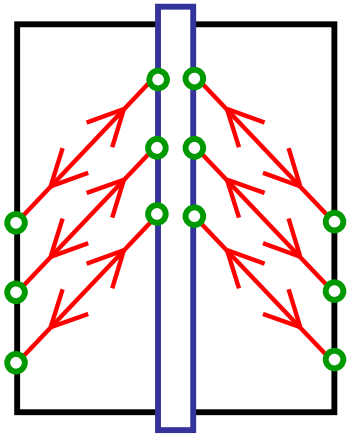
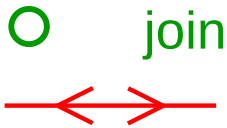
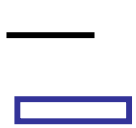
Design and preparation of actuators

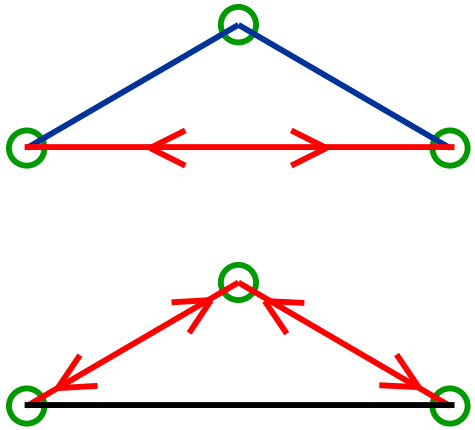
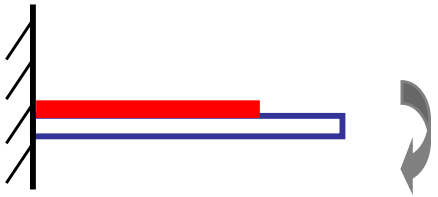
active component lumped	active component shared
	

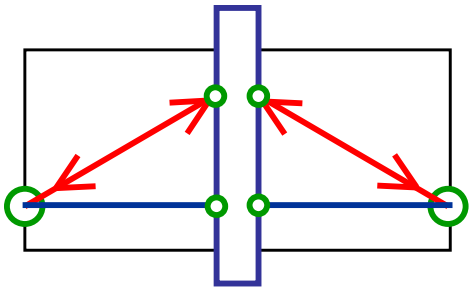
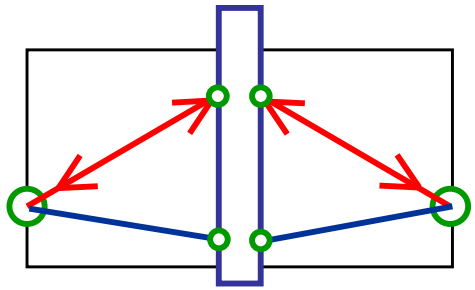

joint

active (piezo) component


case, fixed point

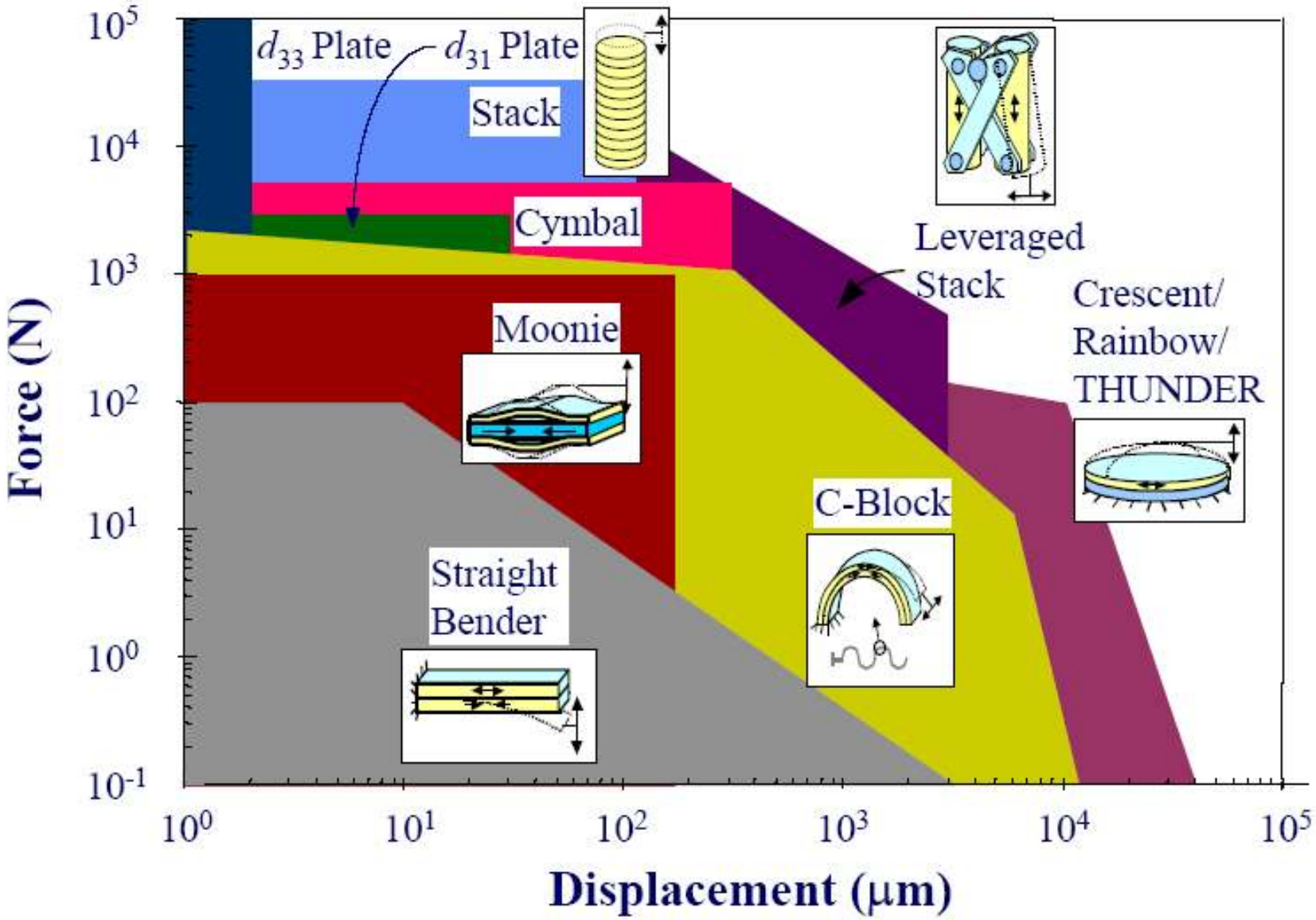
transmission

transformation of stroke linear	transformation of stroke nonlinear
	

kinesic behaviour linear	kinesic behaviour nonlinear (snap effekt)
	

joint — case, fixed point

active (piezo) component — transmission



Source: Brei, D.

VW TDI Motor

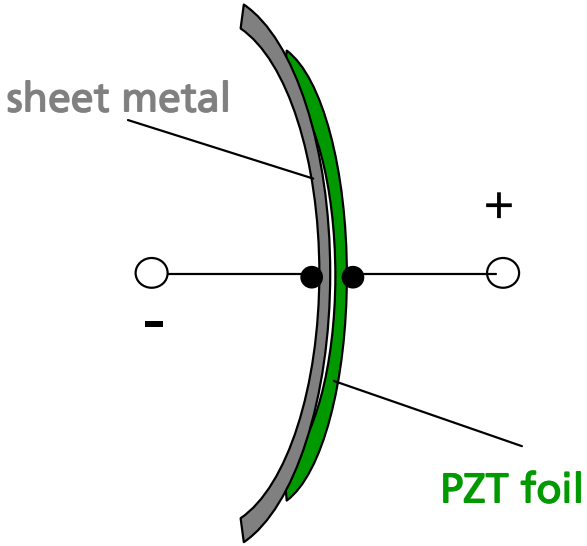
Piezo-pump-injector-technology

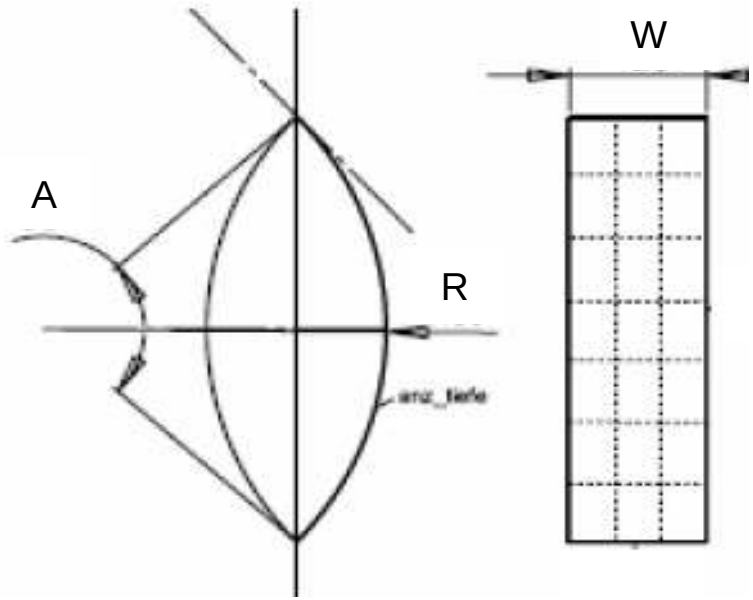
VW TDI Motor

Common-rail-technology

C-BLOCK, BOW ACTUATOR

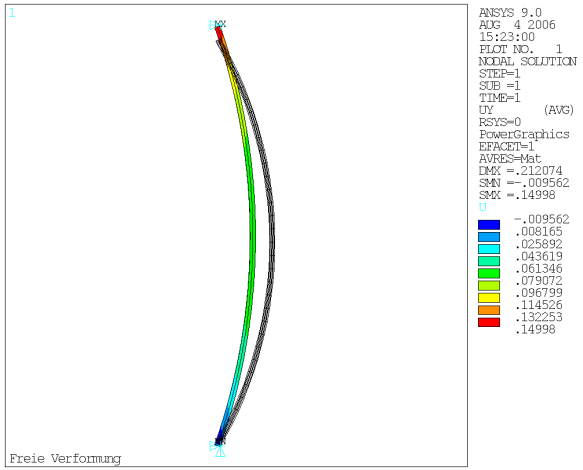
As the **basic component** for the actuator System was used **composite bow actuator**
(PZT foil sintered on a curved sheet metal)



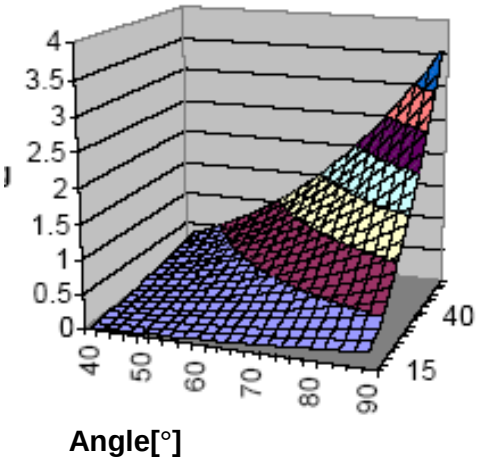


following parameters should be changeable:

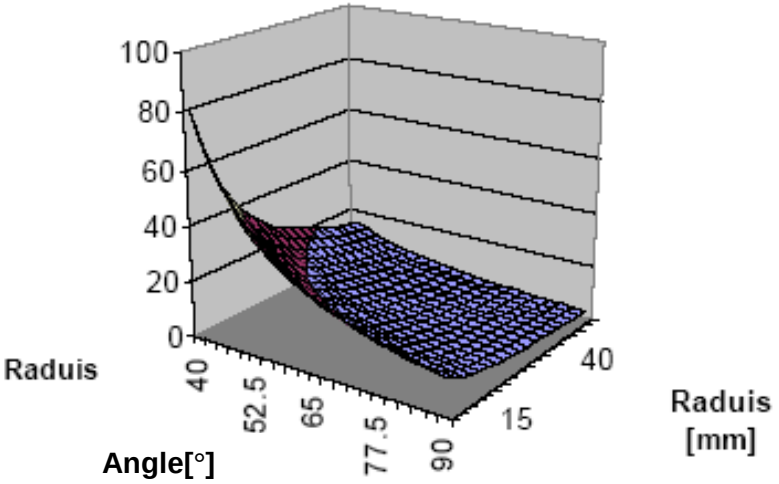
R - Radius
A - Angle
W - Width
TP - Thickness of the PZT foil
TS - Thickness of sheet metal



Stroke function



Blocking force function



Steel sheet metal	**Piezo ceramics**	**Bow Actuator (Basic Component)**
Thickness: 200 µm Width: 20 mm Length: 31,4 + x mm	Thickness: 200 µm Width: 20 mm Length: 31,4 mm	Radius: 40 mm Angle: 45° Length: 31,4 mm Height: 30.61 mm

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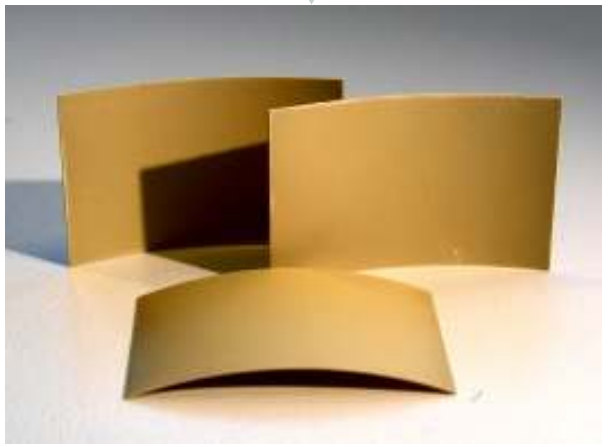
PREPARATION of BOW ACTUATOR

laminating process
20 MPa/70°C/ 10 minutes

Laser cutting process

Sintering process
1050°C/ 2 h



Sonox P505 CeramTec ceramic green tape thickness of 0.1mm

PREPARATION of BOW ACTUATOR

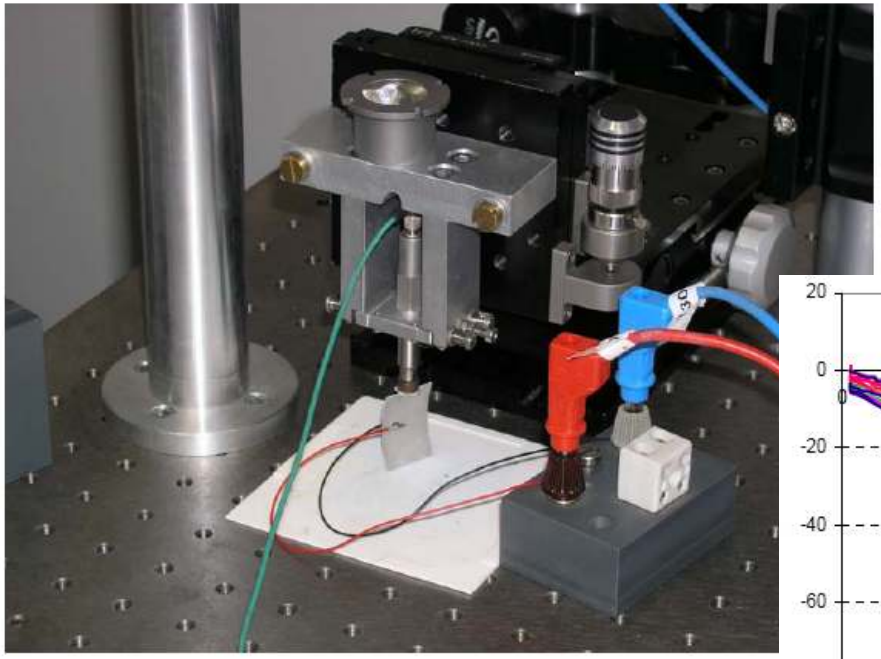
Sputtering of electrodes/ Poling process

500 V/
10 minutes

Curved piezoceramic
+
precurved steel sheet

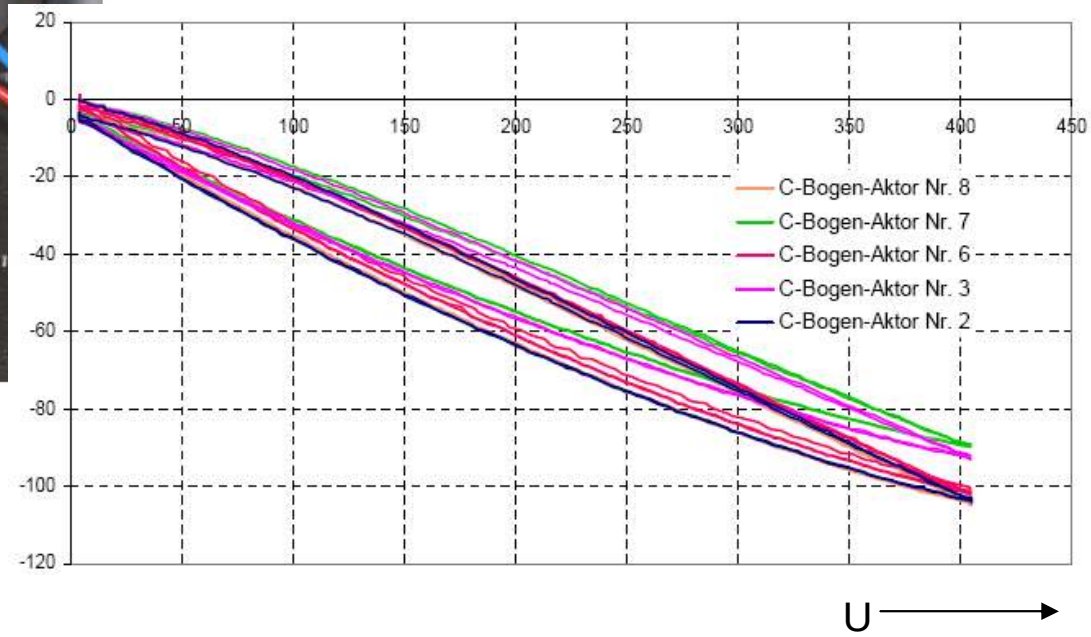
greecyanacrylate loctite 454

CHARACTERIZATION of BOW ACTUATOR



Measuring of stroke h (in no load operation):

U: 0 V...400 V...0 V



➡ h = 100 ... 145 Mikrometers

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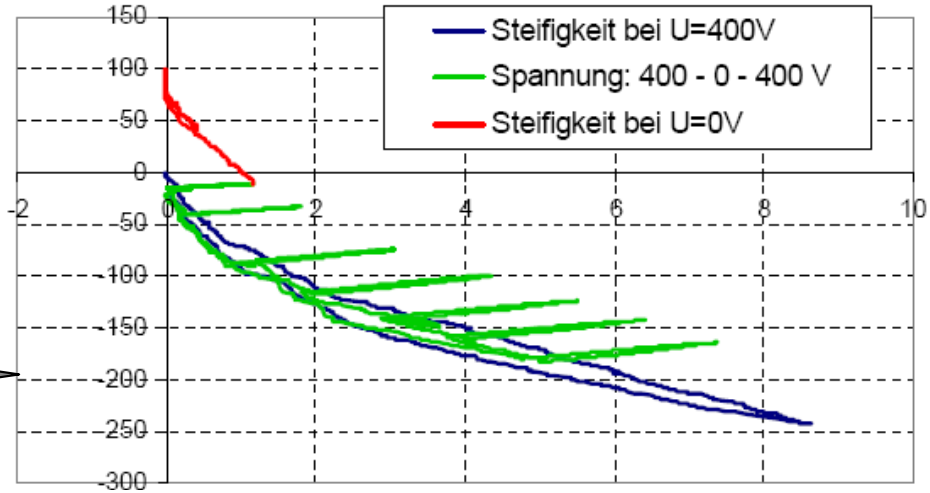
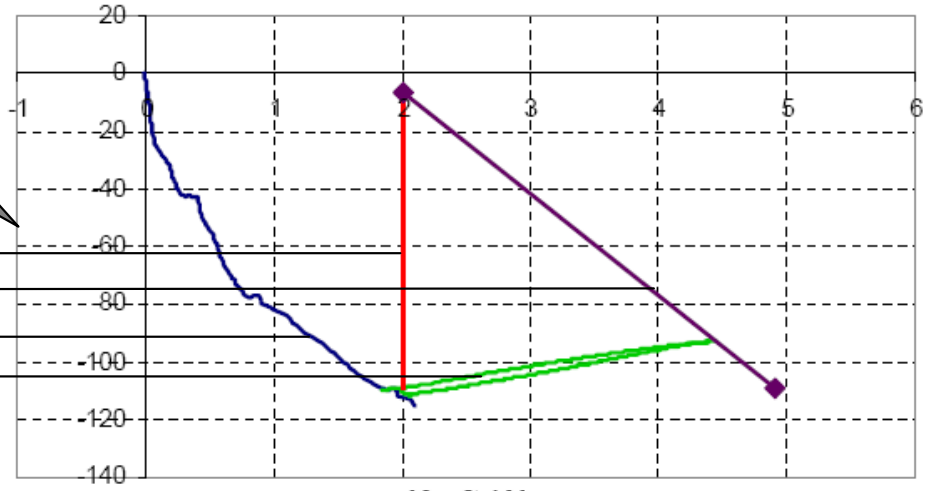
CHARACTERIZATION of BOW ACTUATOR

Force sensor: Kistler 500 N
Charge amplifier: Kistler 5011
Laser interferometer: Zygo

Measuring of stiffness



Measuring of blocking force
U: 0 V...400 V...0 V



free stroke
load line
clamping
Stroke under load

F_B = 1.9 ... 3.5 N **!**

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Construction of a modular actuator system

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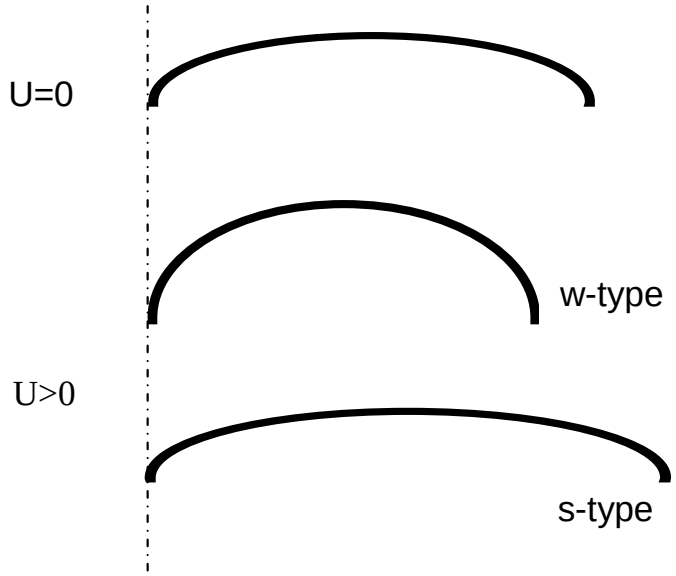
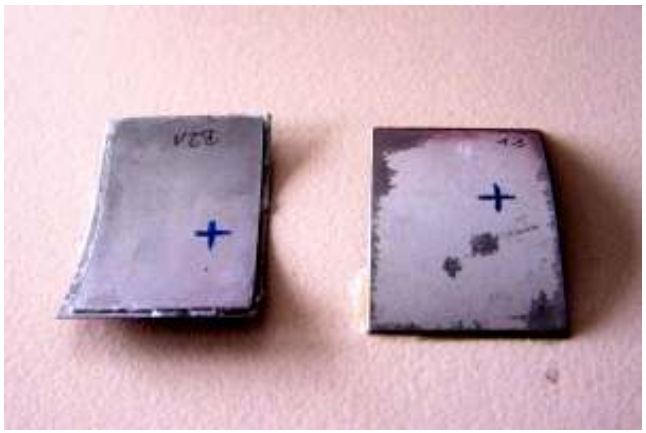
2 TYPES of ACTUATOR REACTION

w-type: actuator **w**rithes

s-type: actuator **s**tretches



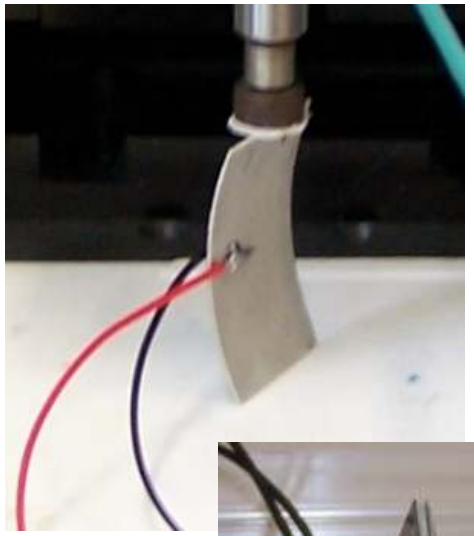
if voltage U > 0



w-type-actuator (piezoceramics interior, exterior steel)

s-type-actuator (piezoceramics exterior, interior steel)

INTERCONNECTION of SIMILAR BASIC COMPONENTS



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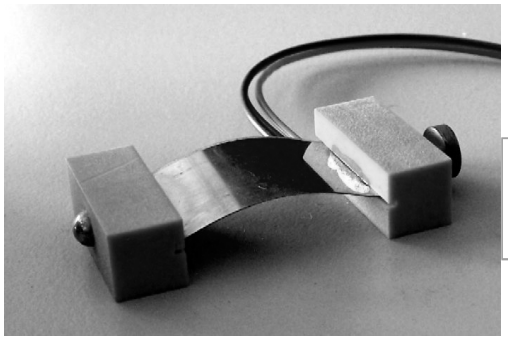
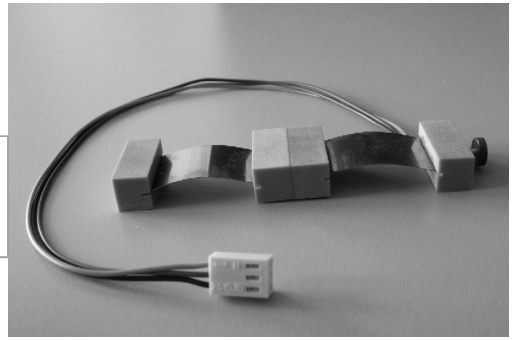


w-type basic component

Factor for

h_{maxn} n F_{max}

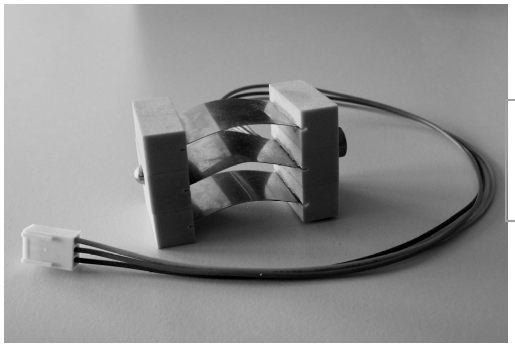
1	1	1	r	r	1



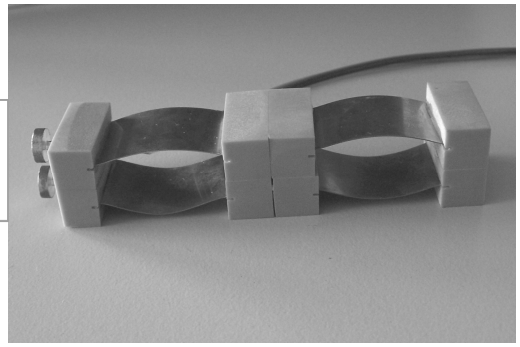
(mechanical) series connection

r=2

Interconnection of basic components



1	1/p	p	r	r/p	p



(mechanical) **p**arallel connection

p=3

ser**r**ies-**p**arallel-connection

r=2, p=2

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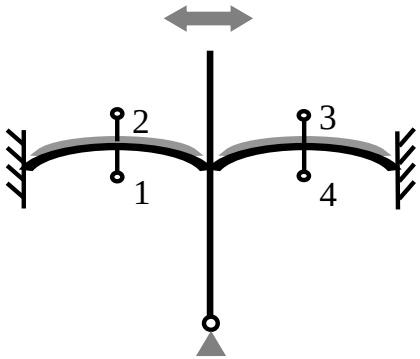
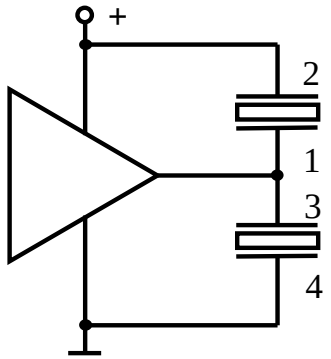
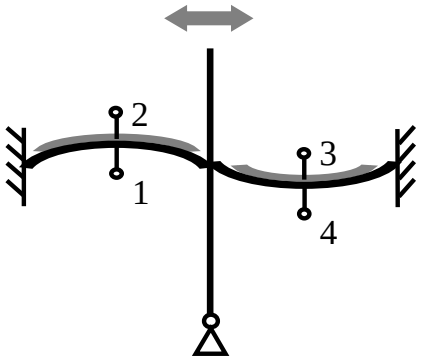
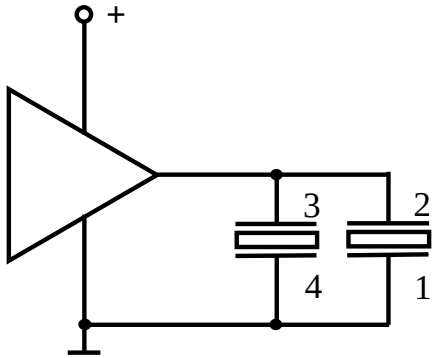
INTERCONNECTION of VARIOUS BASIC COMPONENTS

Experimental Setup









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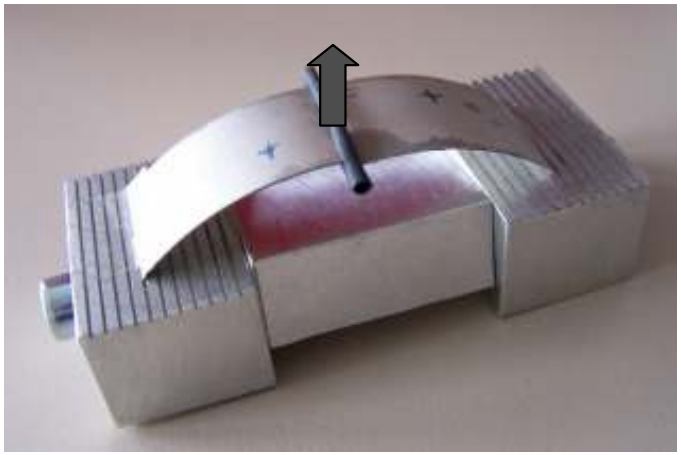
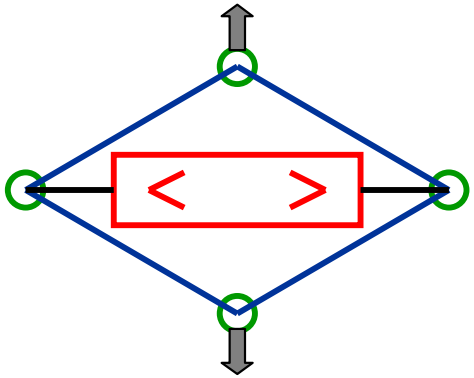
SPECIAL SHAPES of INTERCONNECTION of BASIC COMPONENTS

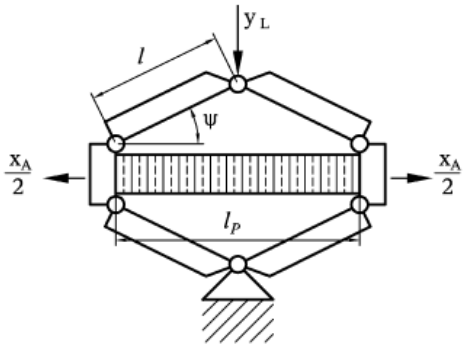


Stroke > 500 Mikrometers

1 mm

Quadrant Kinematics





$$\frac{\Delta y_L}{\Delta x_A} = \frac{l_P}{\sqrt{l^2 - \left(\frac{l_P}{2}\right)^2}} = \frac{l_{P0} + x_A}{\sqrt{l^2 - \left(\frac{l_{P0} + x_A}{2}\right)^2}} \approx \frac{l_{P0}}{\sqrt{l^2 - \left(\frac{l_{P0}}{2}\right)^2}}$$

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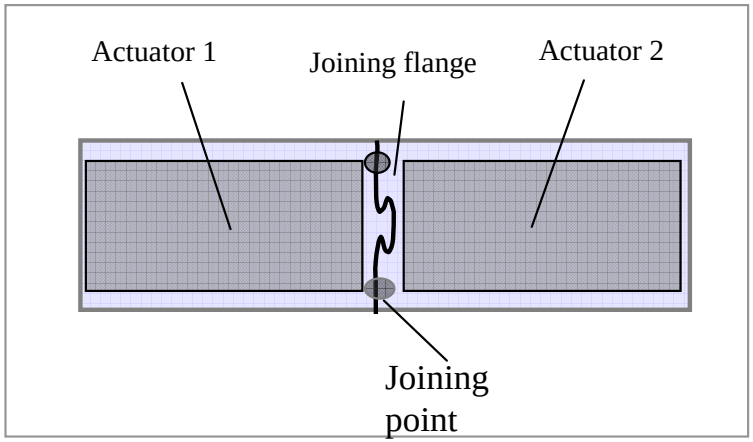
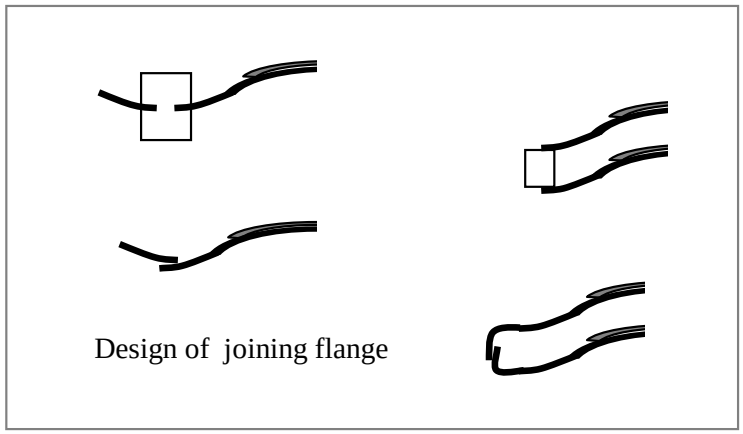
JOINING TECHNIQUES for BASIC COMPONENTS

- Spot Welding
- Laser Welding
- Clinching

It is essential to design the basic components for these joining techniques





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New modular piezo actuator with built-in stress-strain transformation

Summary and Outlook

- Piezoelectric composite bow actuator with inherent stress-strain transformation
- Basic components are curved piezoceramic foils, laminated with steel sheets
- The high level of performance allows to adapt these actuators to a wide range of applications
- The current work includes the optimization of the system
- **Future projects** will include studies on miniaturization of the actuator for example for use in medical engineering

Thank you for your attention!