

Robust design of active systems – an approach to considering disturbances in the selection of sensors



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ISoRD 2014

SFB 805



*produktentwicklung
maschinenelemente*

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Agenda

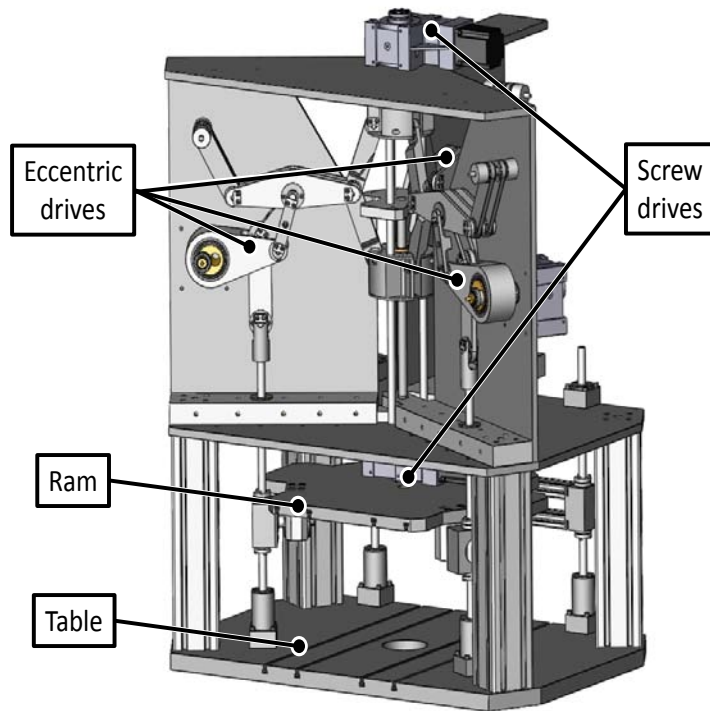
- The 3D - Servo press
- Model based system Analysis
- Uncertainty in active systems and robust design
- Conclusion and Outlook

Agenda



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- Outlook

The Project – 3D Servo press



(Avemann, 2012)

Background

Cooperation with the *Institute for Production Engineering and Forming Machines (PtU)*, *Technische Universität Darmstadt (TUD)*

Objective

Development of a 3d Servo press (free bending) to adapt for variability in production processes.

- Different production processes
- Varying conditions
- Varying Material Input

Implementation of an active system to realize the adaption

Agenda



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- The 3D - servo press
- **Model based system analysis**
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Some definitions



A System in a technical context contains of technical processes and technical products.
(following Gramlich, 2013)

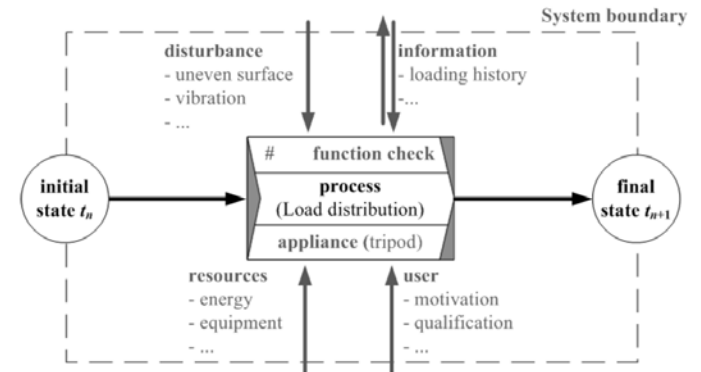
Model based system analysis

A Model is a simplified and abstracted representation of the complex reality.
(following VDI 2221, 1993)

Processmodel

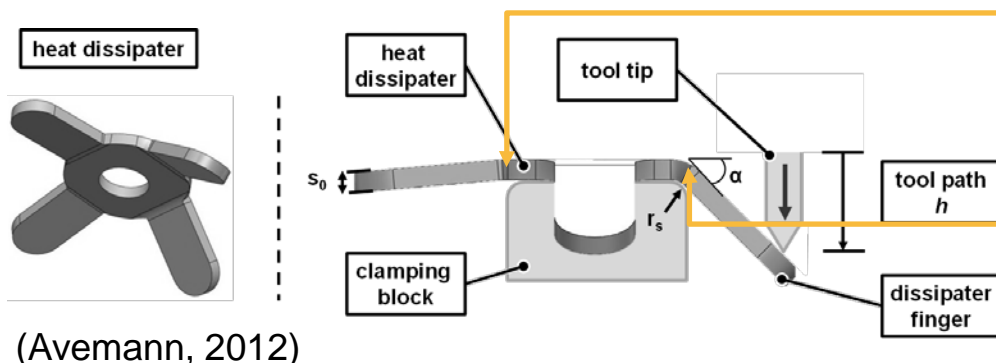
Process

Time dependent and purposeful transformation of an operand from one state into another.
(Heidemann, 2001)



(Eifler et al., 2009)

Example



Initial state

- $\alpha \approx 0^\circ$
- $r_s \approx \infty$

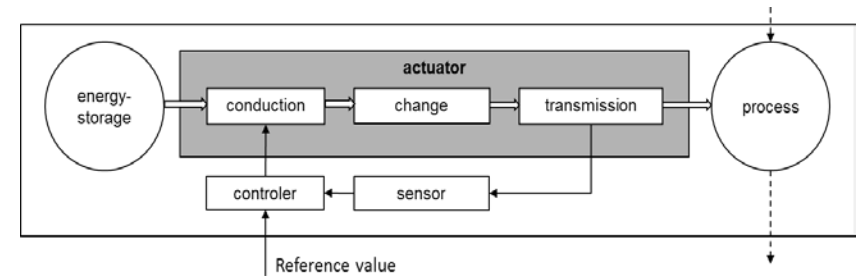
Final state

- $\alpha \approx 40^\circ$
- $r_s \approx 40\text{mm}$

Appliancemodel

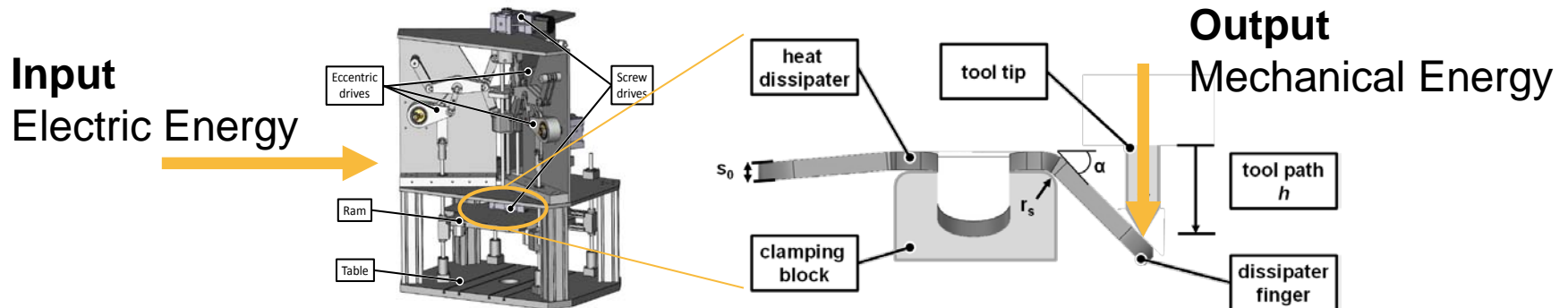
Appliance/ Functional model

Causal relation between input and output parameters.
(following VDI 2221, 1993)



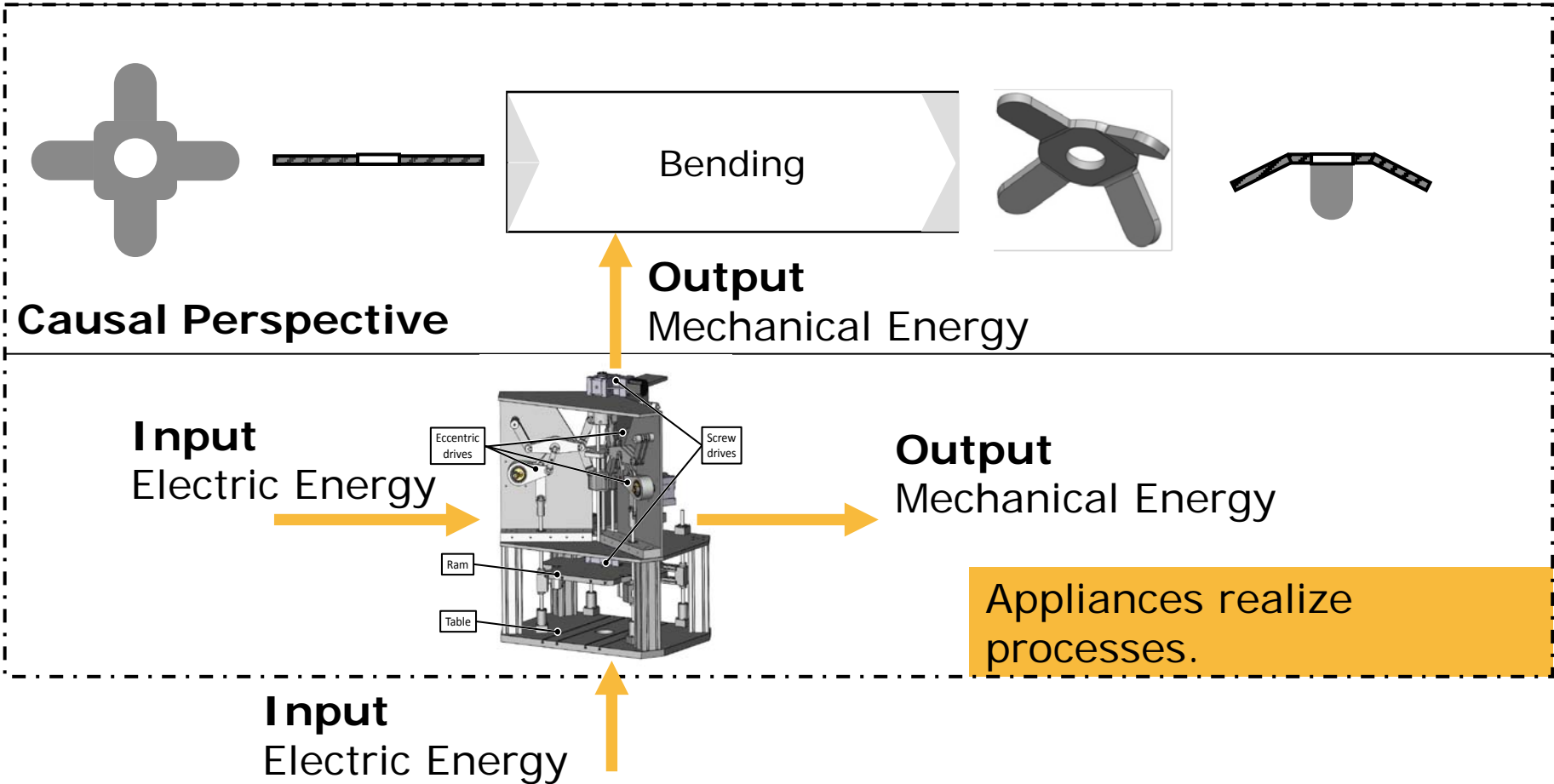
(Nordmann, 2005)

Example

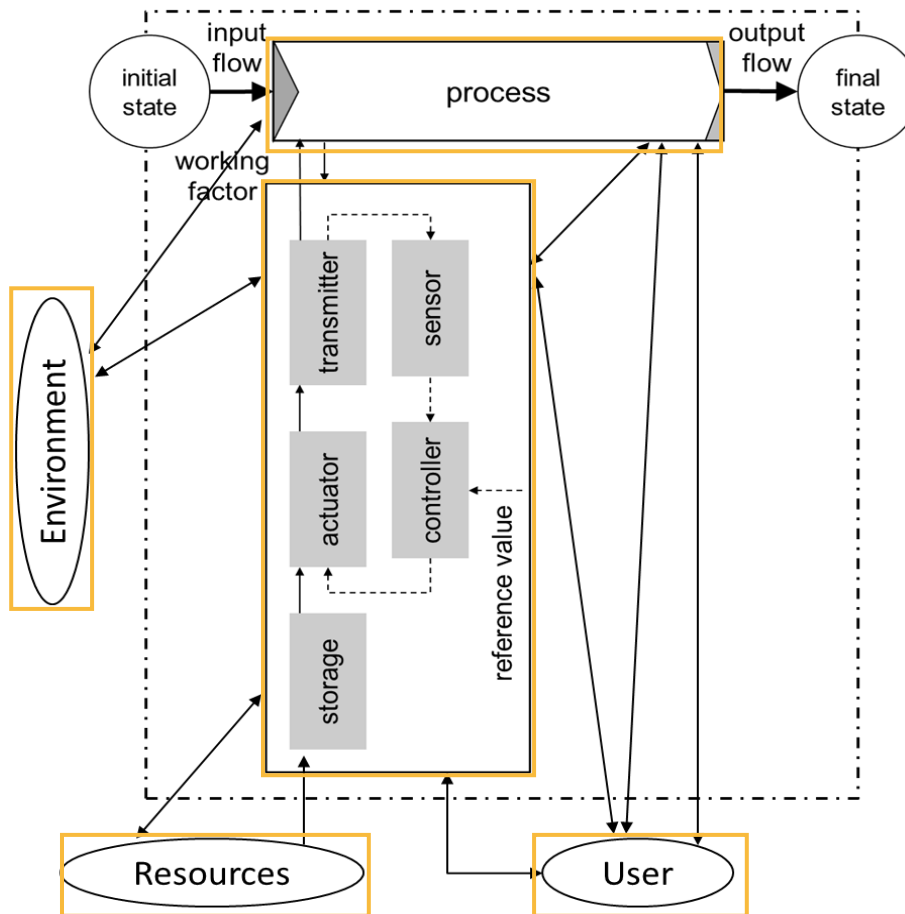


Relation between process and appliance

System for Perspective



SFB805 model of technical systems (SFB805 MTS)



The relations can be characterized by intended and unintended interactions between

- Process
- Appliance
- User
- Resources
- Environment

The appliance model contains

- Storage
- Actuator
- Transmitter
- Controller
- Sensor
- Material-, Energy-, Signal flow

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Some definitions

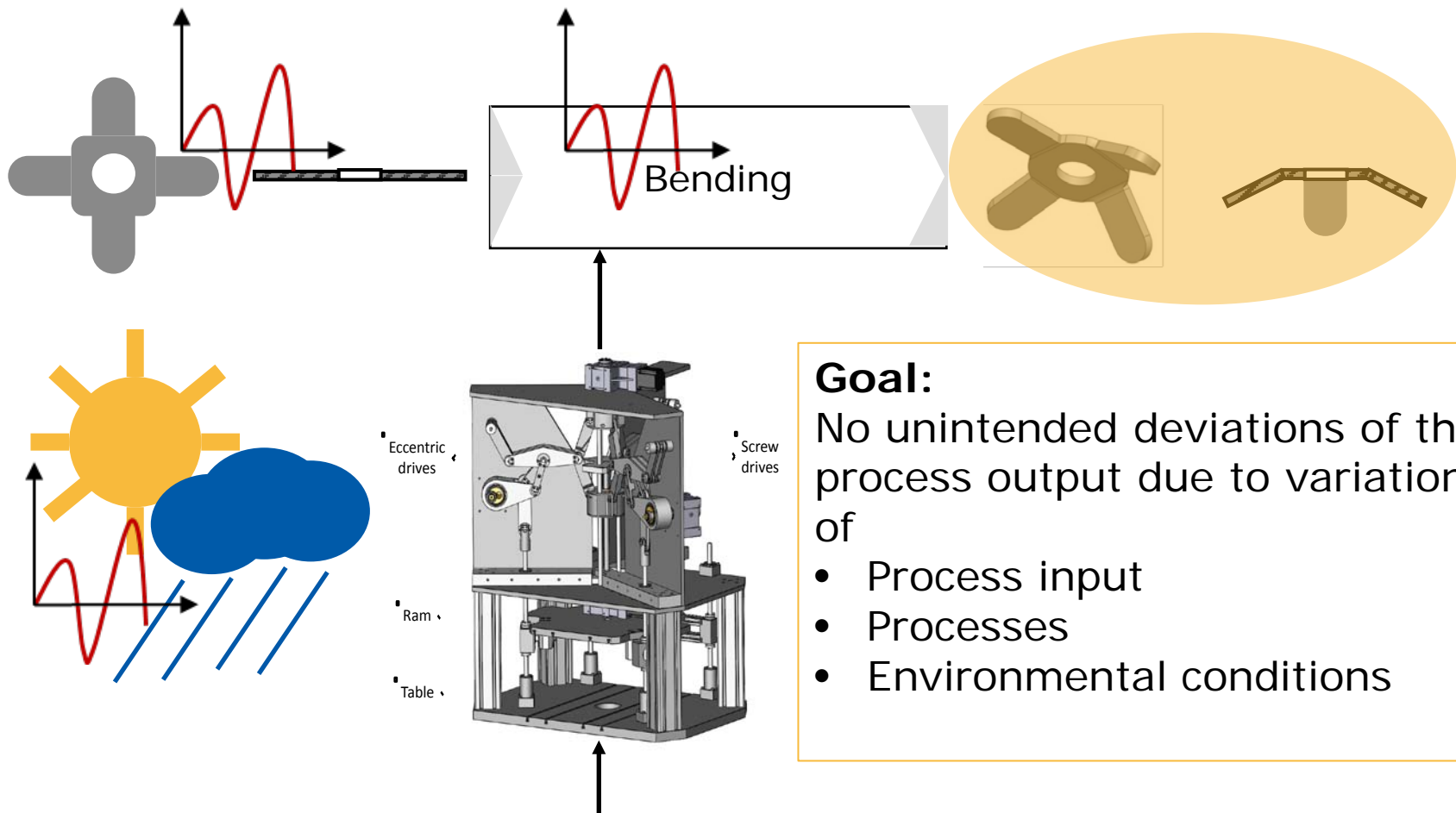
Uncertainty occurs in processes if process properties cannot be determined.
(Hanselka, 2012)

Controlling Uncertainty in active systems through Robust Design

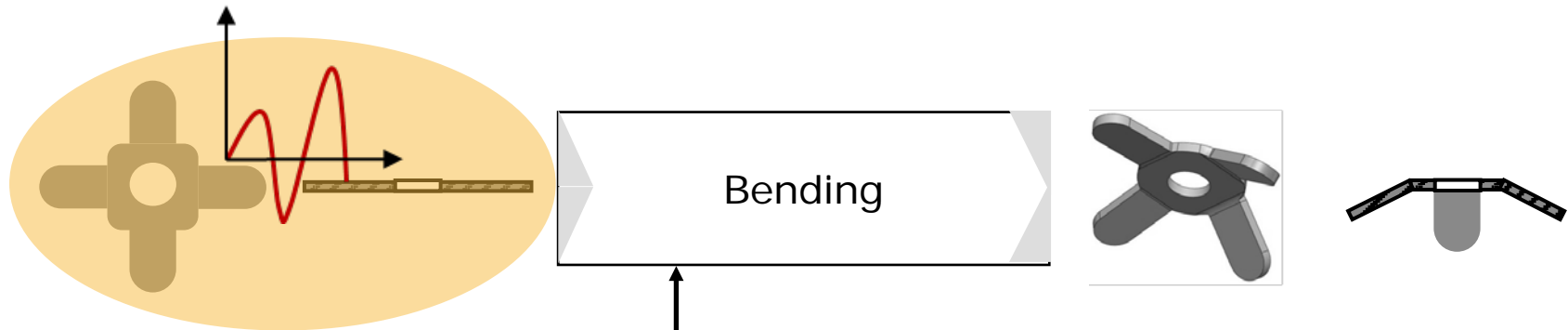
Additional energy for adaption. Includes semi active and active system behaviour according to VDI 2064.

A robust product is insensitive against occurring deviations or unexpected disturbances.

Robust Design of the 3d Servopress



Adaption for Input deviation



Input deviations:
Varying sheet metal properties such as

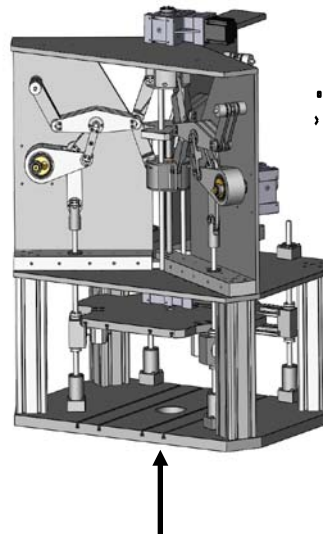
- Modulus,
- Thickness,
- Width,
- Stiffness.

Eccentric drives

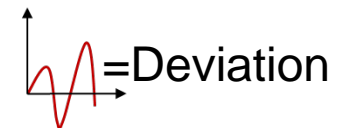
Screw drives

Ram

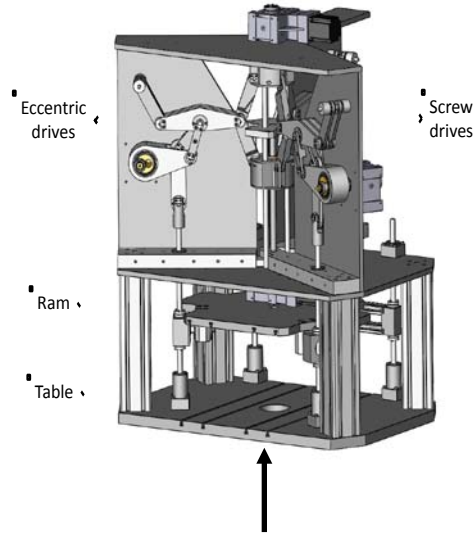
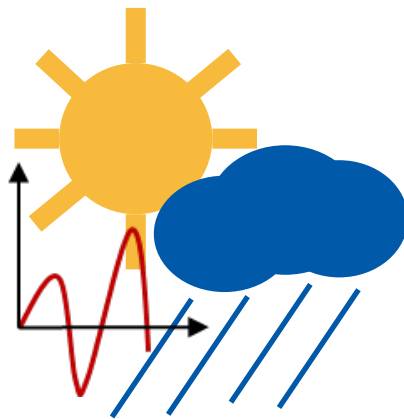
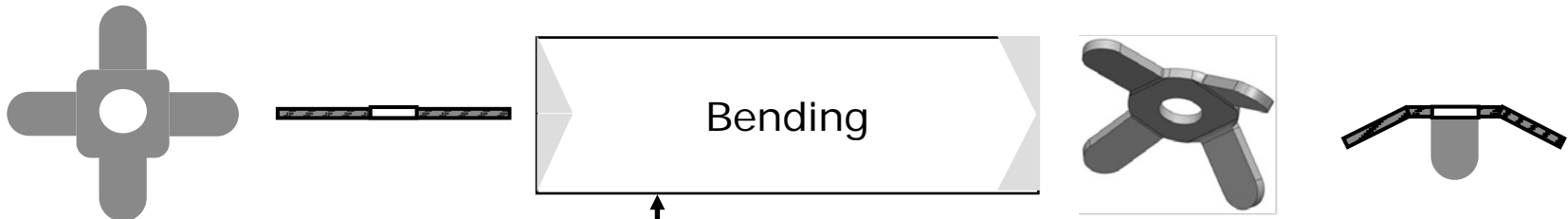
Table



Approach:
Additional process to measure the force/deformation relation of the sheet metal and adapt for it.

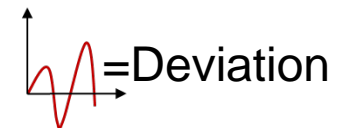


Adaption for environmental deviation



Disturbances:
Environmental
conditions like

- Dirt
- Humidity
- Radiation
- Heat
- ...



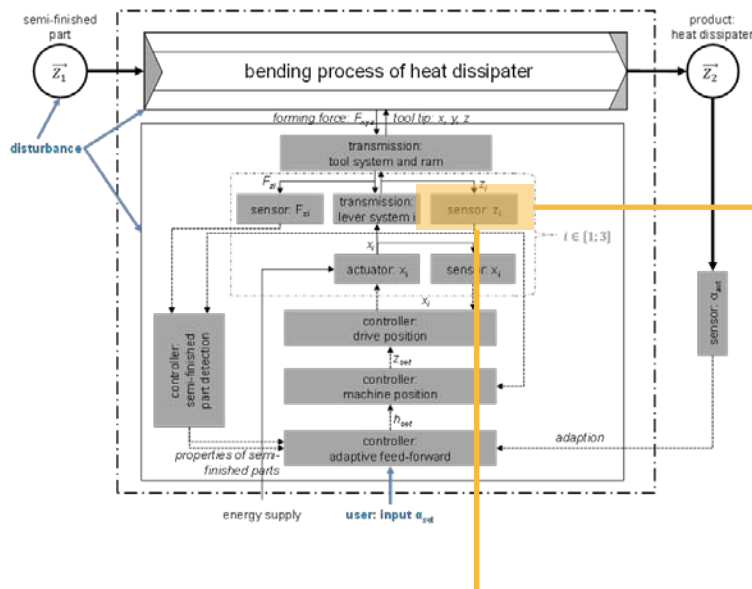
Robust Design for active components - Design Catalogue



measurand	measuring principle	sensor	measuring range	measuring resolution	No.	influence of disturbances				
						Temperature change	(electro-) magnetic field	humidity	vibration	dust and dirt accumulation
1	2	1	2	3		1	2	3	4	5
distance	magnetostrictive	magnetostrictive transducer	25-8000 mm	> 1 μ m	1	●	●	●	●	●
	magneto-resistive	digital ruler	< 100 000 mm	> 2,5 μ m	2	●	●	●	●	●
	resistive	(conductive plastic) potentiometer	< 4 000 mm	> 1 μ m	3	●	●	●	●	●
force	piezo-electric	piezo-electric force sensor	50 N – 1,2 MN	> 0,5 mN	4	●	●	●	●	●
	resistive	strain gauge (SGS) force sensor	1 N - 10 MN	> 0,4 mN	5	●	●	●	●	●

legend: ● no influence ● marginal influence ● strong influence

Robust Design for active components – Analysis



measurand	measuring principle	sensor	measuring range	measuring resolution	No.	influence of disturbances				
						Temperature change	(electro-) magnetic field	humidity	vibration	dust and dirt accumulation
1	2	1	2	3	No.	1	2	3	4	5
distance	magnetostrictive	magnetostrictive transducer	25-8000 mm	> 1 μm	1	●	●	●	●	●
	magneto-resistive	digital ruler	< 100 000 mm	> 2,5 μm	2	●	●	●	●	●
	resistive	(conductive plastic) potentiometer	< 4 000 mm	> 1 μm	3	●	●	●	●	●
force	piezo-electric	piezo-electric force sensor	50 N – 1,2 MN	> 0,5 mN	4	●	●	●	●	●
	resistive	strain gauge (SGS) force sensor	1 N - 10 MN	> 0,4 mN	5	●	●	●	●	●

Distance sensor of the lever system

- Marginal influence of temperature changes
- Strong influence of magnetic fields
- Marginal influence of dirt accumulation

Robust Design for active components – Synthesis



Project

Development of an innovative, active stabilizer for a *Dart Racing* car.

Application of the *SFB805 Model of Technical Systems (SFB805 MTS)* and the design catalogue for robust sensors.

Procedure

- Modelling of lifecycle processes (Manufacturing, Maintenance, Transport, Application scenarios, ...)
- Analysis of the occurring disturbances based on the various *SFB805 MTS*
- Selection of a robust measurement principle for the sensor and application of robust design strategies

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- Robust Design for Sensors
- Outlook

Conclusion and Outlook

What we did

Development of a model that is capable to represent complex technical system through combination of existing models.

Development of an approach for the design of robust sensors using a design catalogue.

Application in an analysis and a synthesis case.

What we have to do

The *SFB805 MTS* has to be proved useful in more use cases, some details have to be improved and clearly defined.

Investigation of deviations of processes.

Development of a methodology to design robust, active **systems**

- Uncertainty in Controllers
- Uncertainty in active component Chains



Thank You for Your attention



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Literature 1

AVEMANN, J., CALMANO, S., SCHMITT, S. & GROCHE, P. 2014. Total Flexibility in Forming Technology by Servo Presses. *WGP Congress 2012 - Progress in Production Engineering*. Berlin, Germany: Trans Tech Publications.

EIFLER, T., et al., 2011. Approach for a consistent description of uncertainty in process chains of load carrying mechanical systems, *Proceedings of ICUME 2011*, volume 104, page 133.

GRAMLICH, S., 2013, *Vom fertigungsgerechten Konstruieren zum produktionsintegrierenden Entwickeln*. VDI Verlag

HEIDEMANN, B., 2001, *Trennende Verknüpfung - Ein Prozessmodell als Quelle für Produktideen*. Düsseldorf. VDI Verlag

KLOBERDANZ, H., et al., 2009. Process based Uncertainty Analysis – an Approach to Analyse Uncertainties using a Process Model. *Proceedings of the International Conference on Engineering Design (ICED)*, volume 2, page number 465.

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Literature 2

NORDMANN, R., 2005. *Mechatronische Systeme im Maschinenbau 1*, Aachen, Shaker Verlag GmbH

HANSELKA H., PLATZ, R., 2012, *Controlling Uncertainties in Load Carrying Systems*, Konstruktion 11/12 – 2010, page 55 - 62

ROTH, K., 1982, *Konstruieren mit Konstruktionskatalogen*, Heidelberg, Springer Verlag

VDI2221 - Methodik zum Entwickeln und Konstruieren technischer Systeme und Produkte, 1993, VDI Verlag Düsseldorf

http://dart-racing.de/index.php/news_und_medien.html, 13.8.2014

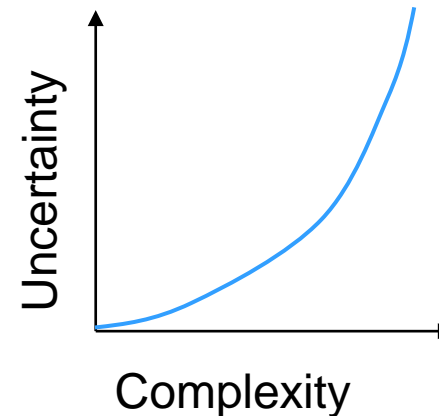
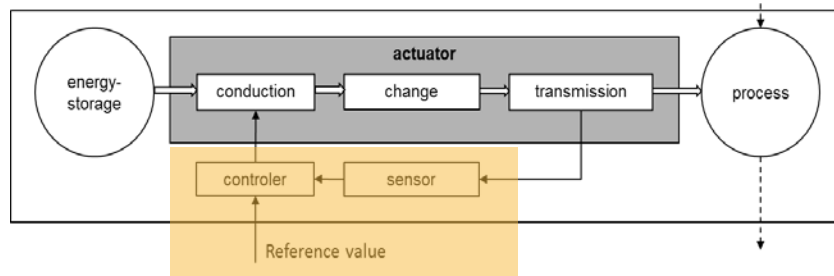
Additional information

3d Servopress – challenges

Active systems cause additional uncertainty trough additional

- components
- relations
- related behaviour

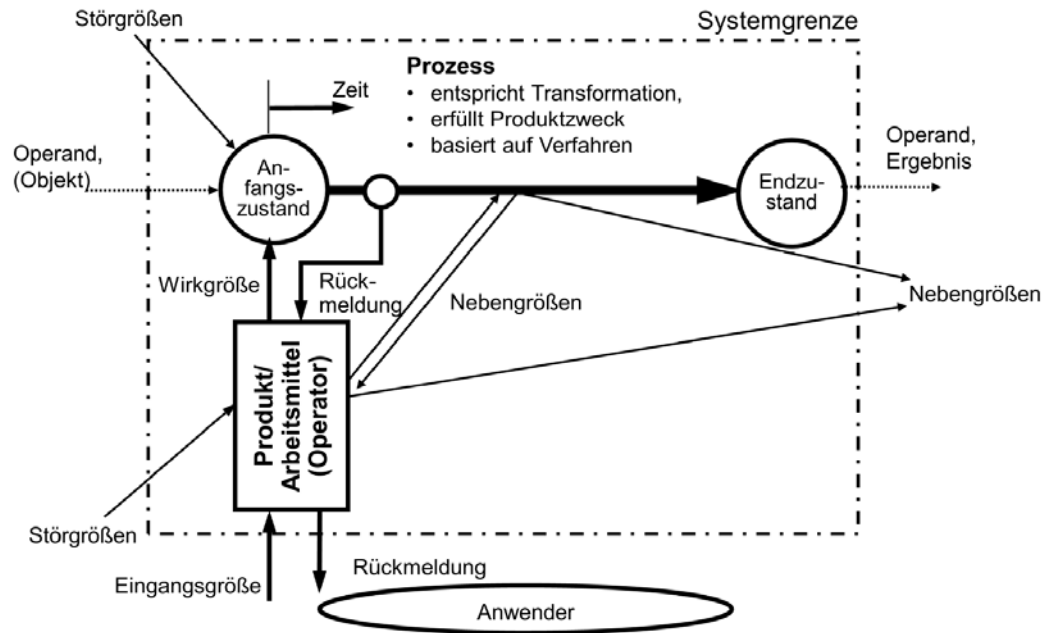
(Nordmann, 2005)



Approach:

Development of a Methodical Support for the designer to control uncertainty in active systems trough Robust Design containing of models, tools and procedures.

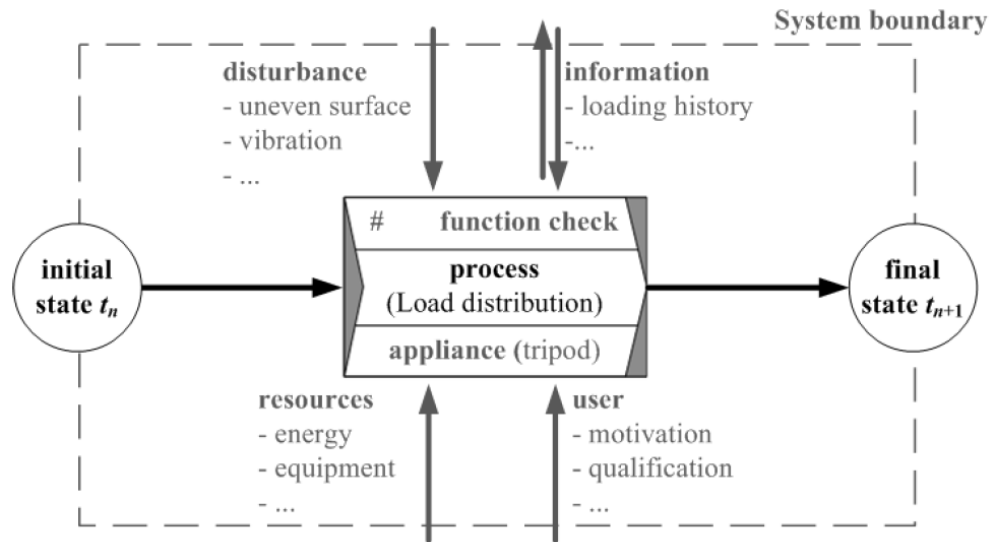
Process model according to *Heidemann*



(Heidemann, 2001, 138)

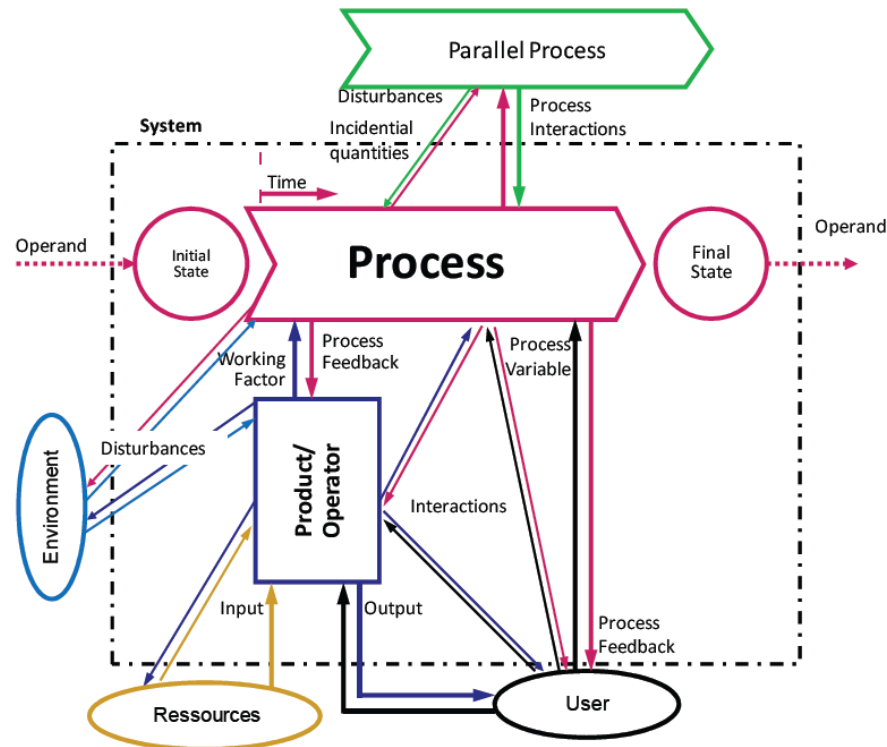
Erweiterte Darstellung, angepasst
nach Birkhofer

SFB 805 Prozessmodel



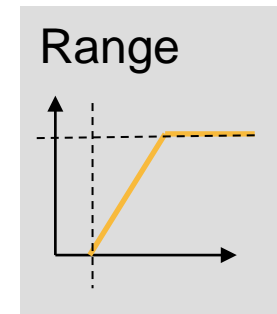
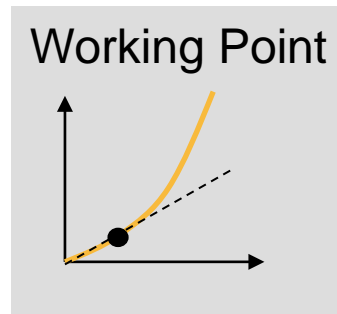
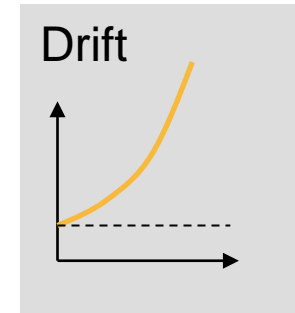
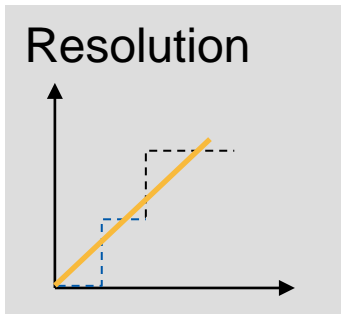
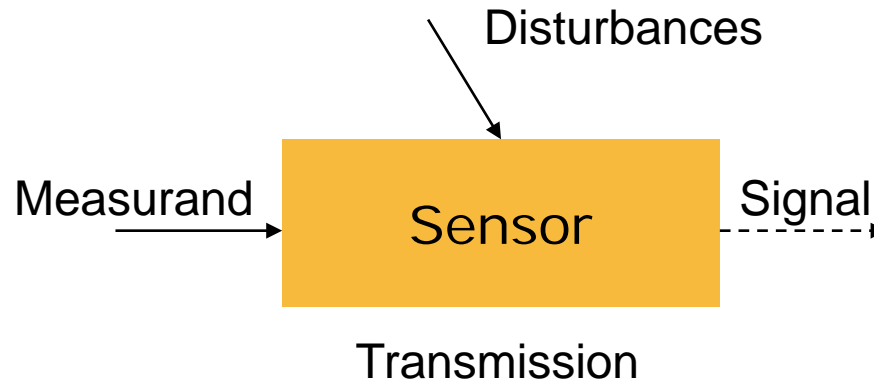
(Eifler et al., 2009)

Processmodel according to *Kloberdanz*



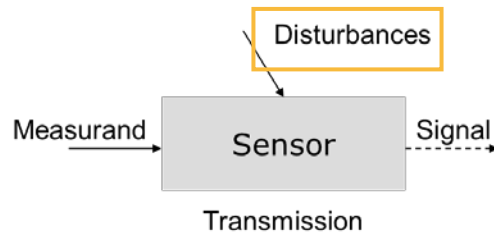
(Kloberdanz, 2009)

Additional uncertainty in active systems - sensors



Robust Design for sensors - RD Strategies

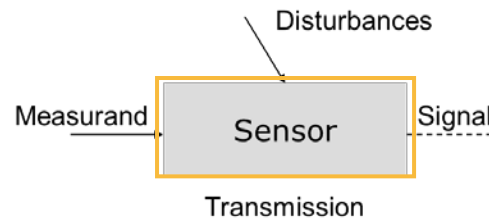
Eliminate disturbance



Disturbance does not occur.

- Housings
- Application Limits

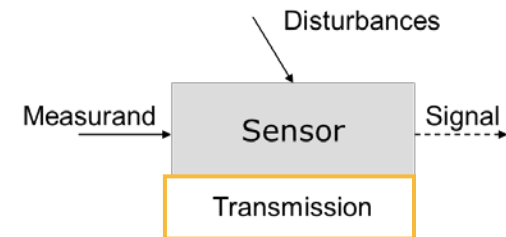
Eliminate influence



Disturbance does not influence the sensor.

- Isolation

Eliminate impact

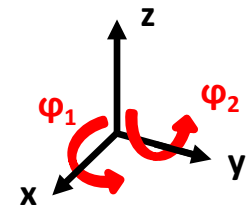
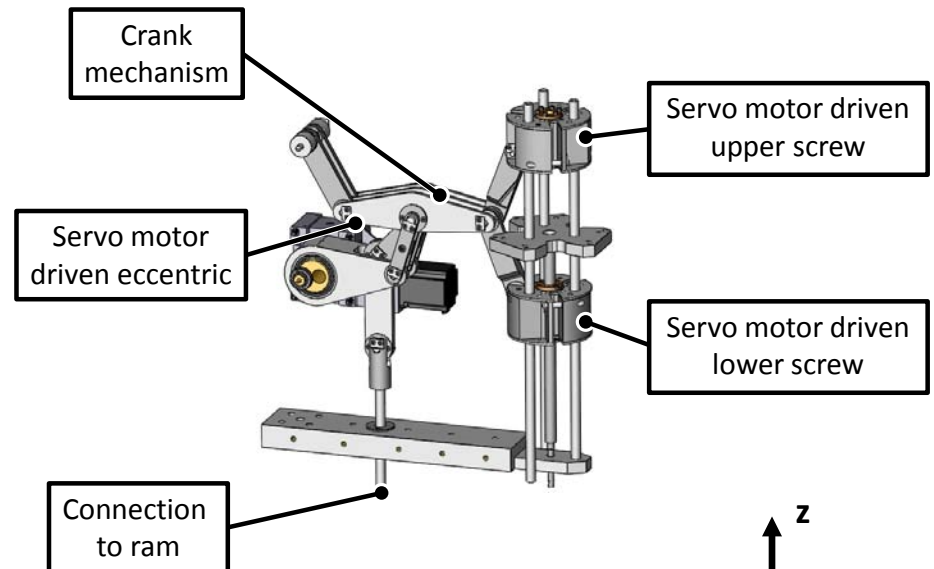
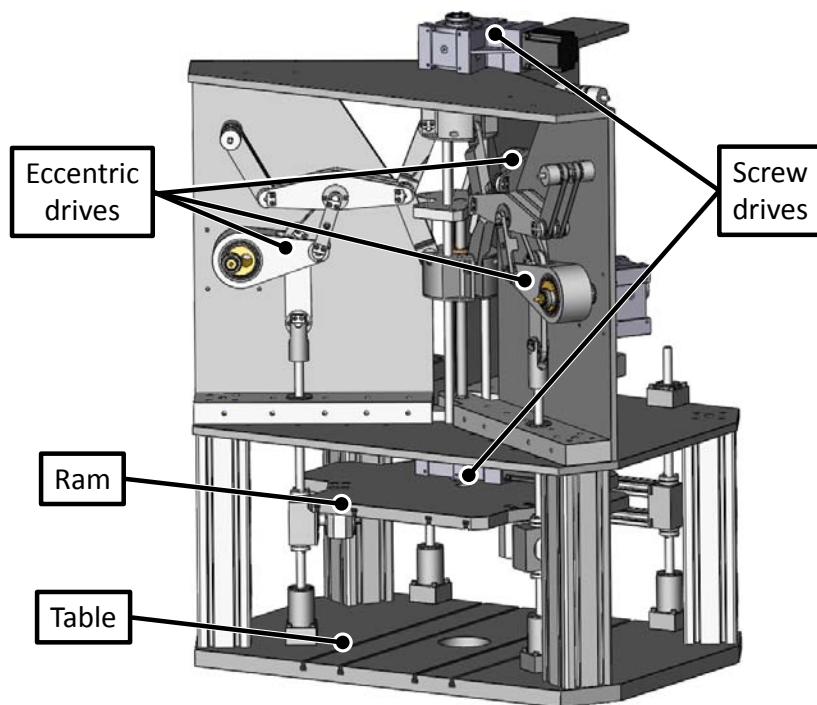


Disturbance does not impact the behaviour.

- Recalibration

(following Mathias, 2010)

The 3d Servopress



(Avemann, 2012)

Example: 3d Servopress represented through *SFB805 MTS*

