Mechatronic Simulation of Electromechanical Servo-Presses

Example and Challenges

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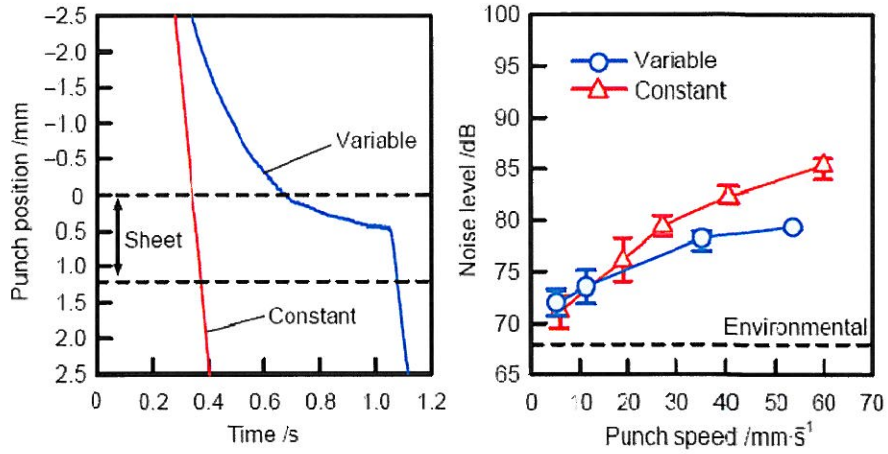
Technological Challenges - Shearing

Example 1: Reducing blanking noise by modified motion of slide



Source: Otsu, M.; Yamagata, C. & Oskada, K.: (2003). Reduction of Blanking Noise by Controlling Press Motion. CIRP Annals Manufacturing Technology: Vol. 52, Issue 1, pp. 245-248.

Technological Challenges - Shearing

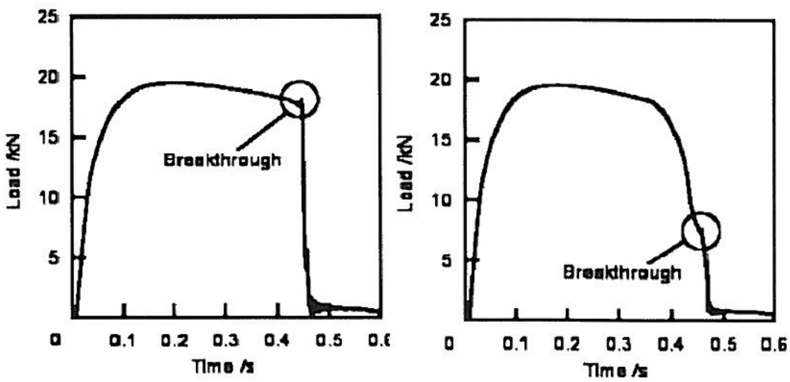
Example 1: Reducing blanking noise by modified motion of slide

Improvement of:

→ Air-borne noise

→ Structure-borne noise
(cuting shock)

→ Quality
(Flush-cut amount)



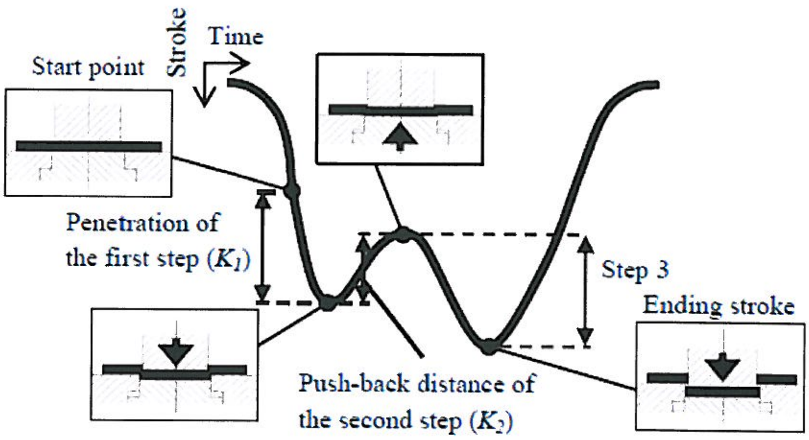
(a) Noise level: 76.1dB

(b) Noise level: 71.0dB

Source: Otsu, M.; Yamagata, C. & Oskada, K.: (2003). Reduction of Blanking Noise by Controlling Press Motion. CIRP Annals Manufacturing Technology: Vol. 52, Issue 1, pp. 245-248.

Technological Challenges - Shearing

Example 2: Burr-Free shearing by modified motion of slide



Source: *Koga, N.; Kubo, M. & Junlapen, K.: (2007); Burr-Free Shearing by Vibration Mode Using NC Servo Press Machine The Proceedings of the 58th Japanese Joint Conference for the Technology of Plasticity, Vol. 48.*

Technological Challenges – Deep drawing

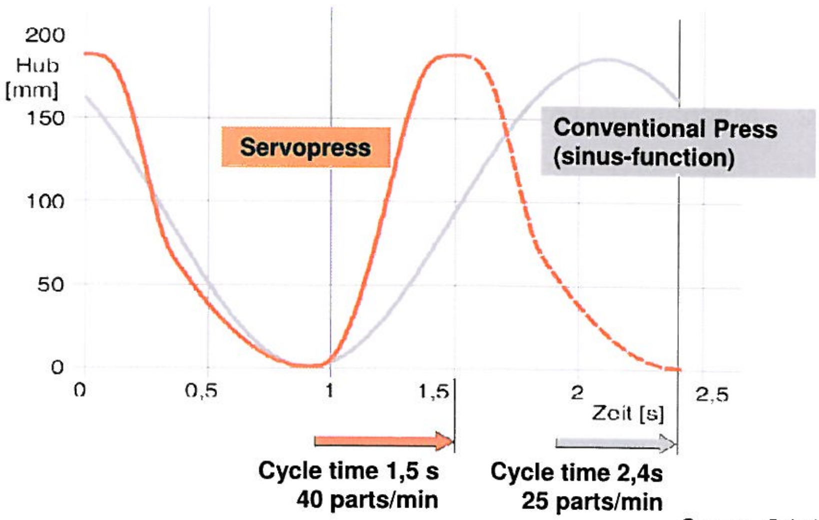
Example 3: Increasing of output by modified motion of slide

Improvement of:

→ Output

→ Energy Consumtion

→ Simplified Automation



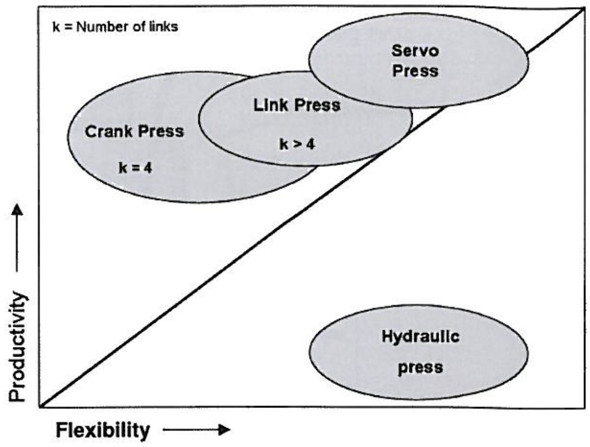
Source: Schuler

Technological Challenges – Trends

New technological conceptions **requires**:
- a **higher motion dynamic** and
- a **modified motion** of slide

electro-mechanical servopresses are suitable

Mechatronical System



Source: Miyoshi, K: Current Trends in Free Motions Presses, Proc. 3rd JSTP Int. Seminar on Precision Forging, (2004), pp. 69-74.

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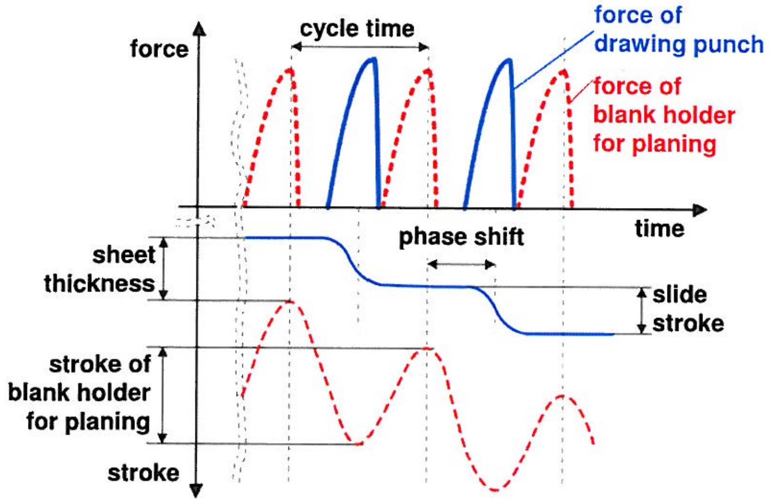
Principle of synchronous deep-drawing



- **Deep-drawing operation** with drawing punch and blank holder
- **Phase-shifted force** of drawing punch and blank holder → **possibility of a two-phase process:**

1st phase
Deep-drawing without blank holder
→ less tensions
→ higher draw depth

2nd phase
Planing of creases by blank holder

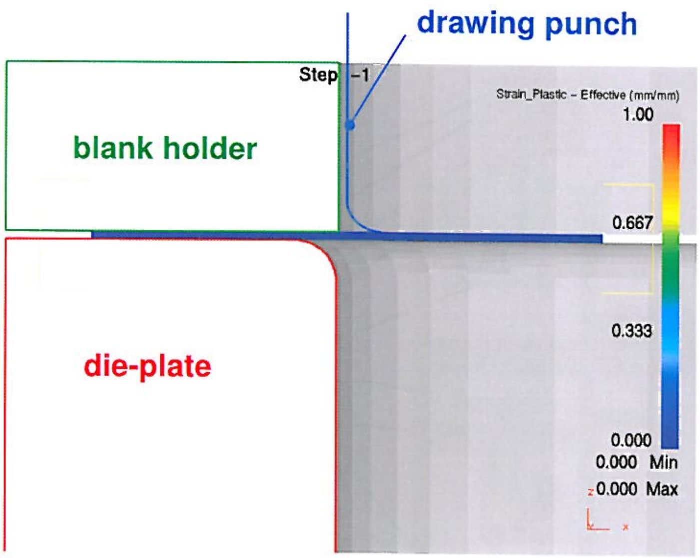
Source: IWU

Process simualtion of synchronous deep-drawing

Phase-shifted force of drawing punch and blank holder
→ possibility of a two-phase process:

1st phase
Deep-drawing without blank holder
→ less tensions
→ higher draw depth

2nd phase
Planing of creases by blank holder



Source: IWU

Description of the test equipment

„Promess“ spindel press

Source: *IWU*

Application:

Prototypical process studies

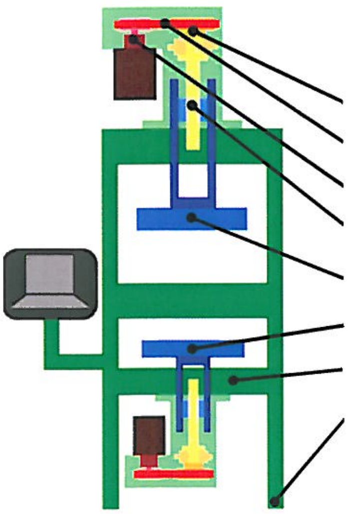
Data:

- Press capacity: 300 kN
- Max. slide velocity: 100 mm/s

During the max. slide velocity are **vibrations up to 3 Hz with a vibration stroke < 1mm** possible.

Modeling – Mechanic Elements

Simplified mechanic model of „Promess“ spindel press



Source: *IWU*

Stiffness, damping and inertia of:

- Axial bearing
- Belt transmission
- Planetary gear
- Spindel drive
- Slide
- Drawing cushion
- Press frame
- Installation, basement

} Linear elastic behaviour

+ Inertia of servo motor and tool

Modeling – Motor and Control

Technology
- process loads & velocities
- motion profile
- command value (force, position)

Drive train concept
- loads and ratios
- kinematic structure
- limitations
- singularities

Mechanical structure
- system configuration (cushion, guiding system …)
- component limitation
- multi axes system
- tolerances
- structural discontinuity

+ + +

Motor & Control Characteristics
- inertia, power, limits
- hardware related timing
- sensor concept
- control concept

Control Model
- control loops
- hardware & control related limitations
- process limits

Prof. Neugebauer

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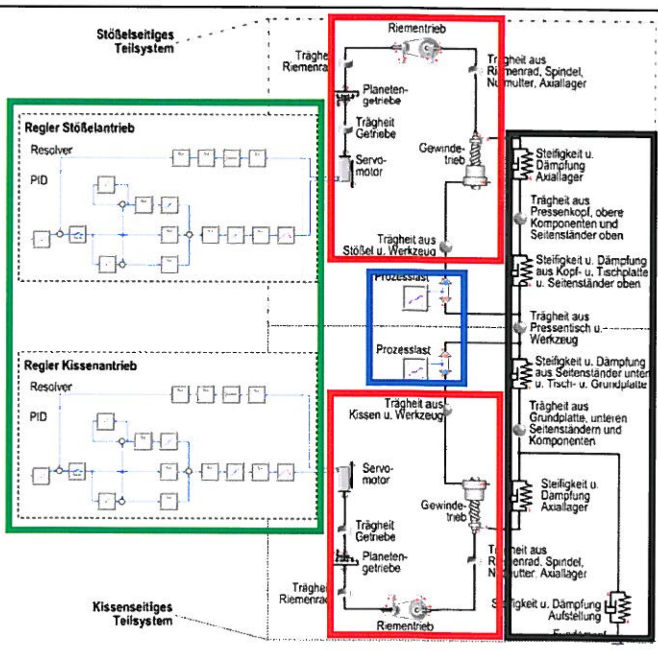
Modeling – Overall Model

- **Process**
- **Mechanics**
- **Drives**
- **Control**



Source: IWU

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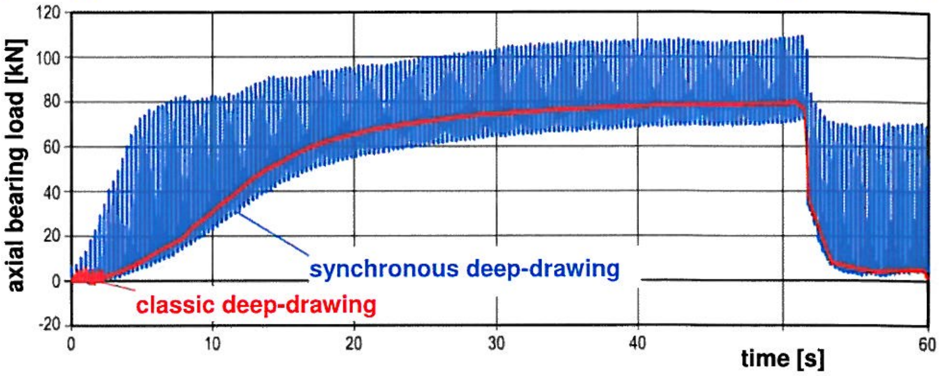
Results - Load of Machine Components

- Example: **Axial bearing of slide drive**
  Axial bearing force curve of synchronal deep-drawing process is **about 25% higher** as force curve of classic deep-drawing → static methods are limited applicable

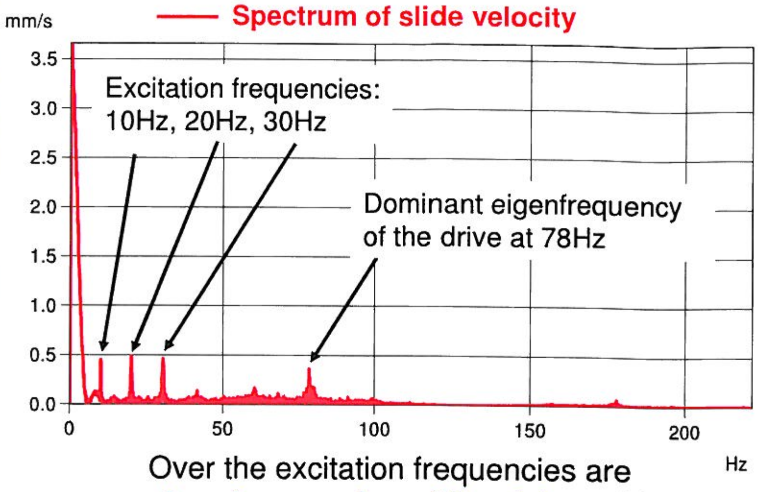
- **Higher motion dynamic** at synchronous deep-drawing
  → **Higher applied loads** of machine components → **forecast by simulation**



Content

1. Motivation
2. Mechatronic Models for Servo-presses
3. Potential of Optimization
4. Summary and Outlook

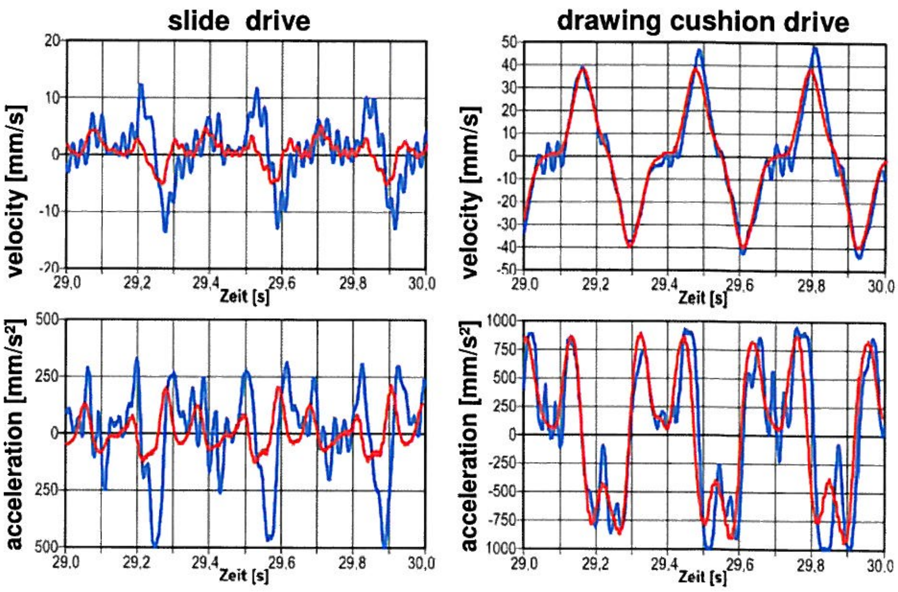
Results - Experimental validating



Source: Dunkes

Over the excitation frequencies are **eigenfrequencies of the drive**, which superimposed the excitation vibrations, especially at 78Hz.

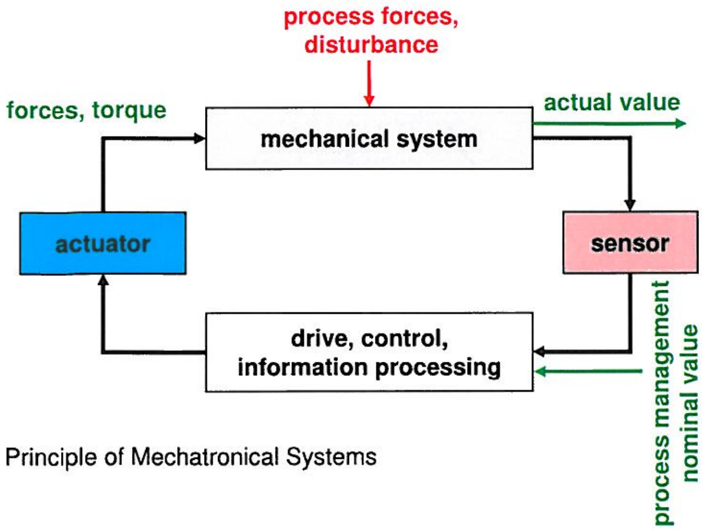
Results - Optimization potential - Comparsion of drive models



Source: IWU

Promess drive — Torque motor

Objectives of Mechatronic Simulation



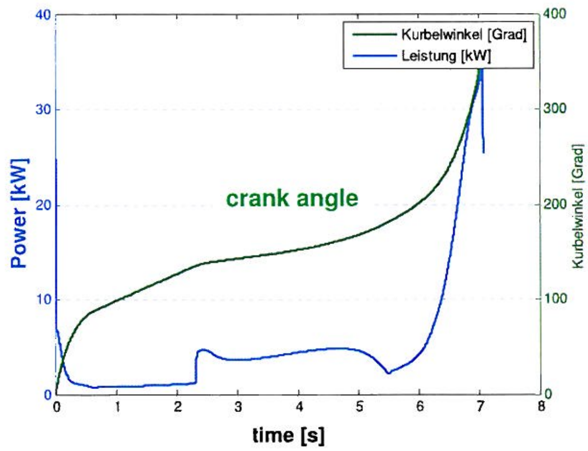
Principle of Mechatronical Systems

Increasing of output
→ Kinematics,
→ velocity profile,
→ automation

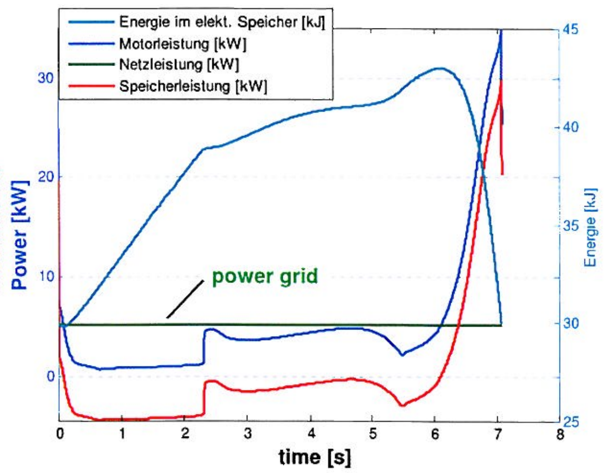
- **Optimization of functional elements**
→ drive system,
→ decrease of rotatory inertia,
→ frame structures
→ energy storage
- **Control of interactions (machine ↔ process)**
→ eigenfrequencies
→ excitation frequencies,
- **Development of Innovative Processes**

Energy Storage

→ process needs



→ dimensioning of the storage



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Potentials

Effective application advantages:

- Productivity benefits by flexibility of stroke function and optimization of automation procedure
- Use of slide oscillating motion
- Cost benefits by loss of expensive mechanic transfer elements and secondary units (hydraulic) in the power train

Open potentials:

- Technology potentials by flexibility of stroke function at process
- Use as a force or energy bounded press → change of control mode at process
- Short-term extreme changes of stroke function (impact) as a technology option (e.g. adiabatic forming and cutting)
- Closed Energy loops

Closed energy circuit

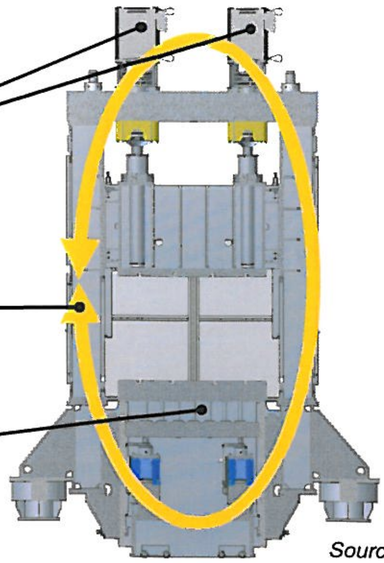
Energy can be attributed

➡ Overall energy efficiency of the whole machine can be increased

Main drives (servo motors)

Closed energy ciruit

Electro-mechanical drawing cushion with servo motors



Source: Dunkes

Research needs

Multi-criteria optimization of drive design under consideration of conflicting criterions

- Energy efficiency
- Flexibility
- Process forces

Optimization of control:

- Flexibility of the open kinematic chain (productivity, automation)
- Flexibility of the closed kinematic chain (process optimization)
- Switch between the states

Thank you for your attention