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VOLUME I

Session 1 - Systems Engineering and Intelligent Systems

Session 2 - Advances in Control Theory and Control Engineering

Session 3 - Optimisation and Management of Complex Systems and Networked Systems

Session 4 - Intelligent Vehicles and Mobile Systems

Session 5 - Robotics and Motion Systems

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Preface

Dear Participants,

Confronted with the ever-increasing complexity of technical processes and the growing demands on their efficiency, security and flexibility, the scientific world needs to establish new methods of engineering design and new methods of systems operation. The factors likely to affect the design of the smart systems of the future will doubtless include the following:

- As computational costs decrease, it will be possible to apply more complex algorithms, even in real time. These algorithms will take into account system nonlinearities or provide online optimisation of the system's performance.
- New fields of application will be addressed. Interest is now being expressed, beyond that in "classical" technical systems and processes, in environmental systems or medical and bioengineering applications.
- The boundaries between software and hardware design are being eroded. New design methods will include co-design of software and hardware and even of sensor and actuator components.
- Automation will not only replace human operators but will assist, support and supervise humans so that their work is safe and even more effective.
- Networked systems or swarms will be crucial, requiring improvement of the communication within them and study of how their behaviour can be made globally consistent.
- The issues of security and safety, not only during the operation of systems but also in the course of their design, will continue to increase in importance.

The title "Computer Science meets Automation", borne by the 52nd International Scientific Colloquium (IWK) at the Technische Universität Ilmenau, Germany, expresses the desire of scientists and engineers to rise to these challenges, cooperating closely on innovative methods in the two disciplines of computer science and automation.

The IWK has a long tradition going back as far as 1953. In the years before 1989, a major function of the colloquium was to bring together scientists from both sides of the Iron Curtain. Naturally, bonds were also deepened between the countries from the East. Today, the objective of the colloquium is still to bring researchers together. They come from the eastern and western member states of the European Union, and, indeed, from all over the world. All who wish to share their ideas on the points where "Computer Science meets Automation" are addressed by this colloquium at the Technische Universität Ilmenau.

All the University's Faculties have joined forces to ensure that nothing is left out. Control engineering, information science, cybernetics, communication technology and systems engineering – for all of these and their applications (ranging from biological systems to heavy engineering), the issues are being covered.

Together with all the organizers I should like to thank you for your contributions to the conference, ensuring, as they do, a most interesting colloquium programme of an interdisciplinary nature.
I am looking forward to an inspiring colloquium. It promises to be a fine platform for you to present your research, to address new concepts and to meet colleagues in Ilmenau.

Professor Peter Scharff
Rector, TU Ilmenau

Professor Christoph Ament
Head of Organisation

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V. Piwek / B. Kuhfuss / S. Allers

Feed drives – Synchronized Motion is leading to a process optimization

The mechanical and control superposition of axis motion is very common and used within industrial engineering. Further more a process optimization is in focus to synchronize the drive on the technological process itself. In this paper the mode of operation, the structure and especially the integration in the control system of feed axis is displayed on two manufacturing processes – an incremental cold forming process and a contour turning process.

1. Linear feed for the incremental forming

The characteristics and the potential of optimization of linear feed axis for high dynamic manufacturing processes with highly variable process loads are considered using the example of rotary swaging by the hitch-feed method [1]. In a rotary swaging machine the shaping of the workpiece is performed in small steps by oscillating action of the dies, **figure 1**.

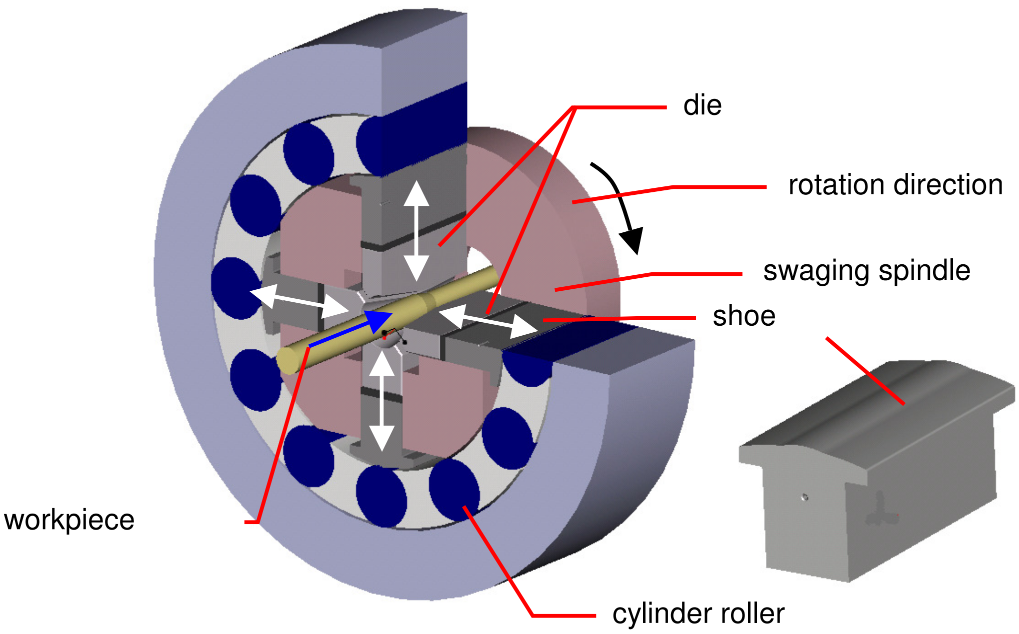
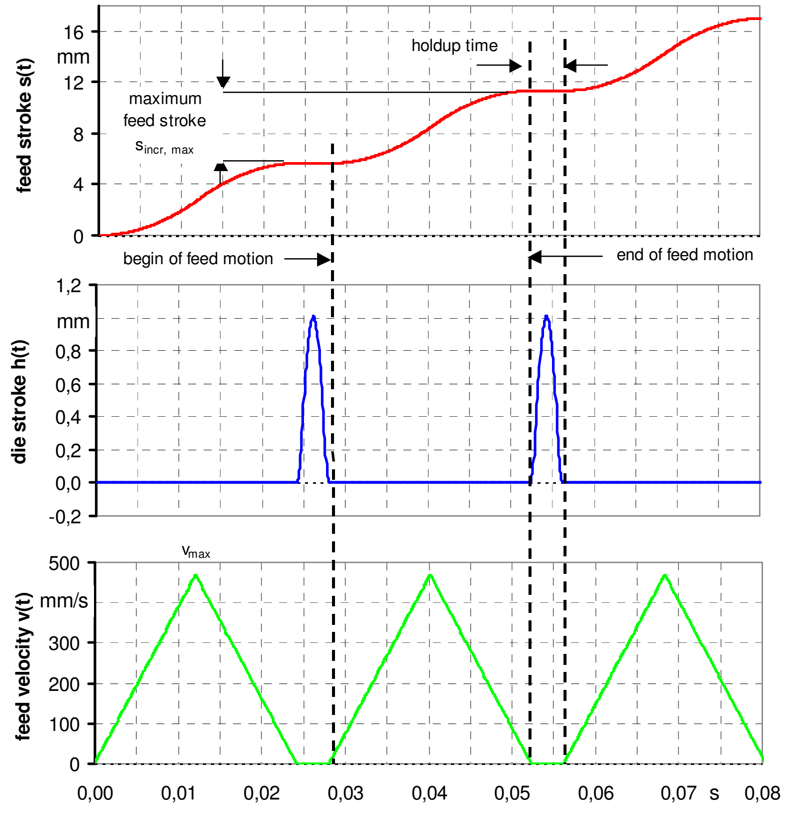


Figure 1: Rotary swaging machine (schematic)

The radial action of the die is generated by rotation of the driven swaging spindle due to the cam shaped outline of the shoe. Through the roll-off-process between the shoes and the cylinder rollers the dies are moved inwards simultaneously at every overrun of the cams. The cross section of the axially feeded workpiece will be reduced. Due to the rotation of the swaging spindle relative to the workpiece a constant circumferential shaping can be obtained.

The outcome of the forming process is an axial impact force which is acting against the feed direction. Furthermore the feed motion is deadlocked by the closing of the dies and the effect of friction and caused by the radial forming force. A significant advancement in the process performance is achieved by synchronized feed and die motion. With the synchronized incremental feed every incremental stroke includes a phase of acceleration and deceleration without axial reaction forces from the rotary swaging process. Because the feed is stopped during the shaping phase there is no additional axial force working towards the swaging machine. Performing this synchronized feed motion the rotary swaging machine is less stressed in axial direction. A feed caused expansion of the swaging machine which can cause a bigger deviation from the ideal diameter can be avoided. Furthermore the restraint feed kinematics can reduce abrasion on the die surfaces by reducing friction. The charts in figure 2 display the strokes of the feed s(t) and the die stroke h(t) as well as the profile of feed rate v(t) for a synchronized incremental travel.



input quantities for calculation:

feed stroke
$s_{incr,max}$ = 5,67 mm

maximum die stroke
h_{max} = 1 mm

die apex angle
α= 10°

closing angle
α_s = 12°

stroke frequency
HZ = 35,57 s^{-1}

spring back
$\varepsilon_{rück}$ = 11 µm

Figure 2: Calculated strokes and velocities for the synchronized incremental feed travel

The feed motion starts when the dies are opening and ends before the next closing phase. The velocity increases until the maximum speed v_{max} is reached at the half of the maximum incremental stroke $s_{incr,max}$. On a synchronized feed system there are extended dynamical requirements as are on a velocity controlled feed system. Constructively this is solved using full hydrostatic guideways. The power supply of the drive and the motion control is carried out by a power converter, which is externally loaded with the enable signal.

The prototype consists of the main components rotary swaging machine and the linear feed, **figure 3**.

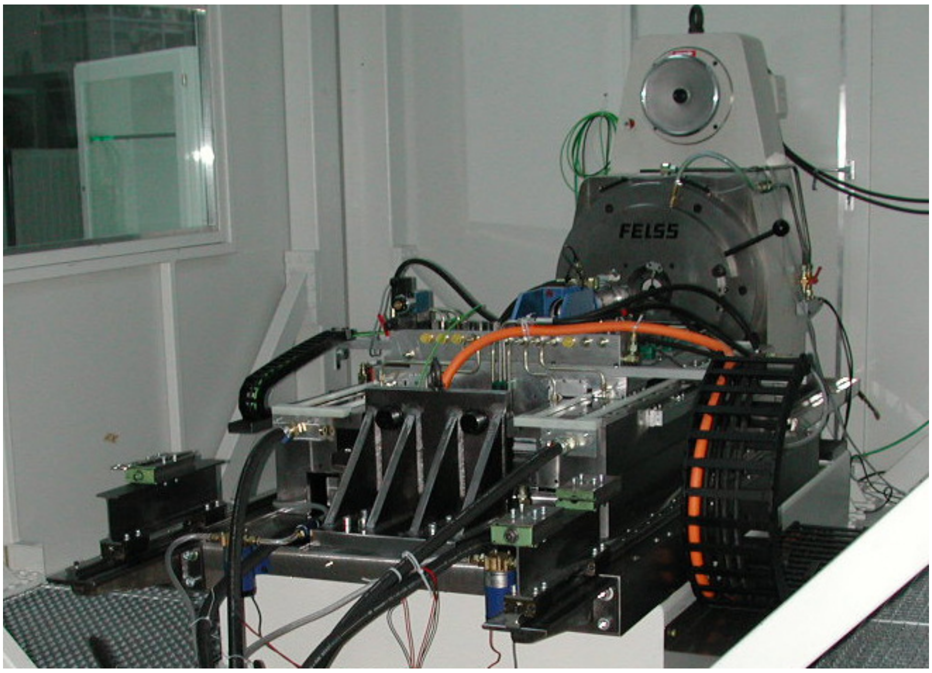


Figure 3: View into the workcore of the prototype

The rotary swaging machine and the feed unit with the bracket unit is mounted on the same substruction. The actual die movement as process factor is detected indirectly by strain gauges on the outer ring of the rotary swaging machine and the signal is conditioned. The extracted square pulse is switched on a hardware input of the power converter and interrupts the motion which is programmed for the entire feed stroke [2]. Thereby the desired cascaded profile of motion is generated.

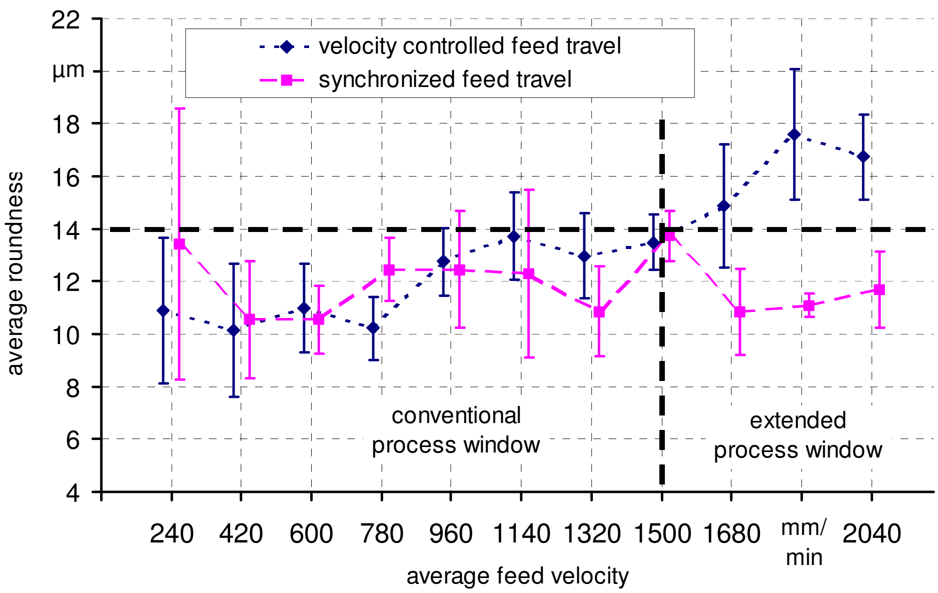


Figure 4: Average roundness

The effect of the synchronized feed system compared to a conventional feed with constant velocity is shown in figure 4. Relating to the quality feature ”average roundness of the workpiece“ an increase of productivity of about 20% can be observed.

2. Contour turning process with Fast-Tool-Servo

The second application is dealing with the manufacturing of contoured workpieces by a turning process [3]. Therefore the tool tip has to be tracked according to a given ovality or to compensate a deformation due to the work fixture clamping [4]. The complete system contains the in-process measurement technique for a continuous registration of the contour, the required controller and the feed systems, figure 5.

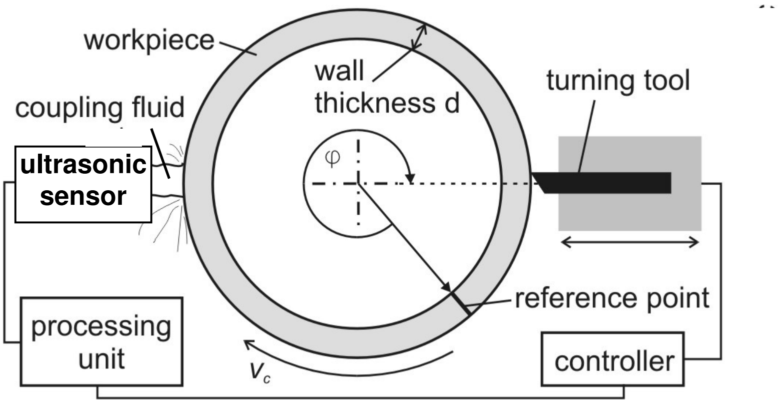
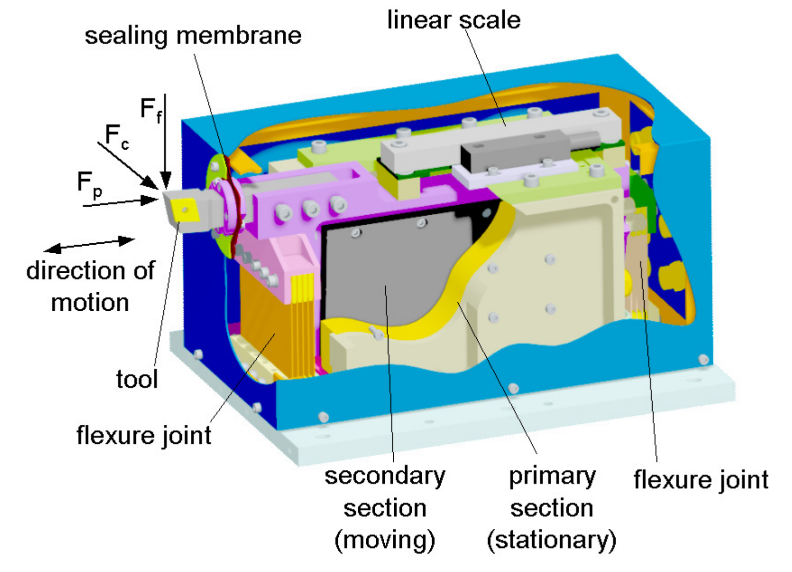


Figure 5: Complete system (schematic)

The cutting edge motion is realized using a linear direct drive guided by monolithic joints. The drive consists of two primary and two secondary parts in a double cam arrangement, figure 6.



Specifications

nominal motion frequency 60 Hz
nominal feed force 1350 N
maximum feed stroke 2 mm
velocity 0 - 282 m/min
stiffness in passiv force direction (spring stiffness) 0,32 N/µm
stiffness in cutting force direction 20 N/µm
stiffness in feed direction 100 N/µm
dimensions without die 400 x 220 x 225 mm
positioning reliability < 3 µm

Figure 6: Linear direct drive with monolithic joints

The monolithic joints are designed as pendulum support to prevent tipping of the cutting edge along the stroke. The vertical displacement is relating to the interesting workpiece diameter a deviation of 2nd order. Considering the geometric design data the displacement amount of 0,38 µm is negligible. The joints are fatigue endurable up to feed stroke of two millimeters. For position control of the cutting edge the current position is measured by a linear measuring scale. Typical frequencies of motion are 60 Hz where by the drive can realize process loads up to 1350 N.

The setpoint setting of cutting edge position is realized by a DSP-Board and TTL-Signals. This board is also calculating the signal from the encoder of the spindle and is generating the synchronization with the feed motion. With a software surface feed motions with different amplitudes and different multiples of the workpiece rotation frequency can be programmed.

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