Innovative Control Concepts for Mechanical Stroke Generators with Integrated Overload Protection and Considerable Energy Saving Potential

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Abstract

Mechanical stroke generators are used in a wide number of industries. One of the most important applications are oscillating displacement pumps.

From the kinematic point of view mechanical stroke generators are a quite discontinuous system when it comes to torque and power. During the execution of a stroke the load differs permanently. Example: Piston-type pumps need a much smaller torque during the suction stroke than during the discharge stroke. It is common practice, that the energy amount required is designed for the maximum load, although it is only necessary during a very short time.

In this report the theoretical basics are shown as well as the development steps of the singular topics. Furthermore, new technological solutions in this sector are presented.

KEYWORDS: energy efficiency, control concept, stroke generator, vector control, energy control, overload protection

1. Introduction

By definition, mechanical stroke generators are to „transform a continuous rotational movement into an oscillating translation movement“. The applications of mechanical stroke generators can be found in nearly all industries. They are used in hack saws, wiper drives as well as in tool drives for shape cutting (slotting machines) or piston compressors and pumps.

One of the most important applications are oscillating displacement pumps. In the following I like to refer to the main structural and functional components of oscillating displacement pumps with adjustable stroke length (piston-type / diaphragm-type metering pumps…) and to show the innovation when it comes to control, safety and energy efficiency.

2. Basics

2.1. Mechanical drives

The kinematic principles of the most popular metering pump drives with stroke adjusting possibility as slider crank drive, polar crank drive or spring cam drive etc. are shown in **Table 1**.

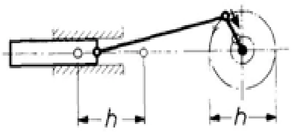
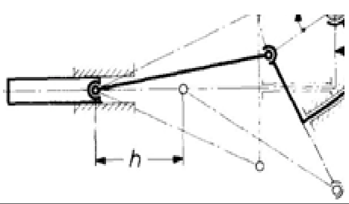
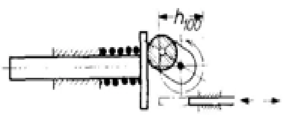
	Motion of piston	Type of stroke setting	Proportion set point / stroke length	Operating range of piston
Slider crank drive 	nearly harmonic	Adjusting of eccentric central axis	linear	constant central position of piston
Polar crank drive 	nearly harmonic	Turn hand crank	not linear	constant front dead point
Spring cam drive 	not harmonic at part load	stroke limit by adjusting screw	linear	constant front dead point

Table 1: Kinematic principles of metering pump drives

As a special version of the oscillating displacement pump **figure 1** shows an electromagnetic linear drive. This system is widely spread in the low capacity range up to 100 Watt.

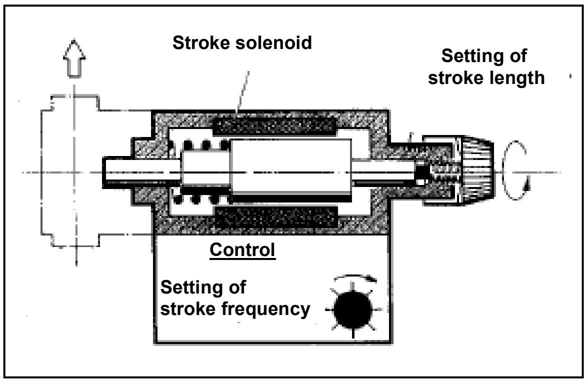


Figure 1: Electromagnetic linear drive

These drives offer generally two possibilities of adjusting the dosing quantity:

- Stroke frequency: The dosing quantity is adjusted via strokes per time unit (stroke / min.) by means of a frequency converter of the drive motor.
- Stroke length: The mechanical adjustment from von 0 to 100 % is realised by means of a hand wheel or an electrical stroke positioning or stroke control motor.

2.2. Liquid ends

There are mainly three types of liquid ends differing according to the displacement body (**figure 2a, 2b and 2c**):

- Mechanically displaced diaphragm metering pump (Fig. 2a)

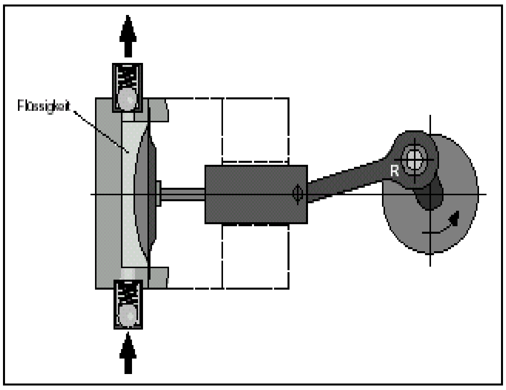


Figure 2a: Mechanically displaced diaphragm version / liquid end

- Hydraulically displaced diaphragm version / liquid end (Fig. 2b)

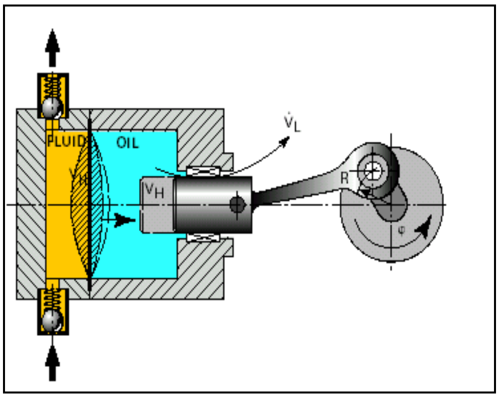


Figure 2b: Hydraulically displaced diaphragm version / liquid end

- Piston-type pump (Fig. 2c)

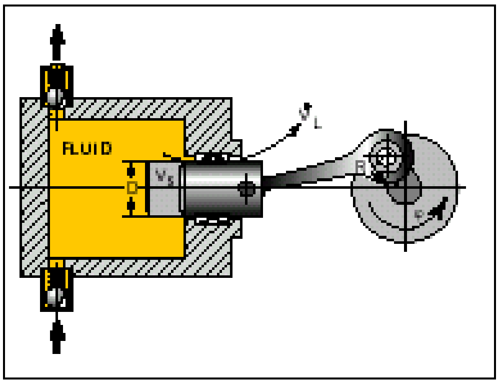


Figure 2c: Piston-type pump

Due to the oscillating movement of the displacement body the dosing characteristic is digital / pulsating (see also **figure 3**).

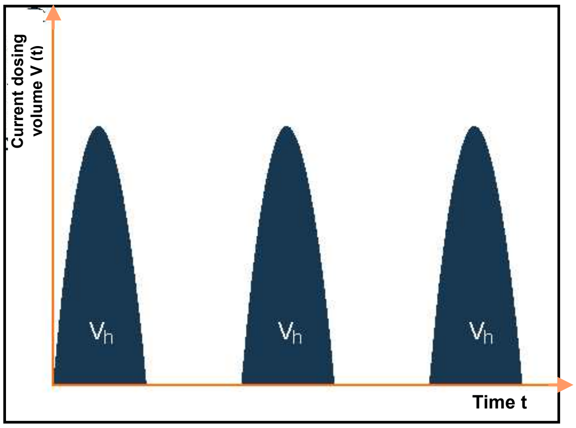


Figure 3: Digital dosing characteristic

2.3. Efficiency

Referring to the mechanical-hydraulic efficiency oscillating displacement / dosing pumps are the most efficient system of all metering pumps with values of 80 – 95% (**figure 4**).

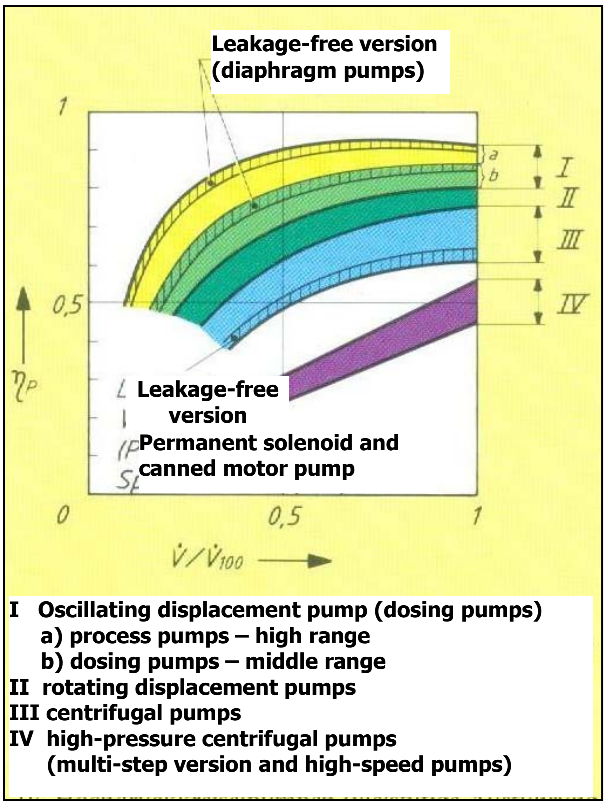


Figure 4: Efficiency of different pump types

From the kinematic point of view oscillating displacement pumps are a rather discontinuous system referring to torque and power, since the loads are differing permanently during the execution of a stroke. Example: Using a single-headed piston-type pump the torque is significantly smaller during the suction stroke than during the discharge stroke. Typically, this leads to the fact that the energy demand of these drives is designed to the maximum load, although it is only used for a very short period. This has a rather negative effect to the total efficiency of the system.

3. Innovation 1 - Control / optimization of energy feed → Efficiency increase

Combining the motion and speed profile of oscillating displacement pumps it can be seen that the total efficiency of the pumps deteriorates significantly during the suction stroke. Generally, it is assumed that efficient drives are to be fed only the energy amount actually required. Applying a vector control of torque and stroke rate ensures that the oscillating displacement drive is fed exactly the energy amount required in the corresponding situation. That means during the suction stroke a correspondingly reduced energy amount of 50% and during discharge stroke only 100 % plus minimum reserve are realised, without the traditionally added reserve of above 20%. In the following detailed information is given hereto by examples and measurements.

4. Innovation 2 – Energy monitoring → Overload protection

Considering the control possibilities mentioned in chapter 3 the actual energy amount of the stroke generator within a complete stroke (suction and discharge stroke) is measured and optimized to the corresponding energy requirement.

A tolerance band of +/- 20 % is now added to the thus known energy profile of the pump as a basis for comparison. If this tolerance is exceeded the pump recognises an abnormal operation mode and gives alarm or shuts off.

This method allows to uses an electronic overload protection also with such a discontinuous energy profile.

5. Example – Motor-driven metering pumps Sigma series (ProMinent)

The spring-cam drive of the Sigma series is combined with an integrated stroke and energy control according to the vector principle (**figure 5**). That means the control unit knows at any time of the kinematic curve, which energy amount is required by the pump and controls the energy amount according to this characteristic curve.

Figure 5: Motor-driven metering pump Sigma with vector control

Figure 6 shows a typical current / energy curve of a pump conventionally controlled with frequency converter and of the new vector-controlled pump. It can be clearly seen that when the pump runs with low torque a significantly lower energy amount is fed to it which results also in a lower total consumption.

Conventional control by frequency converter | **Vector control**

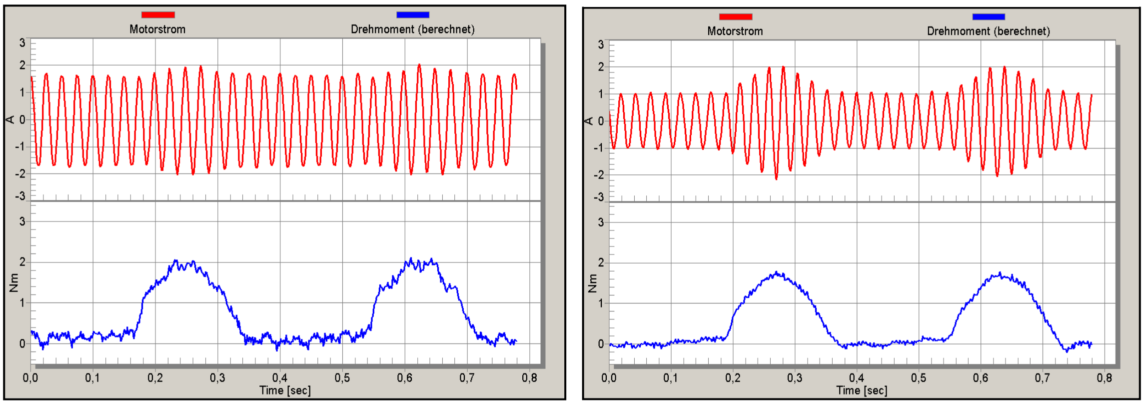


Figure 6: Energetic curve at full load - 10 bar / 100 % stroke length

Red curve: current measured in the supply line

Blue curve: torque calculated from the motor current by means of a rotary position sensor

Even more significant is this deviation at part load, where energy savings from over 30% can be realised. This shows **figure 7**.

Conventional control by frequency converter | **Vector control**

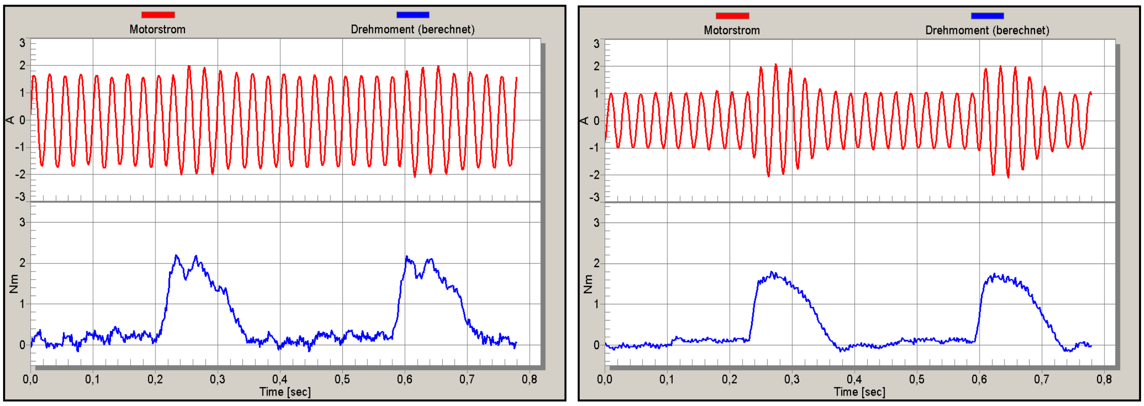


Figure 7: Energetic curve at part load - 10 bar / 75 % stroke length

Red curve: current measured in the supply line

Blue curve: torque calculated from the motor current by means of a rotary position sensor

An effective overload protection is realised by adding a tolerance band to the known energy consumption. Exceeding this tolerance implies an inadmissible mode of operation and secures the pump by shutting it off.

A further advantage is the realisation of different dosing profiles / characteristics. Combining the kinematic basic profile of the mechanics with the electronic vector control a new variable mechatronic system is formed allowing to apply nearly universal speed and dosing profiles (see **figure 8**).

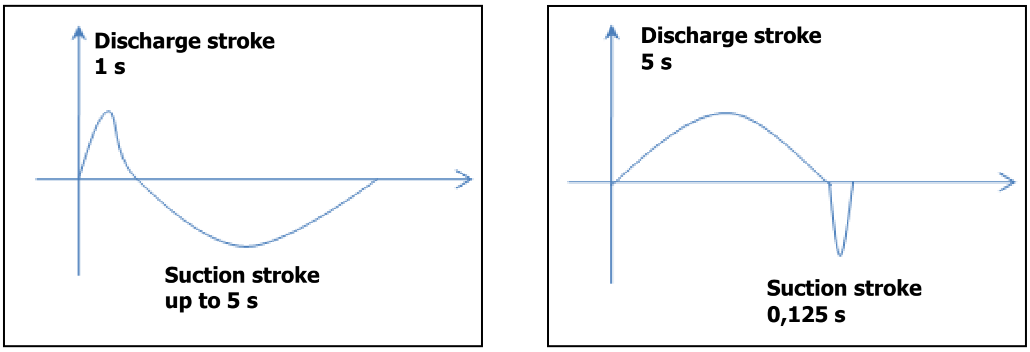


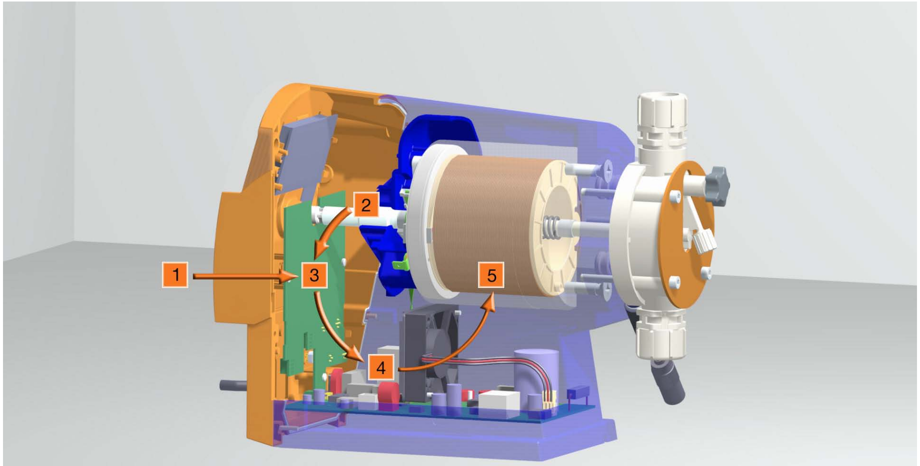
Figure 8: Variable speed profiles

6. Example – Controlled solenoid drive of delta series (ProMinent)

Using the example of a controlled solenoid drive for oscillating displacement pumps we show the multiple new functions resulting from the monitoring of the movement and energy profile.

The optoDrive® drive principle of the delta pump (**figure 9**) combines the characteristics of different drives. The patented controlled solenoid drive made by ProMinent enables the client to choose individually between pulsating and nearly continuous dosing. Up to now different dosing profiles required metering pumps with drives differing significantly with regard to their technology. The delta pump with optoDrive® however can flexibly be used in fast computer-controlled applications or control circuits (e.g. fast dosing stroke without delay) – as well as in applications with continuous dosing of smallest quantities.

The metering pump delta is designed for a maximum capacity of 12 to 80 l/h against a pressure of 16 to 2 bar. By means of the integrated optoDrive® system dosing accuracy is also with very small quantities very high, whereas conventional pumps can realize this task only with complex as well as expensive control circuits. The dosing characteristic can be adjusted – thanks to the optoDrive® – to the respective application. The speed of the suction and discharge stroke can also be adjusted to the chemical dosed. Thus higher viscous media can be dosed reliably as well as degasing media. The drive unit compensates variation of the back pressure in the dosing line automatically and thus ensures a maximum dosing accuracy.



Scheme of the stroke position control / pump cut:

(1) Presetting of dosing characteristic; (2) Detection of diaphragm deflection
(3) Setting and controlling; (4) Power supply of solenoid activation; (5) Solenoid coil

Figure 9: ProMinent metering pump delta with controlled solenoid drive optoDrive®

7. Conclusion

The reduction of the energy to the amount actually required in combination with energy monitoring and overload protection enables us to realise high-efficient and secure systems for full and part load in the future.

8. References

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