Electro-Hydraulic Power Pack for Truck Cab Tilting Systems

Dr.-Ing. Benedikt Müller, M.Sc. Steffen Glöckle

Weber-Hydraulik GmbH, Heilbronner Straße 30, 74363 Güglingen, Germany,
E-mail: benedikt.mueller@weber.de, steffen.gloeckle@weber.de

Abstract

The cab of a typical European truck can be tilted hydraulically. After introducing to the hydraulic system, its components, the requirements and the development of customer requests, the paper presents a new miniaturized electrically driven radial piston pump and the tilting module based on this pump. Further development of this pump, resulting in a new concept of binary displacement control, is illustrated.

KEYWORDS: power pack, radial piston pump, commercial vehicle, cabin tilting system, linear actuator

1. Introduction

The cab of a typical European truck is mounted over the engine, thus needs to be tilted to get access to engine and periphery for inspection or service (**figure 1**).

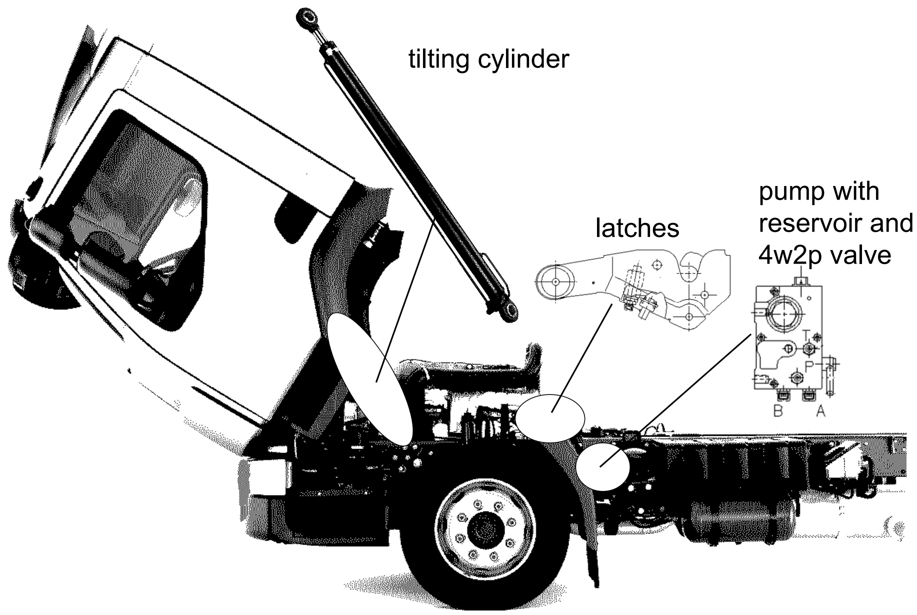

Figure 1: Tilting system components

Requirements on the tilting actuators are various: Safety requirements for example include save load holding, load carrying and overload protection. Forces in the range of several tenth of Kilonewton are usual. The actuators also have to follow relative movements between cab and frame induced by the cab suspension, and friction (damping) forces should be low under these conditions for comfort reasons.

High force density and simple overload protection of hydraulic actuators makes them most suitable for this application, thus all today’s bigger trucks use hydraulic tilting systems. WEBER-HYDRAULIK is designing and manufacturing hydraulic cab tilting systems since 1965.

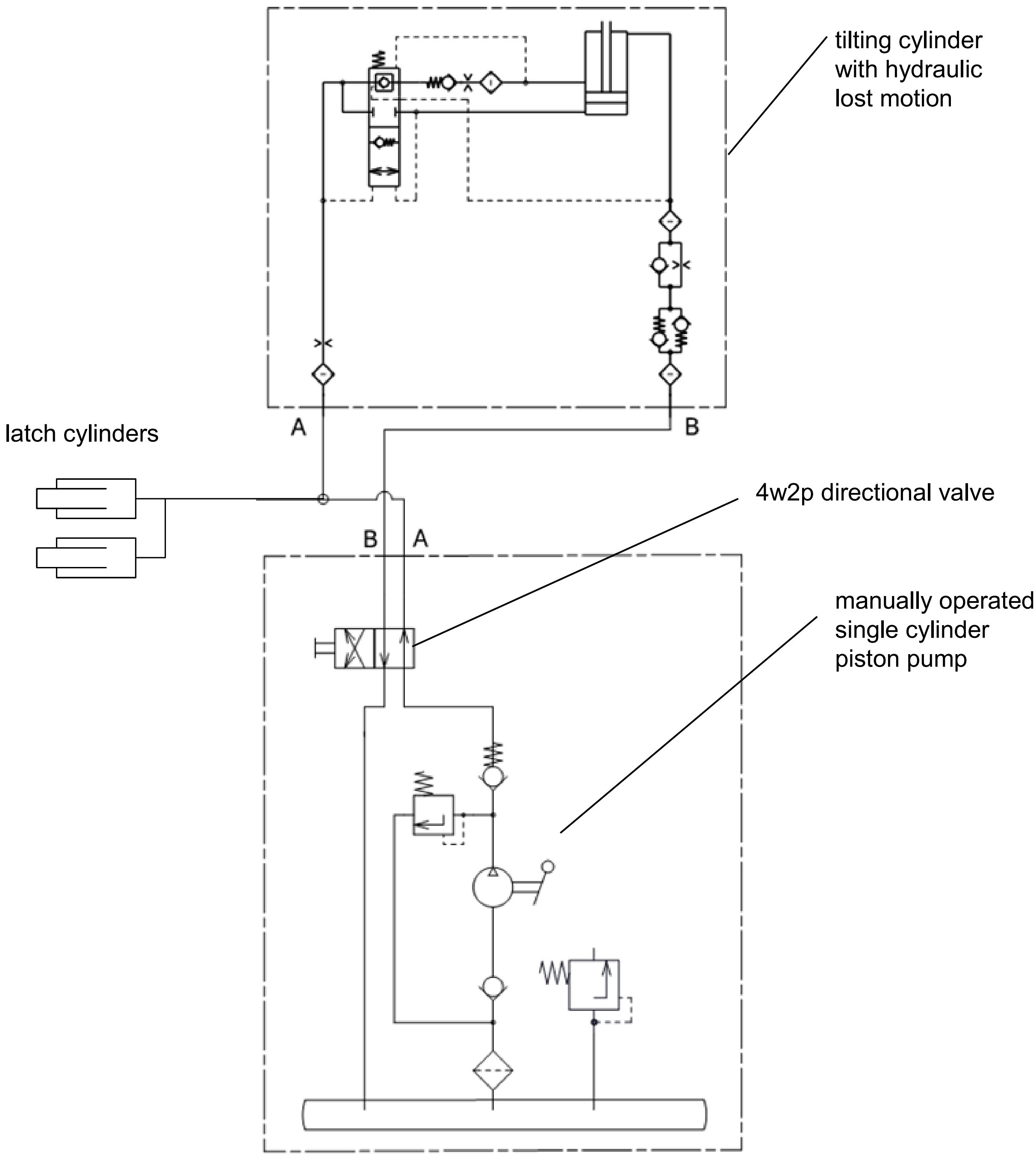

Figure 2: Hydraulic schematic of a typical tilting system with hydraulic lost motion /1/

A typical tilting system as shown in the schematic in **figure 2** consists of a pump, a special hydraulic cylinder enabling the suspension motion, and two latches retaining the cab in the driving position. Small single acting cylinders serve as latch openers. Maximum pressure reaches up to 400 bar.

The system in figure 2 comprises a so-called “hydraulic lost motion” cylinder: This cylinder allows suspension travel of the cab in the range the piston remains between the two lower ports of the cylinder, displayed on the left side of the cylinder in figure 2. Moving in this range, the piston displaces the oil into the tank, generating a partial vacuum inside the cylinder, which reduces the undesired force acting on the cab.

While simple systems still use manual pumps, more and more electrically driven pumps were ordered in recent years. Design of WEBER’s first generation electric pump was based on the manual design. A single piston is actuated by an eccentric mounted on the electric motor’s shaft. Similar to the manual pump shown in figure 2, flow direction is controlled by the suction and delivery check valve. A manually actuated 4w2p directional valve serves to select the direction of motion, as in the schematic in figure 2.

However this technology reached its limits:

- Higher weight and position of the centre of gravity of the cabs lead to an increase of tilting work. The customer request of short tilting time on the other hand requires higher output power of the pump.
- Some customers complain high noise level of the single piston pump.
- Manual actuation of the directional valve is more than a comfort issue. Avoiding manual actuation is even more important for truck designers because of installation flexibility: Access to the pump and valve is no longer required with a fully electric solution.

Based on these facts WEBER decided to develop a new electro-hydraulic tilting system generation.

2. New generation EH tilting system

One of the major requirements on the new system is to avoid manual actuation. An obvious solution would be the electric actuation of the directional valve. However costs of magnet, connectors and wiring were not acceptable.

2.1. The EH pump concept

Decision was made in an early stage of the project in favour of two quadrant displacement control instead: The electric motor's direction of rotation determines the cylinder's direction of motion.

Displacement of the pump was chosen to about 0,1 cm^3 in order to achieve adequate speed of the motor, thus acceptable size. Pressure range, size and reversibility lead to the decision for an outside braced radial piston pump.

Simple check valves can no longer be used to control the direction of flow because of the reversibility requirement. The typical design of outside braced radial piston pumps would use a hollow shaft in this case. However this concept requires extremely accurate manufacturing to achieve adequate volumetric efficiency at the small flow combined with high pressures of up to 400 bar, thus WEBER decided in favor of the concept of an axial valve plate, which also can compensate for wear on the valve plate.

2.2. Pump design details

Figure 3 shows a cutaway model of the new WEBER radial piston pump based on these considerations. An electric motor (not shown) drives the cylinder block, rotating in two ball bearings. The axis of a third ball bearing has an offset relative to the axis of the rotating cylinder block, thus serves as eccentric. This bearing pushes the pump pistons towards the centre over 180° of revolution of the cylinder block, while centrifugal force moves them out over the next 180°, resulting in the displacement motion of the pistons. Through usage of the ball bearing as eccentric ring, piston shoes are not required and very simple steel pins serve as pistons.

The cylinder block has an axial valve plate, sliding on the valve plate of the stator. Two bores on the stator valve plate connect and disconnect to the three axial delivery bores in the cylinder block, according to their rotary position. This results in either delivering oil into conduit A and sucking through conduit B or vice-versa, depending on the direction of rotation. Suction check valves connect conduit A or B to the reservoir. Seals are surrounding the stator at slightly different diameter. They are sealing the cavities A and B against each other and the tank, and create pressurized "steps" on the stator by which it is pushed against the rotor. The surface size of theses steps decides on the hydraulic balance ratio of the valve plate. /2/

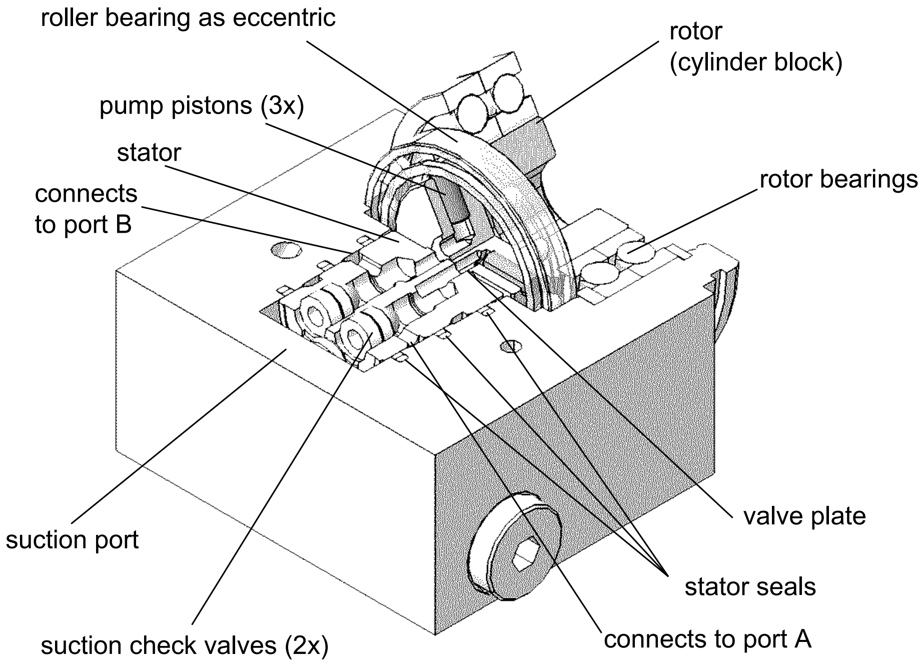

Figure 3: Radial piston pump

The principle of a radial piston pump with axial valve plate is well known /3/. The valve preload however induces high axial forces acting on the cylinder block bearings, resulting in relatively large bearings. Though the bearings of the small tilting system pump still have acceptable size and costs, this might be one of the reasons this pump concept was not successful for bigger pumps.

Another disadvantage gets visible with a closer look at the passageway between cylinder rooms and valve plate: the bores connecting cylinder bore to valve plate must have a certain length and diameter, thus dead volume cannot be reduced as desired. Nevertheless compression losses below 2% per /4/ at a pressure of 250 bar were deemed to be acceptable for this pump size.

2.3. The tilting module

One of the major requirements of truck designers is to reduce the number of components and interfaces. The new pump design, which does no longer require access to the pump for tiling or operation of the 4w2p valve, allows the integration of pump, reservoir, electric motor and tilting cylinder into one tilting module (**figure 4**). A considerable reduction of the number of interfaces – the only remaining hydraulic hoses are connecting to the latches – comes along with less components and reduced assembly and testing time at the customer's truck assembly line. The concept allows delivering fully tested and prefilled tilting modules, also saving filling and testing equipment at the customer.

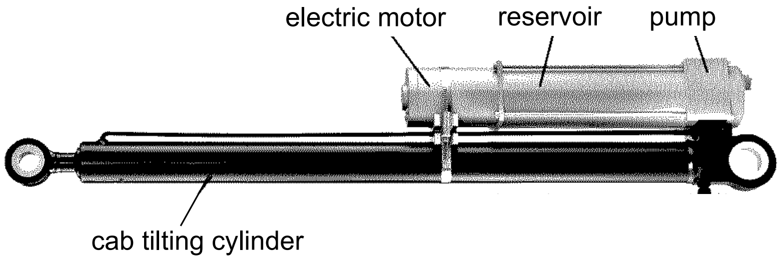

Figure 4: Tilting module

A compact design of the module can only be achieved with the pump flanged onto the bottom end of the cylinder and reservoir and motor arranged along the cylinder. The chosen design is using a tube as reservoir with the pump and the electric motor serving as “end caps”. The drive-through shaft is running inside a protective pipe to avoid agitation of the oil.

3. Next level of development

Even though the new EH tilting system generation’s production is just starting, one of the current base development goals is reaching the next level of comfort improvement by shortening tilting time.

3.1. Conditions and requirements

Tilting force and thus pressure is not a single constant value, but follows a curve over the tilting angle and of course depends on weight and load of the cab and the position of its center of gravity. The system must allow tilting in uphill and downhill conditions up to a certain slope angle.

Tilting back under downhill conditions determines the maximum system pressure with typical tilting kinematics, while worst case conditions for tilting forth appear in the uphill situation but with a lower peak pressure, **figure 5**.

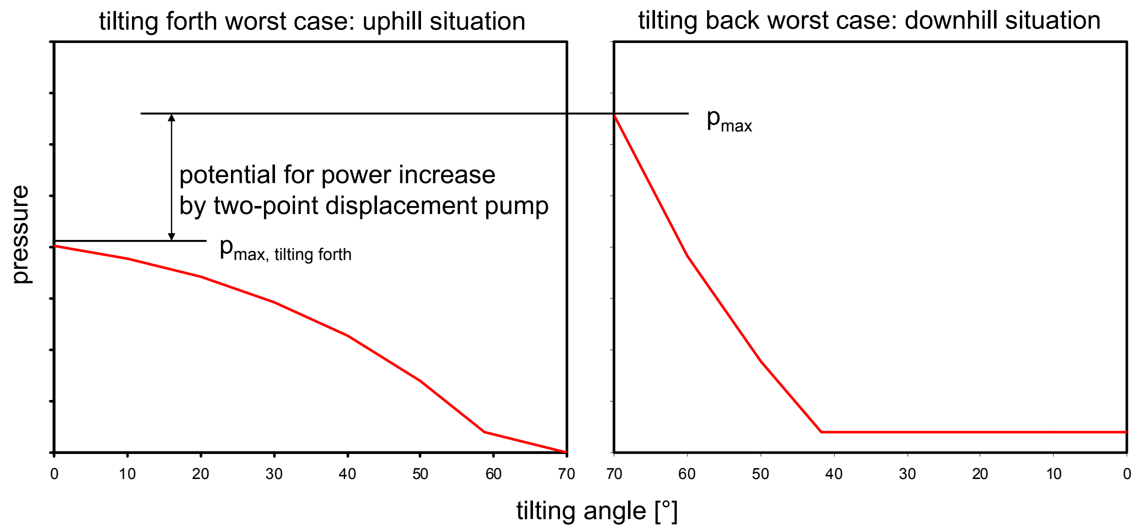

Figure 5: Worst case situations of a typical tilting cycle

Hence the entire system is designed to the achieve p_{max} without exceeding for example the specified maximum electric current, and thus the maximum pump size is given by the p_{max}-condition. The pump size on the other hand determines tilting time, whose major part is given by the tilting forth operation.

Above illustration shows the system works under maximum power conditions only over a short period of the tilting back cycle, while running at only partial power most of the time. The remaining delta could be used to shorten tilting time, e.g. by using a variable displacement pump.

3.2. Binary displacement pump

Typical variable displacement pumps have more or less sophisticated controls. Beside of the costs, which would not be acceptable for this application, they involve the risk of instability.

Looking for a simple solution avoiding any stability issues, WEBER followed the idea of a type of binary displacement control: switching to maximum displacement while tilting forth and to minimum displacement when tilting back could lead to a good compromise on time benefit, costs and system simplicity.

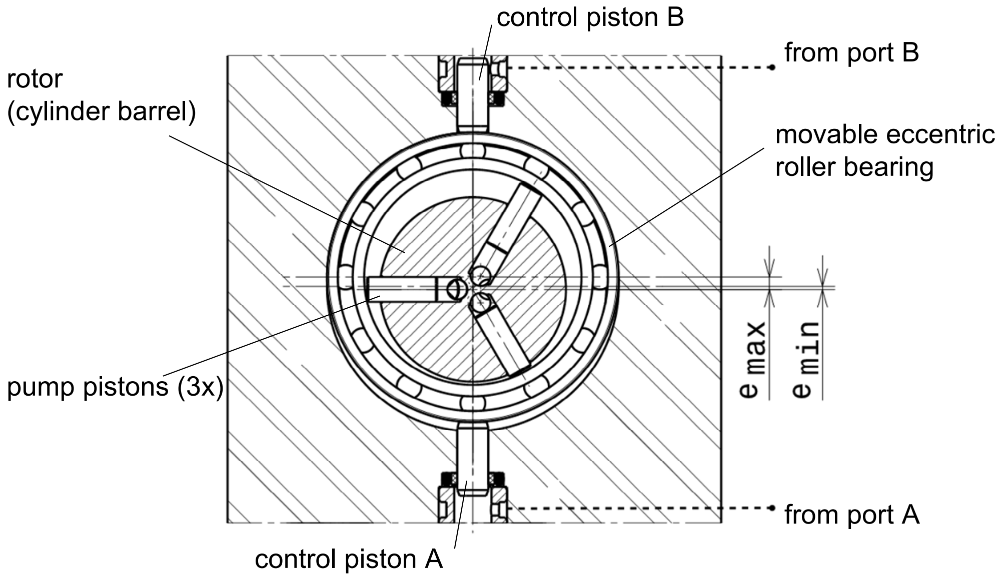

Figure 6: Draft of the displacement control

As switching high pressure between A and B port by reversing speed is already a feature of the original constant displacement system, using these pressures to switch between min. and max. displacement is obvious. **Figure 6** shows the sectional view to the implementation: The eccentric roller bearing now can move between the minimum and maximum eccentricity e_{min} and e_{max}, representing different displacements of the pump. Control pistons A and B push the eccentric ring in either the e_{min} or e_{max}, position, depending on pilot pressure A and B, thus direction of rotation. Positions between e_{min} and e_{max} do appear only during the reversing process, but not under stationary conditions. **Figure 7** shows the hydraulic schematic of the two point variable displacement pump.

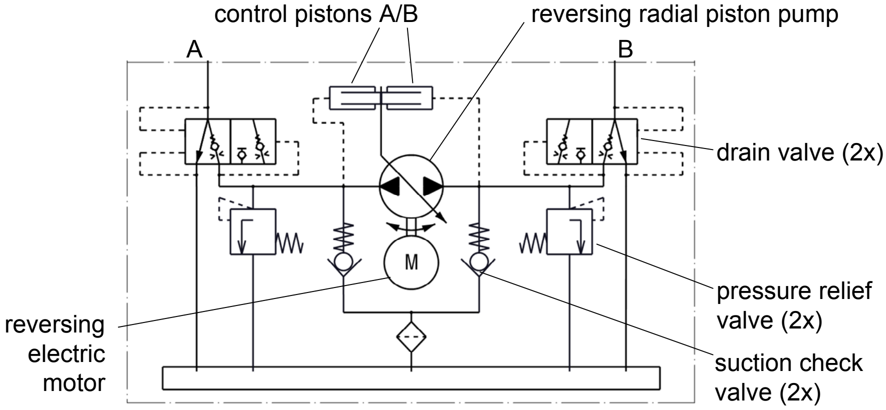

Figure 7: Hydraulic schematic

3.3. Experimental results

The modular test setup allows either different constant eccentricities as basis of comparison, or binary displacement control, where e_{min} and e_{max} are mechanically adjustable through spindles. Control pistons are externally piloted, thus can be connected to pump port A and B or an independent control pressure supply. Latter setup served to determine the minimum control forces required for reliable switching of the eccentricity at different pump pressures. The control piston diameter of the final design was adjusted accordingly to avoid undesired deformation of the eccentric bearing.

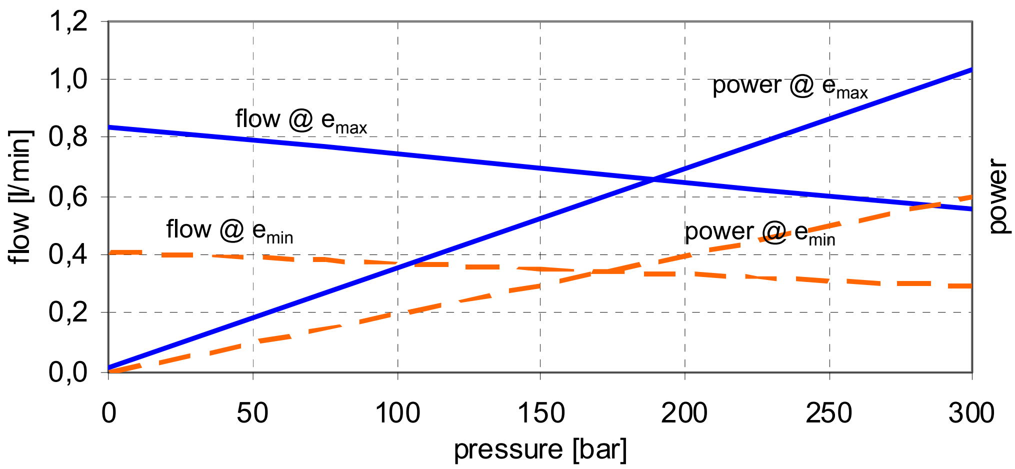

Figure 8: Exemplary flow characteristics at e_{min} and e_{max}

Further testing with the adjusted control forces confirmed the control mechanism is operating stable and reliable. The pump has flow and power characteristics identical to the according measurements at constant displacement. **Figure 8** represents exemplary results of flow versus pressure characteristics of the binary displacement pump.

4. Outlook

The patent pending two-point displacement concept represents a simple and cost effective solution to switch the displacement of a pump in function of the direction of rotation. Beside of its use on cab tilting systems, it may also be advantageous on other applications, e.g. to set similar speed in both directions on linear hydraulic actuators using a differential cylinder, or on all systems requiring different maximum pressure depending on their direction of motion.

5. Bibliography

/1/ L. Sauer, U. Schulz: Hydraulische Kippvorrichtung, Patent DE 197 30 499 B4, 2005

/2/ M. Fischer, R. Saric: Hydraulische Pumpe, Patent EP 1 785 622 B1, 2008

/3/ J. u. M. Ivantysyn: Hydrostatische Pumpen und Motoren: Konstruktion und Berechnung, 1. Aufl., Würzbburg: Vogel, 1993

/4/ H. Murrenhoff: Grundlagen der Fluidtechnik, Band 1: Hydraulikl, 5. Aufl., Aachen: Institut für Fluidtechnik, 2007

6. Symbols

e_{max}	maximum eccentricity	mm
e_{min}	minimum eccentricity	mm