Taking the weight off the axis

Hydraulic weight counterbalancing in machine tools

The quality of the machining work in milling machines and machining centers is decisively influenced by the intelligent compensation of the acting forces. The diversity of the forces that occur and their mutual influence is enormous. A fine adjustment option reduces the load on the axle drive and thus also their energy consumption.
In milling machines and other cutting machine tools, shaping of workpieces is accomplished by cutting off excess material with a tool which is moved along the workpiece. This results in a relative motion between the workpiece and the tool, the so-called feed motion. Depending on the design of the machine tool, either the spindle with the tool or the workpiece itself is accelerated and kept in motion. Various forces act according to the direction of motion. If the motion is horizontal, there are frictional and acceleration forces in addition to the feed force that affects the removal of material. In the case of vertical movements, the weight force must also be taken into account which can make up a considerable proportion depending on the size of the mass to be moved.

Which forces should be considered?
The drive for the feed has to overcome the sum of these forces. Regardless whether the drive is an electric servo motor with ball screw or a linear drive - the usual choices in modern machining centers - the same principle applies in every case. The greater the forces, the more power the drive has to provide. While there is little that can be done to influence the forces for material removal, friction and acceleration, there is a very elegant and efficient method of compensating for the weight force of vertical axes in the form of hydraulic counterbalancing.

What are the benefits of a hydraulic solution?
The basic principle of hydraulic counterbalancing is shown in the diagram. A hydraulic cylinder introduces the weight force into a hydraulic system in which an accumulator and valve block are also installed. The hydraulic pressure in this system equalizes the weight force, which means that no electric power is required in order to overcome this force.

When the hydraulic cylinder is extended, it displaces the medium from the cylinder into the accumulator, the gas in the accumulator is compressed and absorbs energy in the process. When the cylinder is retracted the medium flows back out of the accumulator into the cylinder.

The hydraulic system is prefilled once to the required pressure for operating the machine. It then remains closed and no further energy input is required. Hydraulic counterbalancing thus not only offers an advantage in that smaller drives can be used. The energy efficiency of the machine is also improved since no electric power is needed to overcome the weight force.

Which pressure settings are ideal?
However, there is one point that has to be considered, namely that the gas in the accumulator is compressed to a greater or lesser degree according to the position of the cylinder. Consequently the pressure in the accumulator changes, causing the compensating force of the cylinder to change as well. This effect is undesirable since it can compromise the quality of the machining process.

This pressure or force variation is minimized by keeping the ratio between displaced volume and accumulator volume as high as possible. The size of the accumulator is limited because of the restricted installation space and the requirement to keep costs down to a minimum. It is therefore an advantage to keep the diameter of the cylinder small and the pressure as high as possible. Pressures in the range from 150 to 200 bar have proved suitable for this purpose. In most cases it is also worthwhile to suspend the load from the cylinder.

The area on the rod side of the cylinder is smaller which results in higher pressure and consequently a smaller exchange volume. In addition, it is not necessary to take buckling length into account since in this case the hydraulic cylinder acts as a traction cylinder.

Which other components are required in the hydraulic system?
A component-tested safety valve and discharge valve for the hydraulic accumulator in accordance with the pressure equipment directive. A manometer is also mandatory. This indicates when the system is unpressurized and it is safe for personnel to
carry out service work. The manometer can also be used to monitor the pressure which is set to the required value with the pressure control valve. The control system monitors the accumulator pressure with a pressure switch or a pressure sensor.

However, for analysis purposes the cylinder position must be taken into account as described above. The compact valve bank of type BA from HAWE Hydraulik contains all these standard components. This also saves the need for any pipework and installation work or for a separate block construction.

**What kind of power unit is suitable?**

Naturally, a hydraulic unit is also required to preload the system with the required pressure. A low delivery output is adequate for this since the unit is not required for operating the system. However, it must be ensured that the container has sufficient capacity in order to fill the system including the accumulator with hydraulic oil and to hold the whole volume during servicing. That is a particularly important point if the power pack also supplies other functions as well. HAWE Hydraulik’s compact power pack type MPN, for example, is a suitable choice since it is able to fulfill all these criteria.

If the motive power for the vertical axis is provided by linear drives, hydraulic counterbalancing systems also fulfill an additional safety aspect by preventing the vertical axis from dropping if the linear drive fails. If an immediate stop is required this can be implemented by straightforward hydraulic clamping of the piston rod of the counterbalancing cylinder. Then efficiency and security go hand in hand.
HAWE Hydraulik SE is a responsible development partner with application expertise and experience in more than 70 branches of mechanical engineering. The product range includes hydraulic power units, fixed and variable displacement pumps, valves, sensors and accessories. Electronic components that are exactly attuned to the hydraulic components provide an easy initial operation, precise control and condition monitoring. The intelligent system solutions reduce energy consumption and operating costs. Compact drives save space and allow an innovative machine design. Around 1,950 employees in 16 countries and more than 30 distributors worldwide support the customers locally, professionally and personally.

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