On Improving the Performances of Hydraulic Incremental Positioning Units with Mechanical Position Feedback

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Abstract. This paper presents a method for increasing the speed and the positioning accuracy of the positioning systems with mechanical position feedback. The method consists in using a position transducer for real time determination of the position of the load and correcting this position using an adequate algorithm. It is preferable not to modify the construction of the positioning unit, allowing the user to decide when to use this correction method according to the practical application. An interesting solution to this problem is to use an external space-position finding sensing system, as presented in the paper.

Introduction

The positioning systems with mechanical position feedback [1] are often used in precision actuations. Fig. 1 shows a linear incremental positioning unit [2]. The actuator of the proportional distributor with differential command $\text{DP}^*$ is an electric stepping motor $\text{M}$. This converter has a discrete characteristic which influences the movement of the linear hydraulic motor $\text{MHL}$. For many applications this is not a problem and besides that, an incremental actuator significantly simplifies the control system.

Fig. 1. Linear incremental positioning unit
Speed and positioning accuracy improving methods

If the components of the unit are correctly machined and assembled, the weakness of the unit remains the actuator. The stepping motors are generally used to actuate small loads, under 1 daN. They may be used both for positioning the actuated load and for controlling the load speed. Considering a correct functioning of the stepping motor, the frequency \( f \) of the control pulses must not pass the limit value \( f_c \), determined using the static characteristic of the motor \( M_m = f(f) \).

The load positioning accuracy depends on the positioning accuracy of the motor shaft and it is very important for the motor not to loose any step. So, it is very important to choose a high quality stepping motor. If the incremental character of the movement is a problem, the stepping motor may be easily replaced with a c.c. servo-motor, with no negative consequences. The needed constructive changes are minor, but the power supply and control system must be also replaced.

If the stepping motor is used there are also some methods to improve the positioning inside a step of the motor. One method is to insert a piezoelectric actuator between the feedback screw \( SR \) and the sliding valve \( S \), in order to improve the positioning control of the proportional distributor sliding valve. This method infers constructive complications and a more elaborated control system. Another method is to correct the position of the incremental unit while positioning the load.

The correction method

The positioning accuracy of the incremental unit depends on the value of the displacement increment which also depends on the number of steps per rotation of the motor.

It is obvious that a position transducer is needed for real time determining the position of the load. It is preferable not to modify the construction of the unit and to let the user to decide if this method will be used according to the practical application. An interesting solution to this problem is to use an external space-position finding sensing system [3].

The sensing system is not placed on the hydraulic positioning unit, but in its working space, considered to be a parallelepiped room with known sizes, as shown in Fig. 2.

The sensor for space-direction finding is placed in the fixed point \( O_1 \), that is the origin of the normal coordinates of the sensor. This sensor automatically and permanently follow a light point source \( S \) fastened onto the mobile assembly of the hydraulic positioning unit; the space position finding of the source is carried out by computing the coordinates of the intersection point of the direction pointed by the sensor and the direction of the Ox axis, which is the moving direction of the mobile element of the positioning unit.

![Fig. 2. The general arrangement of the space-position finding system](image)

The configuration of the space-direction finding sensor is shown in Fig. 3.
The sensor is provided with an electro-optical viewing device consisting of the objective 1 and the photo sensor 2; the photo sensor has a circular shape and it is divided into four photoconductive zones, separated by a very thin space, and all on a single silicon chip.

When the axis of the viewing device coincides with the direction of the point source S, the four signals produced by the photoconductive zones are equal and at this moment, if the direction of the axis is known, the direction $O_1S$ is also known.

The viewing device movement in order to follow the moving light point source S is produced by the stepping motors 3 and 4 by means of the worm-gears 5 and 6.

The measurement of the rotation angle $\alpha$, against the vertical axis, is carried out by the rotational incremental transducer 7; the measurement of the rotation angle $\beta$, against the horizontal axis is carried out by the rotational incremental transducer 8.

The worm-gears are provided with backlash-influence eliminating devices; the incremental transducers are directly connected to the rotating shafts by means of the special couplings 9 and 10, in order to minimize the measuring errors.

The electrical signals produced by the four photoconductive zones of the photo sensor give information on the sign of the deviation, and the stepping motors are driven in order to minimize this deviation. When the four signals are equal, meaning that the viewing device axis coincides with the direction of the source S, the contents of the incremental transducers counters are transferred into the memory of the PC and the values of the angles $\alpha$ and $\beta$ are computed. If the point source S is moving, the sensor permanently follows it and gives information on its direction against the origin $O_1$ (the intersection point between the vertical axis and the horizontal axis of the sensor).

The block diagram of the sensor is shown in Fig. 4.

The stepping motors drivers, $SM_1D$ and $SM_2D$ receive from the DAQ board two signals: one for the direction of rotation and the other for stepping, until the signals $U_1,...,U_4$ produced by the four photoconductive zones of the photo sensor and which are applied to four analogical input lines of the DAQ board, become equal. In the meantime, the incremental transducers produce impulse sequences which are applied to the input lines of the impulse counters $IC_1$ and $IC_2$. These circuits detect the rotation direction and count up or down, as needed, so as the number of the counted impulses is proportional with the angular movement, measured from a zero position mechanically established. The two values $n_\alpha$ and $n_\beta$ are picked-up by the acquisition system in the moment the signals $U_1,...,U_4$ become equal, and the direction is computed and given by the pair of angles ($\alpha,\beta$), which defines the direction $O_1S$. 
Fig. 4. The block diagram of the space-direction finding sensor

The space-position of the source \( S(x_s,0,0) \) against the \( Oxyz \) normal coordinates is determined by computing the coordinates of the intersection points of the directions \( O_1S \) and \( Ox \). The initial conditions are the following:

- the working space of the robot is a parallelepiped with sizes \( a, b, c \);
- the sensor is placed in the point \( O_1(0,b,c) \) and the mobile assembly of the hydraulic positioning unit is moving along the \( Ox \) axis;
- on every system-start the point source \( S \) is brought in the origin \( O(0,0,0) \), so that the direction \( O_1O \) becomes the origin for measuring the angles \((\alpha, \beta)\).

Finally, the coordinate of the point \( S \) is obtained as a function of the pair of angles \((\alpha, \beta)\):

\[
x_s = \frac{b \cos(\arctg \frac{c}{a})}{\Delta} \sin(\gamma + \beta) \sin \alpha
\]

with:

\[
\Delta = \begin{vmatrix}
\sin(\gamma + \beta) \cos \alpha & 0 \\
\cos(\gamma + \beta) & \cos(\arctg \frac{c}{a})
\end{vmatrix}
\]

Conclusions

The sensorial system as described shows an important advantage in not being placed on the hydraulic positioning unit and allows the user to decide when to use it. The space-position finding sensing system can be used as an automatic system for following the displacement of the mobile assembly of the hydraulic positioning unit, in order to determine the deviations from the programmed position and to return this results to the control system of the unit so that the position can be corrected.

References


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