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AN EXPLORATORY STUDY FOR CMM SOFTWARE INTEGRATED CONTROLLER – PART 2

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ABSTRACT

The CMM computes programming commands from the inspection software with positioning signals from the optical scales sensors and pass to actuators the driving signals in order to reach the prescribed inspection area. The conversion of the command signal into the driving signal can be elaborate by the computer itself, if the driving signal for motors is digital, or by controllers if the actuating signal is analogical (high voltage). A control system that uses steppers as actuators does not require external controllers or D/A conversion and therefore the driving system can be sustained directly by the process computer with a proper integration of the control algorithm into the main inspection software. Such a program sequence to control a step-motor is described in the present paper, the benefits and the weaknesses for a CMM being underlined.

Keywords: Brushless servomotor, Hybrid stepping motor, Closed-loop controller, Software integrated control, Control strategy

1. HYBRID STEPPING MOTOR FACTS

The coordinate measuring machines use either DC brushless servomotors or hybrid stepping motors as actuators. If DC servomotors application is considered an external closed-loop controller is indispensable due to required D/A conversion of the driving signal for the motor windings. Even if the system structure is complicate and many logical circuits are involved, twenty years before, due to poor development of the digital technology and unreliable stepping motors this architecture was the only robust solution. The technology developed in the meanwhile, but so far the research direction remains the same. Nowadays if a company wants to take advantages of the latest CMM's technology must scrap the old CMM and acquire the new design that in few years will be also obsolete or for a certain price to upgrade, if possible, the old CMM. The entire system (controller and machine) is built in such a way, that it is almost impossible to exchange a controller from one CMM family to another even if both are produced by the same company (inter-company exchange is out of question).

If the steppers are used, an software algorithm integrated in the main application can be apply to close the loop from the incremental encoders, and moreover on the same BUS the computer controls the touch-probe, the probe-head and read the data from the optical rulers. The electrical characteristics and the invariable load on the motor shaft insure the utilization of this type of actuators without any decrease of accuracy. From the electrical point of view, stepping motor is digital incremental mechanism and the input is a digital processed signal in order to obtain specific angular displacement. Each quantum of the input conducts to a certain portion of angular displacement, named step. A position is achieved after the rotor pass through all the intermediate transitions and the controller send out the entire drive sequence. The number of impulses gives the final location in the working volume of the CMM and the drive frequency is direct proportional with the moving velocity.

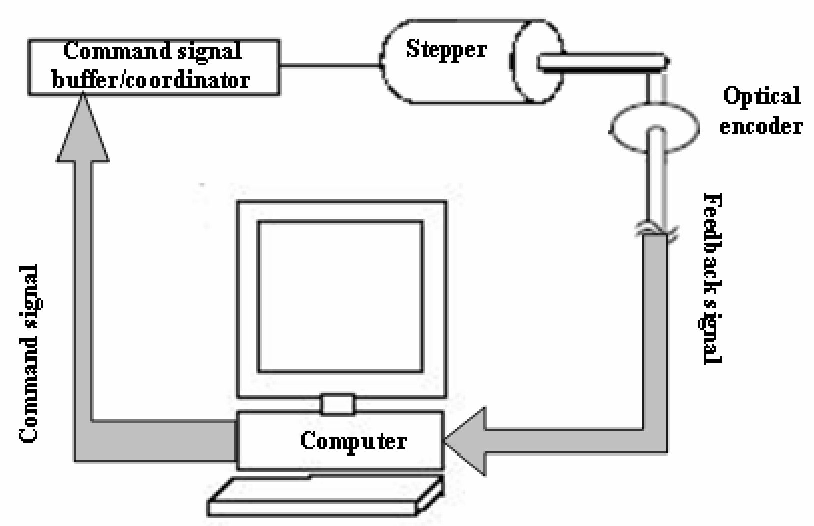

Figure 1. Close loop controller for one stepper (axis) integrated with the computer

The coordinator (figure 1)[2,3] controls the motion of several stepping motors generating for each motor (each axes) two signals: ***mov*** and ***df***. The V-low – V-high transition of the ***mov*** signal causes the motor to perform a single step in the direction determined by the value of ***df*** (***df***-direction flag set the direction of the movement). The algorithm is based on the digital signals ***mov*** and ***df*** that form the prescribed location of the CMM – ***ploc***. The digital encoder outputs the actual location of the motor – ***aloc***. To achieve the prescribe position our controller should evaluate the error between ***ploc*** and ***aloc*** and pass to the motor's windings an excitation signal ***xsig.*** To maintain a constant torque and to achieve the desired location, the controller evaluates the error term ***aloc-ploc*** and as long as the error remains within ±2 steps the excitation signal ***xsig*** is independent of the motor position ***aloc***.

2. THE CONTROL ALGORITHM

Under closed-loop conditions the algorithm generates an excitation which is two steps in advance of the motor position and this provides maximum torque at low stepping rates. The control algorithm can be given by [1]:

```
IF $| Va | > Vp$
        THEN $xu = 3$;
        ELSE $xu = 2$;
ENDIF;
IF $aloc – ploc < -xu$
        THEN $xsig = aloc + xu$;
        ELSEIF $aloc – ploc > xu$
                THEN $xsig = aloc – xu$;
                ELSE $xsig = ploc$;
ENDIF;
```

At high stepping rates, however, the current in the stator windings lags behind the excitation signals because of the effect of winding inductance. To obtain the maximum torque under these conditions the excitation should be more than two steps in advance of the motor position. To obtain a good overall performance it is therefore necessary to employ a variable excitation angle, ***xu*** which changes from 2 steps to 3 steps as the motor reaches some predetermined rotor speed. To determine when to switch the excitation angle the actual speed (***Va***) is monitored and compared with a predefined speed (***Vp***), when the transition must be performed.

The stepper control algorithm is referring to regulation of the speed and the torque of the steppers, but the entire positioning system has to process the signal sent by the optical glasses sensors for each the axes: ***px***, ***py***, ***pz*** in order to acquire a precise set of coordinates, that will be compared with the CAD model/ technical drawing.

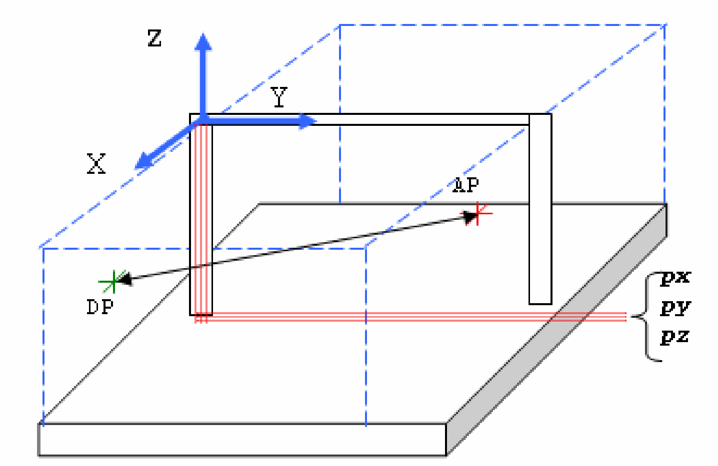

Figure 2 CMM working volume

In Figure 2 the working volume of a CMM and the reference system recognized by the our controller are presented. The optical glasses are read constantly and the movement is evaluated by the check-sum of the 10 mm check-lines. If the the sum does not match an error signal is transmited to the coordinator and the system halt.

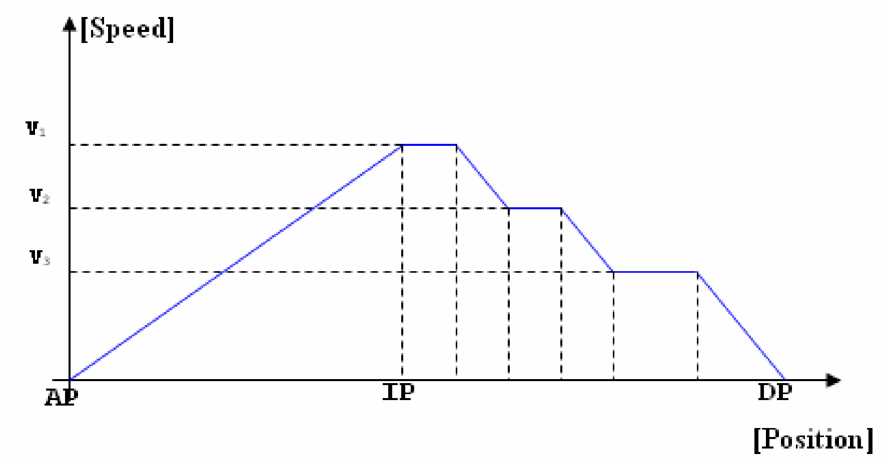

Figure 3. Speed Diagram

For a simple ***AP-DP*** (***AP*** - actual position, ***DP*** -desire position) movement the coordinator calculate the distance and divide by 2 to obtain an intermediary position ***IP***. The distance from ***AP*** to ***IP*** is covered uniform accelerated and the second half the system decelerate so the final position ***DP*** will be achived with no error. This control strategy insure an uniform movement of the CMM ram, without mechanical vibrations induces by a fast break. The decelerate phase have to be travelled as it is shown in the diagram (Figure 3). The last interval must be passed at a steady speed (**v_3**). This can be calculated from the data sheet of the motor in order to achieve the desire position (***DP***) with no inertia error or vibration.

A timer and a counter are started for each axis to supervise the movement. The trajectory vector is decompose in its orthogonal components and the signals ***px***, ***py***, ***pz*** give the position of the mechanism in the working volume. The counter buffer store the distance travelled and the timer signal switch the speed stage. As long as the probe is within the first half of the entire distance the system is accelerated. When it reaches IP position the speed is kept constant for a period determined by the controller. Then the speed is slow down step by step until the final position (DP).

3. CONCLUSION

A standard hybrid stepping motor has two stator windings, each of which must be capable of being excited in either sense. In a 4-step sequence both windings are excited at all times and four steps advance the rotor by one tooth. For rotor with 50 teeth, a 4-step sequence gives 200 steps per revolution and a step size of 1.8 degrees. A smaller step size is provided by the 8-step sequence in which eight steps advance the rotor by one tooth. This gives 400 steps per revolution and a step size of 0.9 degrees. The improved resolution obtained at the expense of a slightly reduced torque is not affecting the CMM driving system thanks to the invariant load on the motor shaft[1,4].

There is a speed barrier to achieve a position in the CMM working volume without errors or vibrations of the ram. That’s why the inspection time can be decreased only by shortcutting the signal path and the processing of the signals. Having 3 or 4 decision structures (computer, main controller, probe-head controller and the touch-probe controller) the signals processing is very slow. The control algorithm together with the architecture described in the first part of this paper offer an alternative solution to the actual CMM constructive types.

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