Study of the Stop Phenomena at the End Sliding Plate Movement with Reciprocating Rectilinear Motion Driven by Direct Current Motors

Adrian Cernăianu(✉), Corina Cernăianu, and Eugenia Stăncuț

Faculty of Mechanics, University of Craiova, Craiova, Romania
adrian.cernaianu@edu.ucv.ro

Abstract. The paper aims to present a series of applied studies on specific phenomena, which occurred when stopping the mobile sledge-type subassemblies with reciprocating rectilinear motion. These phenomena can influence the accuracy of the movements necessary for the technological processes of processing on machinery and manufacturing equipment through mechanical processing. For the study, a sledge-guide device was designed, made and tested, with the actuation of the mobile element by means of an electro-mechanical transmission. Two drive variants were used, with DC motor and stepper motor driven by an Arduino controller. The curves of the variation of the displacements were recorded and drawn, by means of a recording device, in different actuation variants and the obtained results were interpreted. In order to be able to develop as comprehensive conclusions as possible on these specific phenomena, several process parameters, such as the speed of travel or the travel of the moving element, have been modified using actuators and control of the drive components. Significant differences were found in the data obtained, both in terms of the limits of variation of the process parameters and in terms of the solution chosen for operation.

Keywords: Alternating rectilinear motion · Elimination stop phenomena · DC motor drive · Stepper drive · Measurement

1 General Considerations

Manufacturing machinery and equipment, machines and production systems consist of moving elements (sleds, tables, etc.) that can move either on straight or circular paths [1]. Depending on the type of drive used, with or without self-reversing, it is necessary to reverse the direction of movement when the rectilinear is moving. In this case, various disturbing phenomena may occur due to the inertia of the moving masses, the variable rigidity of certain structural elements or even the drive systems (eg transmissions with rubber belts without insert). These phenomena occur more often when the mechanisms and elements that generate the movement do not reach a fixed quota, there is a danger of exceeding the allowed limit. The stop and reversal control are given by a series of stops and stroke limiters, which transmit signals through the specific electrical circuits to the control elements of the drive motors.

I. Dumitru et al. (Eds.): ICOME 2022, AHE 15, pp. 398–406, 2023.
https://doi.org/10.2991/978-94-6463-152-4_44

The drive motors can be alternating current, direct current or stepper motors. In the latter case, these phenomena are less present because the electric self-locking of the stepper motor occurs when the control pulses disappear. In the industrial practice of the manufacturing industry, relative to manufacturing machinery and equipment, there are examples of machine tools that are provided with translational moving components. These components, tables, sleds, moving elements, etc., move between two fixed positions (but with the possibility of adjustment) and therefore it is necessary to use stop options at elevation, as accurate as possible.

The phenomenon that can cause deviations from the prescribed processing quotas is the type of exceeding the prescribed strokes due to the inertia of the moving masses or the games in the drive mechanisms, which causes deformations of the mechanical system. The higher the travel speed, the greater the position deviations and therefore it is necessary to take specific measures to limit them, as will be seen below.

Elevation Shutdown Phenomena. In the case of kinematic chains generating alternative rectilinear motions, which move the moving elements over a certain distance l, undesirable phenomena occur that produce positioning errors at the final dimensions. Thus, the movement on the distance l implies an acceleration of the mobile element from a speed equal to 0 to the maximum speed, followed by a bearing with constant speed. In order to achieve the desired stroke, it proceeds to a deceleration phase, from maximum speed to speed 0, followed by returning to the initial position. And this stage is carried out on the same principles, acceleration, constant speed and deceleration to 0.

In order to achieve stopping at a more precise level, a series of limiting elements are used, such as those with contact (electric limiters or microlimiters) or without contact (optical limiters, with Hall effect, etc.), adapted to the type of kinematic chain drive. Generator. The variation graph of the speed of movement of the mobile element, with the three distinct stages, as well as the possible positioning errors at the prescribed dimension L is presented below (see Fig. 1.) [2].

In order to ensure that the final strokes and dimensions are as accurate as possible, the limiters and stops must be positioned and adjusted accordingly, using micrometric screws or optical or inductive aiming devices.

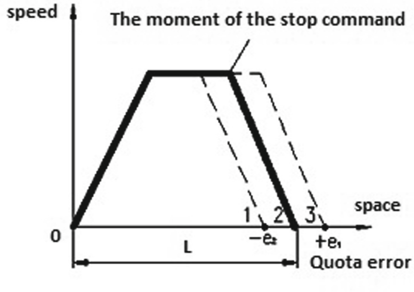


Fig. 1. Moving element positioning error graph

2 The Experimental Device for the Study of Stop Phenomena

In order to study the stop phenomena described above, a stand with a double source of motion was designed, designed, made and tested, which allows the movement of a mobile platform on a rectilinear trajectory. The stand is provided with a brushless DC motor, type ME 21068037 - IMC Universal Magnetics Corp, with voltage U = 24 Vdc, as well as a stepper motor type Nema 17 - 1.8 - 1.7A, model 42SHDC3025-24B [3].

The DC motor is powered and controlled, for the realization of the linear strokes of the mobile platform, by means of a programmable adjustable source DC-DC type DPS5020 with USB, and the return and resume commands of the multiple strokes are made by means of a relay circuit with self-maintenance and a pair of electric limit switches.

The stepper motor is controlled by means of a circuit composed of a development board UNO R3 ATmega328p [4, 6] and a driver type DM542H, DC9-42v, 0.5 ~ 4.8A Microstep Driver [5].

For the graphical recording of the distances made at the linear strokes with self-reversing, the stand was provided with a system for unrolling and rolling a paper roll. Displaced.

the salt of this roller is made with the help of a DC motor-reducer, powered and controlled by means of an adjustable, programmable source type DC-DC DPS5020 with USB.

The two motion sources allow, alternatively, the transmission of the regulated speed either by the programmable adjustable source or by the circuit controlled by the development board, to a pulley system with rollers and extended wire that allow the movement of the mobile platform. The platform is supported by a pair of cylindrical guides.

The signal writer is of the adjustable type, arranged on an articulated arm, so as to establish an optimal recording pressure.

In the images below you can see the components of the experimental stand (see Fig. 2).

Fig. 2. Double operated stand

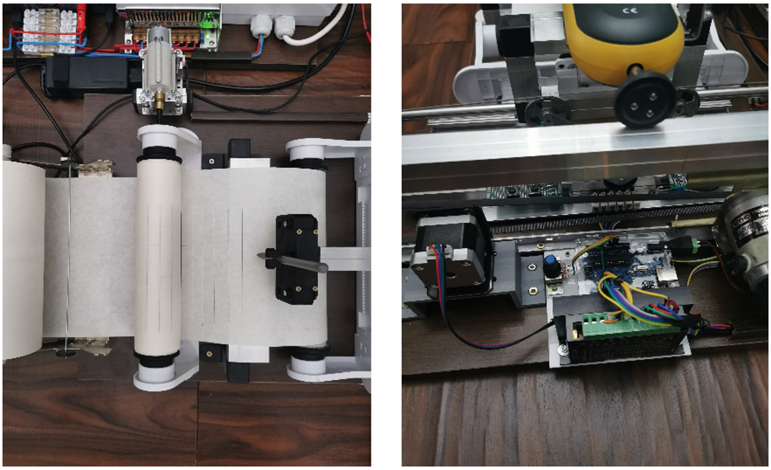


Fig. 3. Graphic recording system and stepper motor control

Fig. 4. Software for command and control of DC motors and programmable adjustable sources

The graphical recording system of the alternating linear displacements of the mobile platform, the two electric motors and the step-by-step motor command and control circuits can be seen in the image below (see Fig. 3).

To establish and determine the travel speeds of the mobile platform, the stand was provided with the digital tachometer with contact type AX - 2901, set to determine the linear speeds. Two programmable adjustable sources were used to command and control the two DC motors, the one for operating the graphic recording system (the scroll for the paper roll), as well as the one for realizing the stroke of the mobile platform. They are connected via USB ports to computers which, through dedicated software (DPS5020 PC Software V1.4 [7]), allow the establishment of a test program with the modification of process parameters. These elements can be traced in the images below (see Fig. 4).

3 Experimental Data on the Study of Stopping Phenomena

The study of stopping phenomena was carried out on the basis of a program of experiments which included the programming phases of the programmable adjustable sources, the position of the pairs of electric limit switches for the DC motor, as well as for the stepper motor. Another phase is the programming of the UNO R3 development circuit, in such a way as to ensure the possibility of realizing the two alternative rectilinear races. The speed variation is performed by a potentiometer, correlated with the supply voltage values and with the speed of movement of the mobile platform.

The values of the parameters set for the command and control of the DC motor for the mobile platform stroke, introduced in DPS5020 PC Software V1.4, can be seen in Table 1 and allow the sequencing of the movement correlated with the advance of the drum with writing paper. These are the voltage (V), the current consumed (A) and the time sequence for the characteristic movements. The output data are also presented, representing the values of the output current (A), the power consumed (W), the average travel speed (m / min), as well as the distance travelled (mm).

The values equal to 0 of the supply voltage represent the travel periods of the paper support, for the transition to a new double stroke, with increased tension, so with a higher travel speed. Also, in the case of the DC motor-reducer for moving paper for burning double strokes, the same steps are followed to set the DPS5020 PC Software V1.4 program. The values of the process parameters as well as the recorded data are presented in Table 2. From the evolution of the recorded data it is observed that, with the increase of the travel speed, from 7.23 to 12.87 m/min, the measured power also increases, from 1.68 to 2.80 W, by 66.7%.

Table 1. Parameters set for command and control and experimental data for operating the mobile platform with the DC motor

Nr. Crt.	Voltage (V)	Current (A)	Delay (s)	Ouput current (A)	Ouput power (W)	Speed (m/min)	Distance (mm)
1	6	10	10	0.27	1.68	7.23	138.00
2	0	10	5	-	-	-	-
3	7	10	10	0.30	1.18	8.80	140.00
4	0	10	5	-	-	-	-
5	8	10	10	0.41	2.16	10.42	142.00
6	0	10	5	-	-	-	-
7	9	10	10	0.31	2.79	11.82	143.61
8	0	10	5	-	-	-	-
9	10	10	10	0.32	2.80	12.87	144.75
10	0	10	5	-	-	-	-

Table 2. Parameters set for command and control and experimental data for drive paper for writing with the DC motor reducer

Nr. Crt.	Voltage (V)	Current (A)	Delay (s)	Ouput current (A)	Ouput power (W)
1	0	10	12	-	-
2	1.2	10	1	0.49	0.59
3	0	10	14	-	-
4	1.2	10	1	0.45	0.59
5	0	10	14	-	-
6	1.2	10	1	0.51	0.62
7	0	10	14	-	-
8	1.2	10	1	0.39	0.57
9	0	10	14	-	-
10	1.2	10	2	0.55	0.52

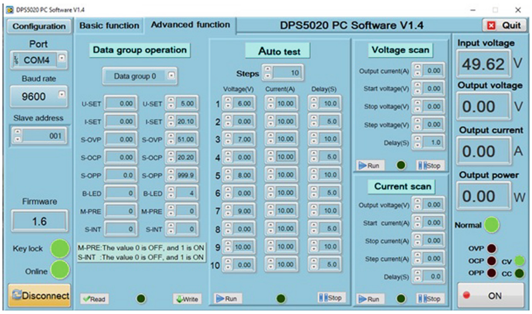


Fig. 5. Set and experimental data for DC motor (Test 1)

The two graphical interfaces of the programs for the command and control of the DC motor for moving the platform with the graphic recorder (see Fig. 5) and for the advance of the paper support (see Fig. 6), can be seen in the figures below. After entering the input data, the simultaneous start-up of the two programmable adjustable sources is correlated with the input data provided in the Auto Test section.

Following the development of the experimental research program, a series of graphs inscribed on paper appeared. These were analysed and the measurements carried out resulted in a series of data showing indications of the phenomena that occurred when moving the moving elements and stopping at the level.

Measurements were made in the two variants mentioned above, with the actuation of the mobile element by the DC motor and, by comparison, by the stepper motor. The travel parameters as well as the initial distance set to be covered by the mobile platform were established as common parameters. In the images below are presented the two

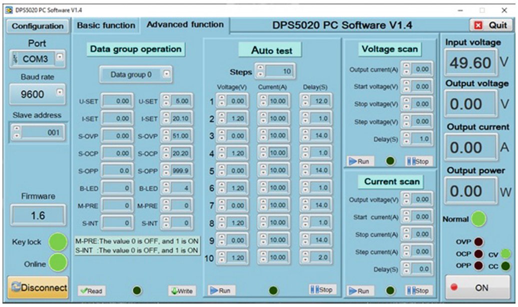


Fig. 6. Set and experimental data for DC gearmotor (Test 1)

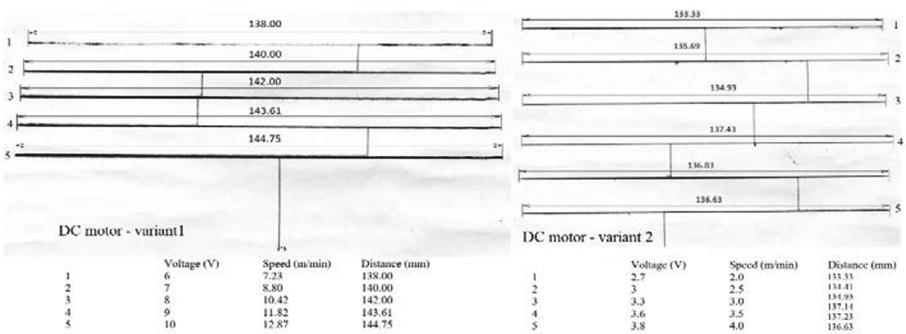
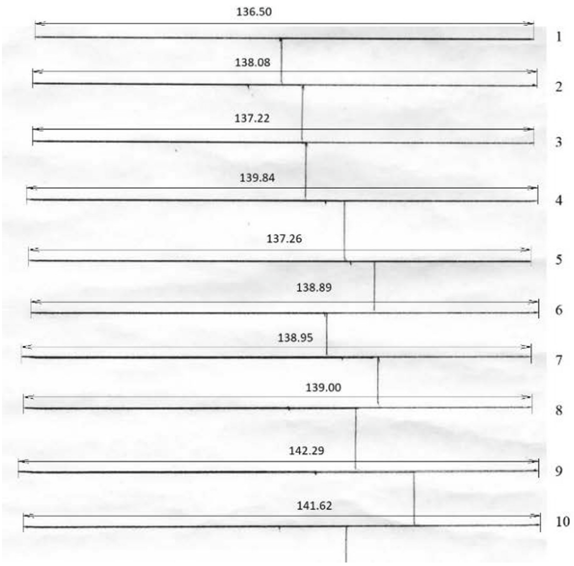


Fig. 7. Graph of the movements of the mobile platform when driven by direct current motor

variants of graphic recordings, with the operation of the mobile platform with direct current motor, in two variants (see Fig. 7.) and with stepper motor (see Fig. 8).

Analysis of Experimental Data Analysing the experimental data obtained and presented previously, it is found that, in the case of operating the mobile platform with direct current motor (first variant), the strokes have a large amplitude, reaching the value of 138.00 mm and up to 144.75 mm, i.e. An increase by 6.75 mm, representing 4.89%. The main reason is that the travel speed is high (up to 12.87 m / min) and therefore inertia produces effects that further move the moving masses. In the case of powering the motor with lower voltages, between 2.7 and 3.8 v, corresponding to speeds of the mobile platform between 2.00 and 4.00 m / min, it is observed that the travelled distances decrease reaching values from 133.33 mm and up to 137.23 m / min. In this case the increase is only 3.90 mm, representing an increase of 2.92%.

The following data set was obtained when moving the mobile platform using the stepper motor. The reference size considered was the travel speed, between 2.00 m / min and 4.00 m / min. Analysing the experimental data shown graphically in Fig. 8, it is observed that in this case the mobile platform has a stroke with amplitudes between 136.50 mm and 141.02 mm. There is an increase of the stroke by 4.52 mm, representing 3.33%. In the case of DC motor operation, the gradual increase of the distances covered has values between 0.09 and 2.21 mm, and in the case of the stepper motor, the gradual



	Speed (m/min)	Distance (mm)
1	2.00	136.50
2	2.25	137.08
3	2.50	137.22
4	2.75	139.27
5	3.00	137.26
6	3.25	138.52
7	3.50	138.95
8	3.75	139.00
9	4.00	141.02
10	4.25	141.62

Fig. 8. Graph of the movements of the mobile platform when driving with a stepper motor

increase of the distances is from 0.04 to 2.07 mm. It is observed that in the latter case, the increase is smaller, the explanation can be found in the operation of the stepper motor. It benefits from a much-diminished inertia and especially from the self-locking at the end of the supply sequence with the drive pulse train. In the case of actuation with the DC motor, the average of the gradual increase of the distances is 0.975 mm, and in the case of the stepper motor, it has a value of 1.13 mm.

4 Conclusions

From the analysis of the experimental data presented above, a series of partial conclusions can be drawn, leading to the idea that, in both cases, the actuations of the components with alternating rectilinear translational motion can be performed either with direct current motor or stepper motor. The differences between the two methods appear when the structure of the assembly of the construction system differs in terms of rigidity, or when it is desired to obtain speeds in a certain range required by the respective technological process. Thus, at higher speeds (for example 12.87 m/min), the drive system with DC motor can be used, and at low speeds (for example 4.25 m/min) and very high accuracies, stepper motor drives can be used. However, it is necessary in the future to continue research and approach other high-performance systems, which will ensure greater control of unwanted phenomena that occur when stopping moving elements.

References

1. Cernăianu, A.: Maşini, utilaje, echipamente şi sisteme avansate de fabricaţie. Teorie și aplicații, Editura Universitaria, ISBN 978–606–14–0920–4, 671 pag., Craiova, 2015.
2. Dumitru, C., Cernăianu, A., Popescu, D., Dumitru, V.: Sisteme automatizate de fabricaţie reconfigurabile. Concepte, problematică şi aplicații, Editura Universitaria Craiova, 2011, 423 pag., ISBN 978–606–14–0128–4.
3. https://ardushop.ro/ro/printare-3d/103-motor-pas-cu-pas-nema17-18-grade-18a.html?search_query=42SHDC3025-24B&results=1.
4. https://dronebotworkshop.com/big-stepper-motors/ .
5. https://ardushop.ro/ro/cnc/788-driver-motor-pas-cu-pas-dm542hdc18-80v1545a.html .
6. https://www.schmalzhaus.com/EasyDriver/Examples/EasyDriverExamples.html.
7. https://www.manualslib.com/manual/1614637/Ruideng-Dps-Series.html#manual