International Journal of Scientific Engineering and Science
Volume 2, Issue 6, pp. 12-15, 2018. ISSN (Online): 2456-7361

Simulation of a Computer Printer DC Servomotor Positioning for Fast Response Performance

Chieme Gabriel C.[1], Nkanyi Nwadiogo G.[1], Ezeobi Stanislaus O[2]
[1]Department of Computer Science Technology, Anambra State Polytechnic, Mgbagwu, Nigeria
[2]Department of Computer Engineering Technology, Anambra State Polytechnic, Mgbagwu, Nigeria

Abstract— *Most of the low-cost product commonly used in homes and offices such as printers, domestic appliances, air conditioning system etc., and a DC motor belt drive arrangement is used for positioning, speed, and precision performance improvement. This paper has presented simulation of a computer printer DC servomotor positioning for high speed performance. It is required to improve the positioning and speed performance of a computer printer. Then the objective is to design a compensator that will be included in the forward path of the servomotor system. The dynamic model of a DC motor used for positioning and speed control of a printer is obtained. A proportional integral and derivative (PID) compensator is designed using MATLAB software PID block of Simulink. Simulations were conducted for two different conditions, uncompensated and compensated. The compensated system proves more effective and efficient with respect to the settling time, settling time and overshoot.*

Keywords— *Computer,Compensator,DC servomotor, PID, Printer.*

I. INTRODUCTION

In a belt and pulley system, the pulley can be driven normally in one direction. Also the arrangement will be such that the belt is crossed so that the direction of the driven shaft is changed in a two pulley system. In a case where the belt drive system is used as a source of motion, the belt is adapted to continuously carry a load from one point to another.

Smooth transmission of power is provided by a belt drive between shafts at a favourable distance. As source of motion, belt drives are used to efficiently transmit power or to track relative movement. They are widely used in all fields where it is required to transmit mechanical energy from the rotating shaft to the objects of the control. Among the many industrial applications that use belt drive system are the Computerized Numerical Control (CNC) machines in particle cutting machine tools and 3D-printers [2]. There are many examples of belt drives implementation in our life such as cars, audio and video devices, computer devices, etc. [3].

Presently, many belt drive systems use Direct Current (DC) motors as a result of precise, accurate, wide, simple and continuous control characteristics. They are basically driven by DC motors. A DC motor is referred to as an electrical machine that converters electrical energy into mechanical energy. In industry, high performance DC motor belt drives are very important. This is also the required in other applications. A good dynamic speed variable control and load response regulation is generally one of the main characteristics of high performance motor drive assembly.

In most of the low-cost product commonly used in homes and offices such as printers, domestic appliances, air conditioning system etc., a DC motor belt drive arrangement is used for positioning, speed, and precision performance improvement. A typical printer for a computer system which uses a belt-drive mechanism to laterally move a printer devices across a printed page based on the action of a DC motor is considered.

It is desired in this paper to design a proportional integral and derivative (PID) controller to improve the positioning and speed response of a DC motor derive of a printer through computer simulation using MATLAB software. In order to realize the objective of this paper, it has been organized into five parts. The first presents the introduction, the second part reviews related literature, the third part deals with the methodology, the fourth part presents the simulation results and discussion, and the fifth part provide the conclusion of the paper.

II. REVIEW OF RELATED LITERATURE

Doug [4] studied control systems challenges in the HP personal ink jet printing application faced by Hewlett-Packard Company in designing competitive ink jet mechanisms for desktop printer and multifunction device market. Parkkeinen et al. [5] implemented and tested a cross-coupled controller with biaxial linear tooth belt drive system for motion synchronization. Accurate positioning of a belt driven mechanism using a feed-forward compensator under maximum acceleration and velocity constraints was proposed in [6]. The PID control for accurate tracking control and accurate position control was designed and applied to the real test setup for belt drive system in [7]. Musselman and Djurdjanovic [8] presented improvement of belt tension monitoring in belt-dive automated material handling system.

III. METHODOLOGY

In this section technique used to realize the objective of the paper is presented. It is required to improve positioning control and speed control performance of DC motor drive system for a typical computer printer. In order to address the poor response performance, mathematical equations representing a belt and pulley dynamics and the rotational dynamics of a DC motor were obtained. A proportional integral derivative (PID) control compensator is developed. The objective of the paper is to design a compensator that will optimally improve printing performance of a printer belt drive system in terms of positioning and speed performance of the DC motor.

A. Dynamic Equation of DC Servomotor System

A typical printer belt drive system for a computer is shown fig. 1. R is the resistance of motor circuit, L is the inductance of motor armature, τ is the rotational torque of motor shaft, v_b is the back induced electromotive force (e.m.f), J is the total inertia of printer belt drive, v_a is the applied voltage, $i(t)$ is the current of the motor circuit, θ the angular positioning of the motor of the motor shaft and θ_p is the angular positioning of the pulley.

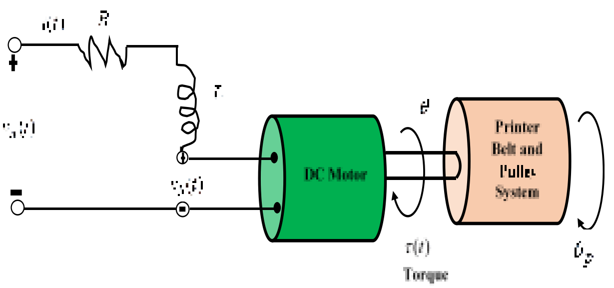

Fig. 1. Printer belt drive system.

The printer belt drive system basically consists of two main components. These are: the electrical components of the DC motor and the mechanical components of the printer belt and pulley system.

Electrical energy received from electrical supply system by the DC motor is converted to mechanical energy for driving the belt and pulley arrangement. The electrical components of the DC motor is shown in fig. 2. It is assumed in this paper that the field current of the armature- controlled DC motor is constant.

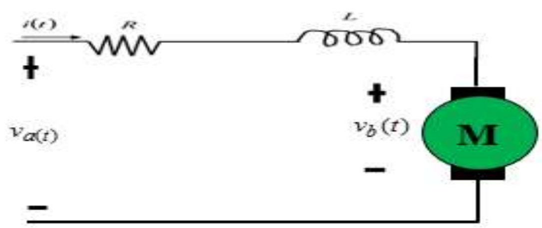

Fig. 2. Electrical circuit DC motor.

In this way, it acts as an actuator. Applying Kirchhoff's voltage law to the DC motor circuit gives:

$$v_a(t) = Ri(t) + L\frac{di(t)}{dt} + v_b(t) \quad (1)$$

The angular positioning of the shaft θ and the angular speed of the shaft ω are related as follows:

$$\omega(t) = \frac{d\theta(t)}{dt} \quad (2)$$

The back e.m.f $v_b(t)$ is directly proportional to the angular speed of the motor shaft. This is given by:

$$v_b(t) = k_m \frac{d\theta(t)}{dt} \quad (3)$$

where k_m is the motor torque constant. Substituting Eq. (3) into (1) gives:

$$v_a(t) = Ri(t) + L\frac{di(t)}{dt} + k_m\frac{d\theta(t)}{dt} \quad (4)$$

Equation (4) is expressed in Laplace transform as given by:

$$V_a(s) = RI(s) + LsI(s) + k_m s\theta(s) \quad (5)$$

The rotational elements of the DC motor shaft are represented by:

$$\tau(t) = J\frac{d^2\theta(t)}{dt^2} + f\frac{d\theta(t)}{dt} \quad (6)$$

The rotational torque of the motor shaft is:

$$\tau(t) = k_m i(t) \quad (7)$$

Substituting Eq. (7) into Eq. (6) and expressing the resulting equation in Laplace transform gives:

$$k_m I(s) = Js^2\theta(s) + fs\theta(s) \quad (8)$$

Elimination of $I(s)$ from Eq. (5) and Eq. (8) gives:

$$G(s) = \frac{\theta(s)}{V_a(s)} = \frac{k_m}{s[(Js+f)(R+sL)+k_m^2]} \quad (9)$$

Equation (9) is the DC motor servo positioning transfer function.

In order to perform simulation so as to check performance characteristics of a printer DC motor derive for a computer system considered in this paper, the following parameters in table I are obtained from [1].

TABLE I. Parameters of a typical printing device.

Parameter	Symbol	Value	Unit
Light sensor	-	1	V/m
Inductance	L	0	H
Viscous force	f	0.25	Nms/rad
Resistance	R	2	Ω
Motor torque constant	k_m	2	Nm/A
Inertia	J	0.01	Kg/m^2

It should be noted that the total inertial of the system is equal to the sum of the inertial of the DC motor (a typical 1/8 hp DC motor) and the pulley given by Eq. (10) [1]:

$$J = J_{motor} + J_{pulley} \quad (10)$$

Substituting the parameters in table I into Eq. (9) gives the transfer function of DC motor drive positioning for a typical printer as presented in:

$$G_m(s) = \frac{2}{s(0.02s + 4.5)} \quad (11)$$

B. System Configuration and Controller Design

The configuration of the servo system of a printer DC servo-based motor system integrating a PID controller in MATLAB/Simulink is shown in fig. 3. The system is a single input single output (SISO) system.

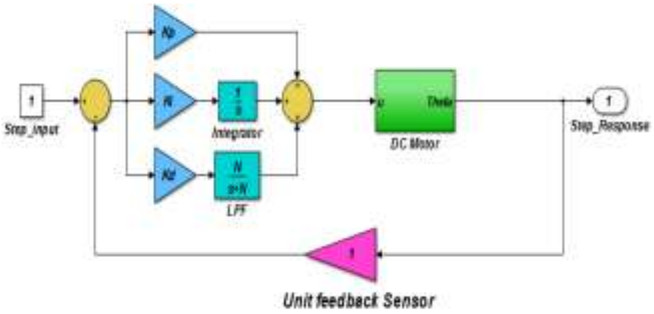

Fig. 3. Simulink configuration of servo positioning system.

System specification

It is required that the servo positioning system of the printer meets the following specifications with 90% criterion:

1. Rise time of $\leq 0.01s$
2. Settling time of $\leq 0.1s$
3. Overshoot of $\leq 10\%$

The controller is designed using the PID block of the MATLAB/Simulink. Robust tuning was performed to obtain the appropriate gain for the designed PID controller as shown in table II. The designed controller is given by:

$$k_p + k_i * \frac{1}{s} + k_d * \frac{s}{Tf * s + 1} \quad (12)$$

TABLE II. PID controller parameters.

Gain	Tuned
k_p	986
k_i	3.42e+03
k_d	3.3
$Tf = 1/N$	0.00118

Substituting the parameters in table II into Eq. (12) gives:

$$986 + \frac{3.42e+03}{s} + \frac{3.3s}{0.00118s+1} \quad (13)$$

Equation (13) is the designed controller for the servo positioning system considered for a typical computer printer.

IV. Simulation Results and Discussion

A. Simulation Results

Simulations are performed for two separate conditions, when the designed controller has not been added to the process loop (uncompensated) and when it has been made part of the loop (compensated). The simulation results obtained for the various conditions considered are presented in fig. 4 and 5. Tables III and IV show the performance of the system for both conditions.

B. Discussion

The performance simulation of the servomechanism for DC motor use in a typical printer belt drive system for positioning and speed using MATLAB is demonstrated. In fig. 4 the step response plot of the uncompensated system is presented. It can be seen that the uncompensated system is sluggish and overdamped. This undesirable and requires improvement for optimal and robust performance. In fig. 5 the system response performance has been well improved with the PID controller added to control loop of the DC motor servo positioning process. The integration of the controller improves the positioning and speed.

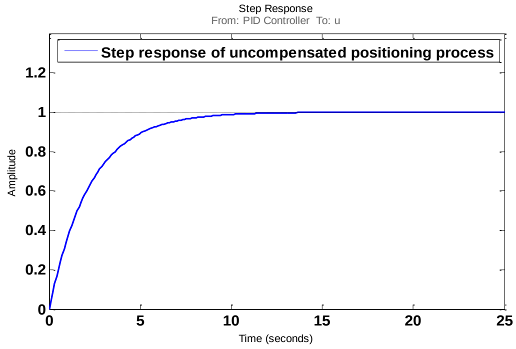

Fig. 4. Step response of uncompensated process.

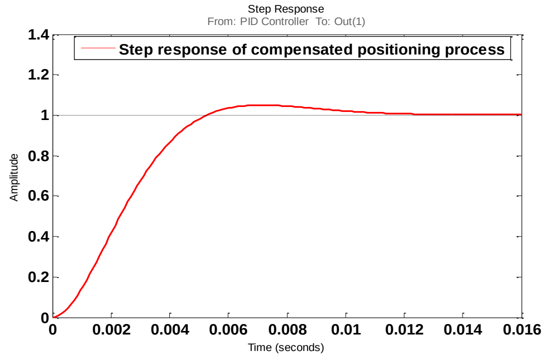

Fig. 5. Step response of compensated process.

TABLE III. Response performance of uncompensated positioning process.

Characteristic	Value
Rise time	4.93 seconds
Settling time	8.79 seconds
Overshoot	0 %

TABLE IV. Response performance of compensated positioning process.

Characteristic	Value
Rise time	0.00342 seconds
Settling time	0.0101 seconds
Overshoot	3 %

V. Conclusion

This paper has presented response performance simulation of a computer printer drive system. The dynamic model of a typical DC motor is obtained for a printer drive system. The objective is to design a robust controller and add it to the forward path of the control loop of a printer drive system. Simulations were performed in MATLAB/Simulink environment for two separate conditions, when the system was not compensated and when it is compensated. The results obtained shows that the performance characteristics of the compensated system were improved.

References

[1] C. D. Richard and R. H. Bishop, *Modern Control System*, Upper Saddle River, NJ: Prentice Hall, 12 ed., 2011.

Volume 2, Issue 6, pp. 12-15, 2018. *ISSN (Online): 2456-7361*

[2] J. Mathias and G. Hubert, "Dynamic modeling and flatness based control of a belt drive system," *Proceedings in Applied Mathematics and Mechanic*, pp. 887–888, 2014.
[3] Y. Pang, "Intelligent belt conveyor monitoring and control," Master of Science in Electrical Engineering, Taiyuan University of Technology, China, 2010.
[4] D. Harriman, "Control systems challenges in HP personal ink jet printing application," *2005 American Control Conference*, Portland, OR, USA, 2005.
[5] J. Parkkinen, M. Jokinen, M. Niemela, T. Lindh, and J. Pyrhonen, "Motion synchronization of two linear tooth belt drives using cross coupled controller," *15th European Conference on Power Electronics and Applications (EPE)*, 2013.
[6] S. Jayawardene, M. Nakamura, and S. Goto, "Accurate control position of belt drives under acceleration and velocity constraints," *International Journal of Control, Automation and Systems*, vol. 1, no. 4, pp. 474-483, 2003.
[7] A. Selezneva, "Modelling and simulation of tracking control for the belt drive system," MSc thesis, Lappeenranta University, 2007.
[8] M. Musselman and D. Djurdjanovic, "Improvement of belt tension monitoring in a belt-drive automated material handling system," *Advances in Sustainable Manufacturing*, pp.135-140, 2011.