Control Engineering

Experiment 4: Position Control by Servo Motor Actuator

GROUP 1:

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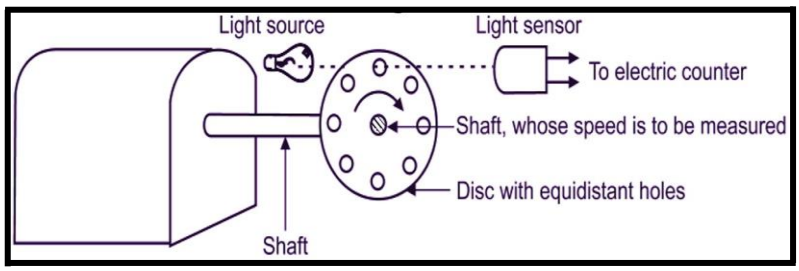
OBJECTIVE

Performance evaluation of a Mitsubishi 230V AC servo motor, controlled by the Mitsubishi MR-JE-40AS servo controller.

WORKING OF CONTROLLER SYSTEM:

1. Photoelectric Speedometer:
    - A Photoelectric Sensor consists of an emitter (for emitting light) and a receiver (for receiving reflected light rays). When emitted light is interrupted or reflected by the sensing object, it changes the amount of light that arrives at the receiver. The receiver detects this change and converts it to an electrical output.
    - So, essentially how the speedometer was used in the motor control was using this property of reflection of light waves. A disc with a small opening was attached to the motor, and the speedometer receiver continuously receives a reflected light wave, except when the opening crosses the sensor. So, by calculating the time between two “no light received” intervals, and knowing the disc radius, the speed of rotation can be easily evaluated.

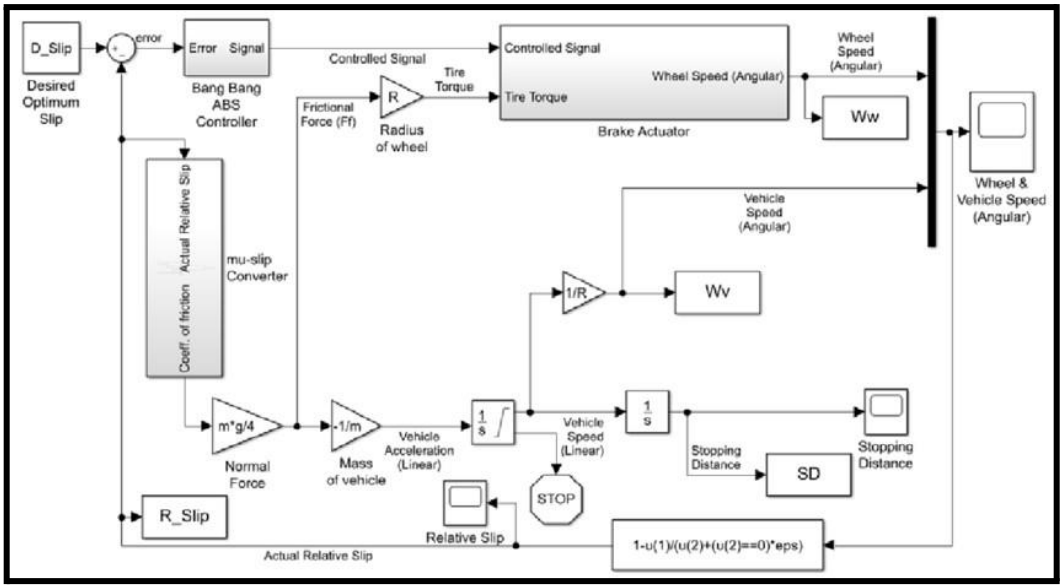


Reference: https://electricalworkbook.com/wp-content/uploads/2021/07/Photoelectric-Tachometer.png

2. Bang Bang Controller:

   - Bang Bang controllers are a kind of feedback controller that switch quickly between two states, in our case motor ON and motor OFF. The working is simple and as follows-
   - Control points are set for the controller- namely the upper and lower set points. What these points essentially do is that they define the limit of error that is acceptable to the system. The reason this is essential is because if we do not set any set points, since this controller automatically switches between ON and OFF states, the output will never settle. Thus, the setpoints must be carefully thought out as a very small setpoint may cause the response to not settle, while a large setpoint allows for a larger error.
   - Once the value is measured, if it lies below the lower setpoint, the controller gives the signal ON (indicating forward direction of rotation) and if the measured value lies above the upper setpoint, the controller gives the signal OFF(indicating reverse direction of rotation).
   - It also contains a hysteresis band, which ensures that the controller doesn't toggle between the ON and OFF states due to minor fluctuations in the output around the setpoint values.
   - A Bang Bang controller is easier to understand and implement, and works well when the system doesn't require very high precision. However, in situations requiring more precision or smoother control, PID controllers are preferred.

- The axle of the servo motor is kept in an air jacket. This is done to provide some damping to the system, in order to reduce the effect of motor inertia on its performance. It also prevents oscillations around the set point as the motion dies down due to the air resistance provided.



https://www.researchgate.net/profile/Prashant-Lakhemaru/publication/363412252/figure/fig1/AS:1

3. Servo Amplifier:

- A crucial part of a servo system is the servo amplifier. It is utilised to boost the bang bang controller signal to a volume suitable for driving the servo motor.
- It is in charge of ensuring that the motor precisely and rapidly follows the desired position indication. By restricting the current and torque that may be supplied to the motor, it also serves to safeguard the motor from harm. Additionally, it modifies the speed control reference point.
- The MR-JE-_A servo amplifier is compatible with both single-phase and three-phase power supplies. As seen below, we leave the L2 pin open for single phase, and the notion is the same for the model we've been using.

OBSERVATIONS AND INFERENCES:

For Speed Control:

Speed	Forward Rotation (rpm)	Reverse Rotation (rpm)	Error (Max on either side)
1	0	0	1
2	0	0	2
5	0	0	5
15	0	0	15
100	100	100	0
200	22647 (BUG)	22647 (BUG)	Error
300	300	300	0
400	400	400	0
500	502-499	502-499	2
600	600-597	600-597	3
700	701-697	701-697	3
800	801-795	801-795	5
900	904-896	904-896	4
1000	1000	1000	0
1100	1097	1097	3
1200	1202	1202	-2
1300	1299	1299	1
1400	1395-1415	1395-1415	15
1500	1507-1487	1507-1487	13
1600	1592-1614	1592-1614	14
1700	1712-1687	1712-1687	13
1800	1823-1794	1823-1794	23
1900	1916-1884	1916-1884	16
2000	2019-1984	2019-1984	19

The trendline observed shows that the magnitude of error is increasing as the speed increases, however, the % error is very high for small speeds and is negligible as the speed increases.

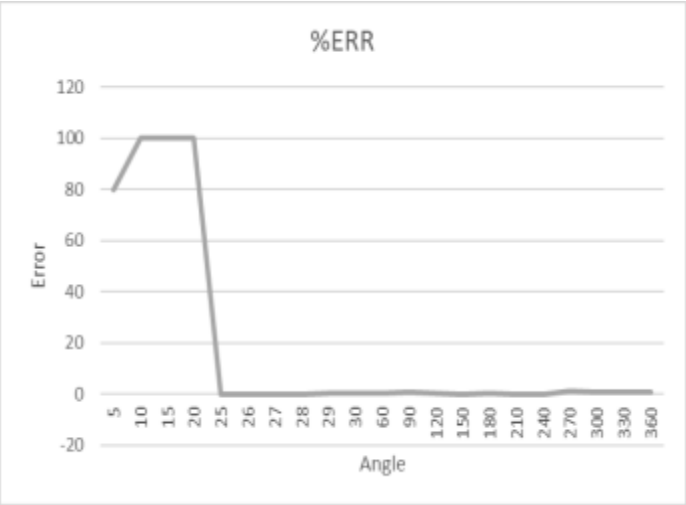
The speed controller functions as follows: at the user-set angular velocity, the reference point established by the Bang Bang controller gradually changes. As a result, the motor pursues the shifting reference point. The servo motor rotates at the specified angular velocity because it follows the spinning reference point.

The servo's real RPM is determined by the photoelectric sensor, which also generates a feedback signal and displays the angular velocity on a screen. The percentage inaccuracy is larger at low speeds because the sensor cannot accurately measure speed or discern whether the motor is motionless or moving slowly. High speeds help to alleviate this problem since the photoelectric sensor can better perceive and regulate speed.

For Position Control:

Angle	Forward Rotation (deg)	Reverse Rotation (deg)	Error
5	1	1	4
10	1	1	9
15	1	1	14

20	1	1	19
25	8	1	17
26	12	2	14
27	21	1	6
28	22	1	6
29	27	15	2
30	27	20	3
60	60	60	0
90	90	90	0
120	120	120	0
150	150	150	0
180	180	180	0
210	210	210	0
240	240	240	0
270	270	270	0
300	300	300	0
330	330	330	0
360	360	360	0



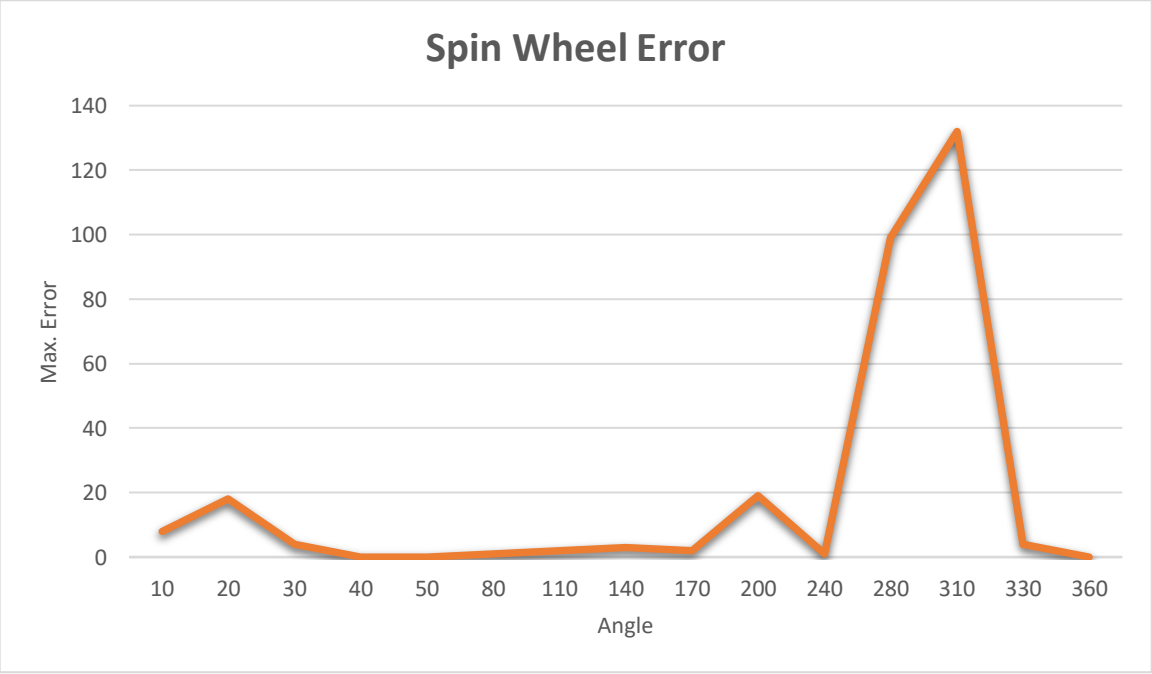
The trendline observed shows that the magnitude of error is decreasing as the speed increases, and the % error is very high for small speeds and is negligible as the speed increases.

Key notes taken:

1. Take note of the fact that our motor travels ahead initially before going backward. It does not go farther in the backward direction than in the forward direction. We can see from our data that we originally moved ahead before moving backward from the same location, and the error for moving backward is determined in the same way.
2. The controller receives the input position and uses it as a reference location before carrying out the remaining operations. The motor is given a full +V or -V supply to go back to the reference position after being informed of the difference between the reference position and the current position.
3. Because the motor doesn't move much, there may be more inaccuracy at smaller angles owing to occlusion of the photoelectric sensor's line of sight, which makes determining the location of the motor challenging.
4. The first table (Machine error) gave the error caused by the controller- servo amplifier system for different speeds. The above table gives the further error caused due to mechanical glitches in the motor (we checked this through the scale attached behind the servo motor).

Spin Wheel Error:

Angle	Fwd. Rotation	Back Rotation	Error (Fwd.)	Error(back.)	Max Error
10	2	2	8	0	8
20	2	2	18	0	18
30	28	24	2	4	4
40	40	40	0	0	0
50	50	50	0	0	0
80	79	79	1	0	1
110	108	108	2	0	2
140	137	137	3	0	3
170	168	168	2	0	2
200	197	178	3	19	19
240	239	238	1	1	1
280	278	179	2	99	99
310	178	178	132	0	132
330	334	334	4	0	4
360	360	360	0	0	0



Conclusion:

In order to examine position control, we first move the motor ahead before moving it backward in accordance with the chosen angle. The Bang Bang controller tracks the angle, which is once more detected by the photoelectric sensor, and sends the proper control signal in response to a positive or negative error to move closer to the reference position. Although the controller includes a tiny hysteresis region in which the motor settles and cannot go farther, it is not completely precise. The hysteresis band's width affects the servo motor's accuracy since a narrower band denotes more precision.

A common finding was that the motor operated flawlessly at greater angles but showed substantial inaccuracy at smaller values. This is due to the fact that at lower angles, a photoelectric sensor's line of sight may constantly be blocked (because the motor does not move very much), making it challenging to establish the servo's location. We tried analysing the possible reasons in error variations and plotted graphs for the same, we emphasized on the motor's practical working basis in both the directions mentioned.