

# Design and Development of Automatic Inner Mirror Endurance Test System

A. M. Yaakob, S. F. Toha, M. A. A. Kadir, M. S. M. Yusof

**Abstract**--- The main role of inner rear mirror is to prevent an accident from happening by giving the driver a line of sight to the rear of the vehicle. In this study, we design and develop an automatic inner rear-view mirror endurance system with an integration of Human Machine Interface (HMI) and the actuator. The objective is to test the endurance of the pivot point of the inner rear-view motor by equipping it with force sensor to measure the force applied in moving the inner rear-view mirror to its limit angle. HMI is used as interaction between user and the actuator because the system requires limit angle and the number of repeated cycles from the user. This paper covers the initial works of the development process. It discusses the design of the system's actuator, design of the HMI and component selection. A few experiments are conducted to establish communication between PC and the microcontroller. There are still more things need to be done to make the inner rear-view mirror endurance test system a reality.

**Keywords:** Rear-view, Mirror; Vehicle; HMI; Design; Endurance test

## 1 INTRODUCTION

In the National Automotive Policy (NAP) is been introduced by the Ministry of International Trade and Industry as to assist the local automotive industry to integrates into regional and global industry networks and survives within the competitive global environment. According to Malaysia Business and Investment Opportunities Yearbook (2008), Proton (first national car) and Perodua (second national car) dominated 64% and 29% of the passenger cars market in 2001 while in the first half of 2002, the percentage decrease 1% leaving both Proton and Perodua with a total of 92% of market share. In 2005, [1] state that Perodua overtook Proton for the first time with 32% of market share compared with Proton's 24%. The market share from [2] show for both national cars increased to 57.2% in 2010 leads by Perodua with 31.2% of the market share. Malaysia has focus on the technology to improve automotive industry by focusing on some part like rear-view, Advanced Drivers Automated System (ADAS) and Automated Brake System (ABS). In this research has focus and improve on the rear-view mirror. Rear-view mirror means a device other than a complex optical system, such as periscope, the aim of which is to guarantee a clear vision towards the rear of the vehicle. Standard No 111 in Code of Federal Regulations of the United States of America specifies requirement for the

performance and location of rear view mirrors. The purpose of this standard is to ensure the driver of a motor vehicle have a clear view to the rear to avoid accidents from happen. The rear-view mirror should consist of a plane or flat mirror with a reflective surface through which the angular height and width of the image is equal to the angular height and width of the object when viewed directly at the same distance.

The inside rear-view mirror shall provide a field of view with an included horizontal angle measured from the projected eye point of at least 20 degree and enough vertical angle to provide a view of a level road surface beginning at 61m to the rear of the vehicle.

The mirror is usually mounted onto the windshield. The mounting is supposed to provide a stable support to the mirror and enable mirror adjustment by tilting in both horizontal and vertical direction. The Fig. 1 show the basic mirror adjustment which tilting in both directions. If the mirror is in the head impact area, the mounting shall collapse without leaving any sharp edge.

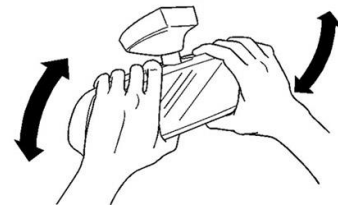


Fig. 1: Mirror Adjustment.

## 2 EXPERIMENTAL BACKGROUND

The standard method to test the inner rear-view mirror is by repeating the series of operation process for a few times and the force measurement is taken for each operation. Theoretically, the force used to adjust the inner rear-view mirror varied for each operation. The purpose of the tester is to monitor this event and make sure the force is within the range set by the Vehicle Standard Committee.

The current inner rear-view mirror tester machine only takes a few force readings since it is taken manually using force gauge resulting in incomplete force information. Current technology of inner rear-view mirror tester used wind gauge to conduct those series of operation process. Since the wind pressure is too strong, sometimes it broke the mirror without completing the process.

Revised Manuscript Received on March 10, 2019.

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The upgrade inner rear-view mirror tester machine is proposed with the capability to take force readings for every operation. This tester machine used servo motor to move the inner rear-view mirror to prevent the mirror from broken. Human Machine Interface is an added advantage since it is user-friendly. Computer will be used to communicate with the tester machine

2.1 Balancing the Rotating Machinery

Imbalance in rotating machine occurs when the principal axis of inertia of the rotor is not coincident with its geometric axis. The mass imbalance caused the machine to vibrate has shown in [3] researched. It is well established that this vibration can be reduced by introducing passive devices into the system. By placing correction masses onto the rotating shaft, the centrifugal forces due to the masses cancel out the force caused by the unbalance mass. In most cases, special planes known as balance planes are chosen specifically for the purpose of adding balancing weight.

There are two types of rotor: rigid rotor and flexible rotor. Each rotor has different method of balancing. Rigid rotors are rotor that exhibits no significant deformation, usually due to low speed of rotation or high diameter/length ratio. Conversely, [4] discuss that flexible rotors are rotor which undergoes substantial deformation whilst in operation due to high operating speed and long length. Two main types of balancing are modal and influence coefficient methods. Modal balancing is the method, whereby the unbalance forces at each mode considered are cancelled out individually. Balancing by influence coefficient method involves selection of correction mass to reduce vibration to zero at various shaft locations and various shaft speeds.

In traditional balancing procedure, the balance distribution required to reduce observed vibration is established using influence coefficient method. If the number of vibrations to be reduced is the same as the number of independent balance combinations, then a set of linear simultaneous equations is the only things needed to solve the vibration problem. If it is not equal, optimization is required. The optimization is used to accurately determine the influence coefficient and produce a detailed mathematical model of the system from which the relationship between measured vibration and forcing function can be properly estimated. The influence coefficient is usually determined by using trial weights. The weights are placed on the shaft and their effect is observed. If the theoretical model is sufficiently accurate, then there is no need for trial weight since the unbalance distribution can be determined directly from measured vibration.

Figure 2 shows a balancer using an active mass redistribution actuator. The balancer consisting of two rings is mounted on the spindle. Those two rings are not balanced and can be viewed as two heavy spots. When the balancer is not activated, these two rings are held in place by a permanent magnetic force. The two heavy spots are designed to rotate with the spindle or controlled to rotate with respect to the spindle. The combination of these two heavy spots is equivalent to a single heavy spot whose magnitude and position can change.

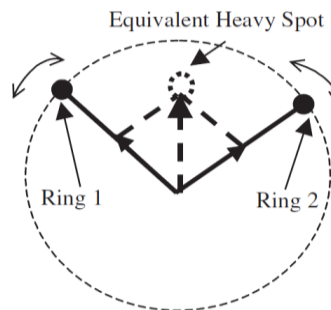


Fig. 2: Balancer using an Active Mass Redistribution Actuator

2.2 Force and Torque Relationship

Force causes linear acceleration while torque causes rotational acceleration. Torque is force times distance. The magnitude of torque applied by force acting on an object is calculated by multiplying the magnitude of the force with the perpendicular distance from the axis of rotation to the line of action of the force.

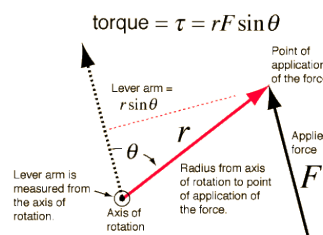


Fig. 3: Torque Calculation

Both force and torque are vector quantity. Figure 3 show the direction of the force vector is determined by the direction in which the force is applied only but the direction of the torque vector is determined by the direction of rotation and the righthand rule. The righthand rule is a trick used to help keep track of vector directions as shown in Fig. 4.

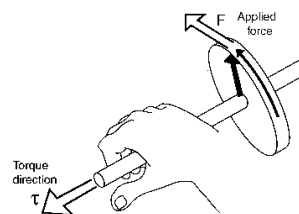


Fig. 4: Righthand Rule

Use right hand and curl the finger around the axis of rotation with the finger tips pointing in the direction of rotation. The direction in which the thumb is pointing indicates the direction of the torque vector.

2.3 Working Principle of Servo Motor

[5] defines the task servo motor as to position mechanical elements in a given position within a given time and with a given precision. Figure 5 shows an example of a control circuit for a servo drive.



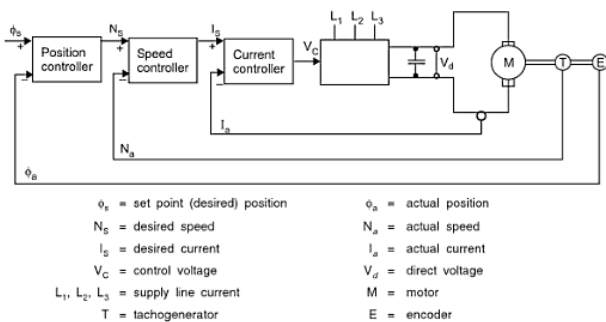


Fig. 5: Control Circuit for a Servo drive

The input to the system is the desired position,  $\phi_s$ . The actual position,  $\phi_a$ , measured by the encoder is given to the position controller as feedback. The tach generator, T compared the actual speed,  $N_a$ , feedback with the desired speed,  $N_s$ . This comparison gives the output of the desired current,  $I_s$ , to be compared with the feedback of the actual current,  $I_a$ . The output of the control voltage is given to the motor by the current controller. A six-pulse bridge with three-phase system supplier gives the direct voltage,  $V_d$ , depending on the control voltage,  $V_c$ .

2.4 Server-Client Method

[6] said “This client/server interaction is a lot like going to a French restaurant. At the restaurant, you (the user) are presented with a menu of choices by the waiter (the client). After making your selections, the waiter takes note of your choices, translates them into French, and presents them to the French chef (the server) in the kitchen. After the chef prepares your meal, the waiter returns with your diner (the results). Hopefully, the waiter returns with the items you selected, but not always; sometimes things get "lost in the translation.””

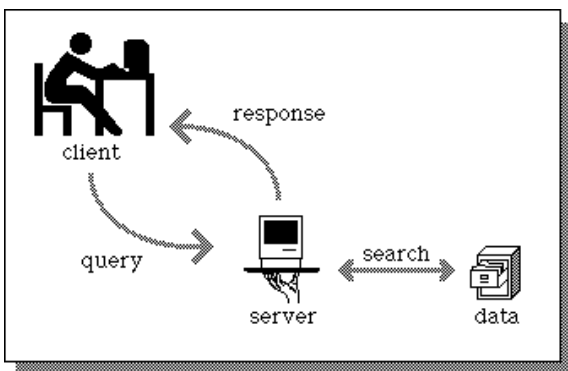


Fig. 6: Server-Client Model

Server is a program that responds when a connection is attempted at a certain point. Server usually listens to a well-known port number so that clients can connect the port to access the server. The communicating client and server applications must establish a connection to enable communication.

The steps for establishing a connection for server and client are different. In the Fig. 6 show that the server must be up and running before the client can run. The server application sets up a queue of connections, which determines how many clients can connect to the server, after creating a socket and binding the socket to a port. Normally, a server listens to anywhere from one to five connections. However,

the size of the listen queue can be adjusted to ensure that the server responds to as many clients as possible. The server waits for a connection from a client after setting up the listen queue.

The client establishes connection with the server after creating a socket and binding the socket to a network address. The client needs to know the network name or IP address of the server, as well as the port on which the server accepts connections to make the connection. After the connection is established, the client and server can exchange data by calling appropriate sockets API functions. The server and client alternately send and receive data like having a conversation. The meaning of the data depends on the message protocol the server and client use.

2.5 Access Serial Port with Visual Basic.Net

Include an imports statement at the top of the file to avoid having to specify the namespace each time use a class member discuss by [7]. For the Serial Port case, use Imports System.IO.Ports.

Create a SerialPort object:

Dim mySerialPort As New SerialPort.

Write the following code at the Form\_Load event:

```
Private Sub CommPortSetup()  
    With mySerialPort  
        .PortName = "COM2"  
        .BaudRate = 34800  
        .DataBits = 8  
        .Parity = Parity.None  
        .StopBits = StopBits.One  
        .Handshake = Handshake.None  
    End With  
End Sub
```

Open serial port using Try/Catch handling:

```
Try  
    mySerialPort.Open()  
Catch ex As Exception  
    MessageBox.Show(ex.Message)  
End Try
```

Write or WriteLine method is used to send data to serial port:

```
Dim instance As SerialPort  
Dim text As String  
instance.WriteLine(text)
```

ReadLine and ReadByte are respectively used to read one line and one byte:

```
Dim returnValue As String  
returnValue = mySerialPort.ReadLine  
Dim returnValue As Integer  
returnValue = mySerialPort.ReadByte
```

3 SIMULATION AND RESULT

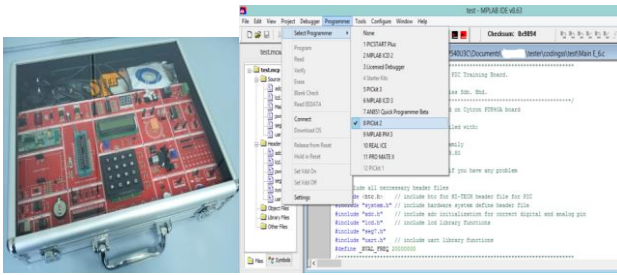
At the beginning of the project, the microcontroller used by the author was PIC16F877 programmed using C language and the Graphical User Interface (GUI) was built



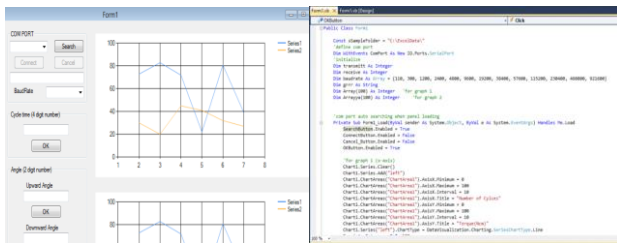


# DESIGN AND DEVELOPMENT OF AUTOMATIC INNER MIRROR ENDURANCE TEST SYSTEM

using Visual Basic (VB). Based on Fig. 7, the hardware is made up of PICkit2. GUI took input from user and sent the information to the PIC16 which later move the motor (actuator) and collect the reading from sensor to be displayed inside VB which is shown in Fig. 8.

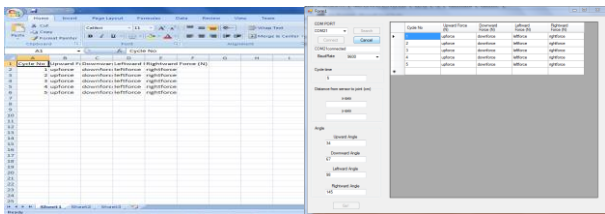


**Fig. 7: Early version of hardware**



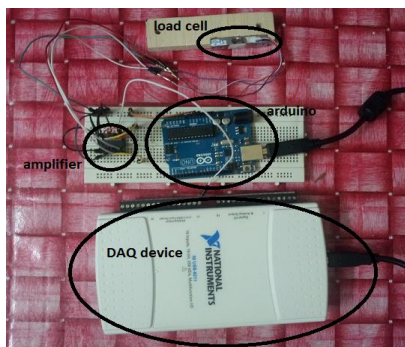
**Fig. 8: Early version of GUI**

As the project progressed, the microcontroller is upgraded to Arduino. However, Fig. 9 show the Visual Basic is used as the medium for GUI with little improvement; show the measured sensor values and saved them into Excel file.



**Fig. 9: Improved GUI**

Later, the system is decided to have a real time feature which VB is changed to LabVIEW, a more suitable software for real time data collection. The data is collected using NI-DAQ USB6211, a Data Acquisition device produced by National Instruments. The connection of the DAQ to the sensor is shown in Fig. 10. The voltage from load sensor is amplified using INA125 before transferred to the DAQ device.



**Fig. 10: DAQ to sensor connection**

This system use cube servo as its actuator which powered by 12V DC adapter. The cube servo communicates with Arduino through a motor driver called GD02 which capable to control two cube servo in one time. The resulting connection is shown in Fig. 11.

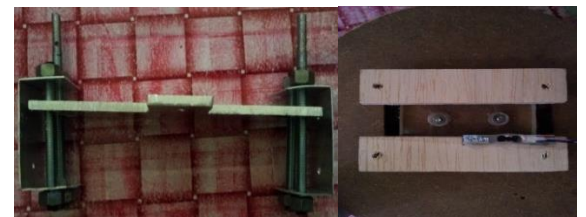


**Fig. 11: Arduino to servo connection**

To ensure this system works with any type of inner mirror, the jig in Fig. 12 was used. The jig only has one hole to fit different type of mounting. Part in Fig. 13 adjusts the height of the jig for the inner mirror to attach properly. The sensor is attached close to the body of inner mirror using the part in Fig. 13.



**Fig. 12: Jig to hold the inner mirror**



**Fig. 13: Part to compensate different height and width**

The whole architecture of the system was shown in Fig. 14 which is supported by two standing beams connected to a steel base. The motor connected to the standing beam is in charge of rotation in upward and downward direction while the rotating part is in charge of leftward and rightward direction. The components are mostly connected together via screws and nuts.

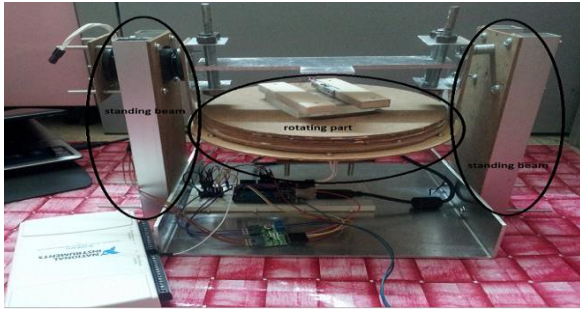


Fig. 14: Architecture of whole system

The system dimension is roughly 0.25-meter-long, 0.25-meter width and 0.25-meter high. A prototype of inner mirror cannot be used to test the system. The prototype in different angle is show as in Fig. 15.



Fig. 15: Inner mirror prototype a) side view b) front view c) top view

3.1 Result

The output demanded by the user is torque used to move the inner mirror. However, the sensor only provides the force value. Thus, a little calculation will be needed. The relationship of torque and force is defined as equation below:

$$Torque = Force \times Length$$

The length is measured as the distance between centre of movement and the point where the force is applied.

Table 1: Test of inner mirror with several parameters

Cycle time	Angle Info (degree)	Length Info (cm)	Force measured (g)	Torque calculated (g.cm)		
1	Up	30	Vertical	2	13	26
	Down	30			13	26
	Left	30	Horizontal	2.6	13	33.8
	Right	30			13	33.8
2	Up	30	Vertical	2	13	26
	Down	30			13	26
	Left	30	Horizontal	2.6	13	33.8
	Right	30			13	33.8
3	Up	30	Vertical	2	13	26
	Down	30			13	26
	Left	30	Horizontal	2.6	13	33.8
	Right	30			13	33.8

Theoretically, the force is decreasing with number of cycle time because the pivot joint starts to lose its effectiveness. However, as shown in Table 1, the force measured is the same. The only explanation for this observation is the change is very small. More cycle time is needed for the change to be

visible. Note that the change in force measurement for the real inner mirror might take longer time to be visible since the joint is designed so that it will not easily wear off.

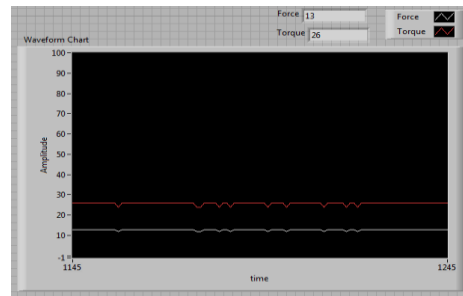


Fig. 16: Result of the individual force and torque monitoring for upward movement with cycle time=1

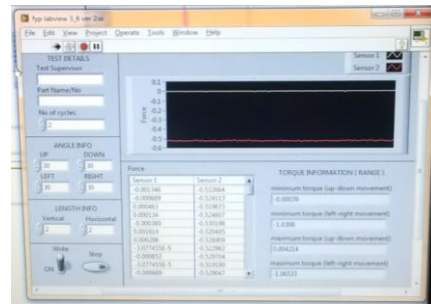


Fig. 17: Resulting GUI

Figure 16 show the result of individual force of the mirror and torque monitoring as to get the reliability data. Then in Fig. 17 show Graphical user interface which present the result of force and torque of the side mirror as to get the extract data and easier for the user to monitor the results.

4 CONCLUSION AND RECOMMENDATION

In conclusion, the objectives of this project that is to design an automatic inner rear mirror endurance test system has been accomplished. The hardware design and the Graphical User Interface (GUI) of the system had been done by using LabVIEW. From there, a feedback loop was created using the microcontroller Arduino. Overall a Human-Machine Interface (HMI) system for real-time data control has been built. However, a lot of improvement need to be done to come out with a better and more reliable design.

Since the arm will continuously rotate, a suitable material should be used as the components of the machine. For the supporting arm, a sturdier material should be used since it needs to hold the weight of the static arm which is placed on top of it. Another recommendation in this project is a more powerful motor should be used as for the industry needed to do continuously more than 10,000 cycles of test. In this project, only a small DC servo motor used which has small torque. An AC servo motor was suggested.



With the development of this test system is hoped that local original equipment manufacturer (OEM) of the automotive industry may produce a better-quality product and advance globally.

### ACKNOWLEDGEMENT

The author would like to acknowledge financial assistance from the International Islamic University Malaysia under the FRGS Grant FRGS14-103-0344.

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