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Design and Development of Special Purpose Joystick

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Abstract- **A joystick is defined as a lever that can be moved in several directions to control the movement of an image on a computer or similar display screen. It can also be used to provide inputs into a control system with each motion of the joystick translating into a specific signal. Common applications of the joystick include navigation systems in aviation industry, earth moving equipment and virtual simulation systems.**

The present work focuses on the design, development and prototype of a joystick for use in the navigational control system for a self balancing vehicle for specific users. The outcome of this work is the introduction of an independently developed joystick for the purpose of controlling the navigation of a self balancing vehicle. The design of the joystick has been fabricated using conventional manufacturing methods to keep costs down. The ultimate goal is to provide an easier experience for navigational controlling of a self balancing vehicle.

Special purpose joystick indicates, forward movement is for acceleration, backward for applying brake and left-right movement is for steering purpose. In regular driving of vehicles there will be clutch-gear mechanism to change the speed every time and turning of the vehicle is done by steering.

First step is to develop the specification, which helps in design of joystick .Different concepts are develop and the final concept is selected using pugh matrix method.In second step CAD model of the joystick is developed using Catia software. The design of joystick has been done for its safe operation.In third step joystick assembly is done, it is tested for its performance and found to be satisfactory. For its reliability failure mode effect analysis, is carried out and the RPN number was found to be satisfactory.

1.1 INTRODUCTION-

In the recent years India has been emerging as a fast growing hub of automobile sector. Many innovative ideas are being developed to build sophisticated automobile, which cater the needs of customer.These efforts of a research and development are mostly concentrated on the four wheeler sector, where in cars are built with luxurious and comfort features. These efforts are seldom concentrated on the two wheeler sector.

Many fruitful efforts can be observed in creating the better components like engine, transmission system and so on. But the luxurious features are not prominently developed for two wheelers. In the Indian market scenario two wheelers are prominently used compared to four wheelers. Hence innovative ideas are adopted to develop the modernized feature which will be more valuable for two wheeler sector. In fact in Indian environment, larger sections of the population rely on two wheeler sector which will help larger portion of the society.

1.2 Drive by Wire System-

Driving systems used in four wheelers were significantly improved with the implementation of automotive electronic technology that led to further significant development of the operability and safety of vehicles. The drive-by-wire (DBW) system became an attractive alternative to traditional mechanical systems. DBW systems include electronic control systems and electromechanical actuators and reduce the force used by the driver to control the steering wheel and pedals. This improves steering accuracy and minimizes the response time in changeable road conditions. The DBW systems are easy for fault diagnostics. They reduce the weight of the vehicle and improve its safety and operability. A significant number of currently manufactured vehicles are based on the DBW technology, which includes throttle-by- wire, brake-by-wire, shift-by-wire, and steer-by-wire (SBW) systems. SBW systems do not require a mechanical connection between the steering wheel and the road wheel.

Drive-by-wire is a technical solution that also allows the interior to be improved. If the steering wheel and the pedals are removed, the passengers have more space and thus more comfort. It also enhances safety because the cockpit and foot well can be designed completely differently. One result is futuristic dynamic handling. The electronics recognise the driver’s commands as requests for a certain driving mode – accelerate, brake, steer, reverse – and decide in a flash how to comply with the commands in the best and safest manner. In response to the actual situation, the computer utilises the information from various sensors concerning travel, wheel and engine speed, road conditions and body movement electronics as an active driving aid. Based on the data, the computer decides how sharply the wheels should be turned when cornering or what engine speed is appropriate for driving on a wet road. The system is interlinked with the active suspension Active Body Control, (ABC). Even in critical traffic situations, the electronics keep the car safely on course by intervening at lightning speed to regulate steering, braking, engine or transmission management and chassis control.

1.3 Joystick-A joystick is defined as a lever that can be moved in several directions to control the movement of an image on a computer or similar display screen. It can also be used to provide inputs into a control system with each motion of the joystick translating into a specific signal. Common applications of the joystick include navigation systems in aviation industry, earth moving equipment and virtual simulation systems.

Joysticks have become the user interface of choice for many industrial and high-performance control systems. For applications as diverse as security-camera surveillance, motorized wheelchairs, microscopes, construction equipment and submarines, joysticks provide the flexibility and precision needed by system designers and users alike.

With these applications, however, come increased requirements for reliability, durability, and overall quality. Manufacturers of front-panel control systems need an input device that matches the sophistication of their underlying control software, can stand up to continual use, and is a cost-effective component of the overall system.

The joystick, as the primary interface between the user and the system, can literally make or break the system, and it presents one of the most prominent visual and physical attributes of the system, conveying a strong impression of the overall quality of the entire system. User studies have shown that an interface that feels well-constructed will be treated as a fine piece of equipment, reducing abuse at the same time that it raises the product's image in the mind of the customer.

The DBW system will be tried for two wheelers. Here instead of steering wheel a joystick-type steering device is used to provide steering, acceleration, and braking inputs. In the traditional steering systems, it is supposed that the driver adapts to the mechanical characteristics of the steering system. In contrast, the DBW technology makes the development of new driving systems possible that can be tuned to drivers' operational characteristics. [1]

The new innovative idea of self-balancing the vehicle with a small joystick called a side stick, instead of handle bar.When the driver pushes the side stick forward, the self-balancing vehicle accelerates. When moves the lever to the right or left, the vehicle steers to the right or left and if driver pulls the lever back, the vehicle brakes and, if desired, reverses after coming to a standstill.

The signals are exclusively transmitted electronically to the relevant components (drive-by-wire). The conventional mechanical control elements used by the driver are now linked to electric and hydraulic actuators, and electronic pulses carry out the desired actions.In response to the actual situation, the computer utilises the information from various sensors concerning travel, wheel and engine speed, road conditions and body movement.Although steering, braking and accelerating with side stick requires the driver to think differently, it opens up new dimensions in driving dynamics, ride comfort and handling safety. The steering ratio and steering forces can be customised and adapted to specific situations like parking is different from negotiating a fast curve. [2]

1.4 Problem Definition

There is a need to increase the comfortness for a two wheeler which can be used for some specific purpose. Hence in this project work an innovative idea of introducing a joystick in place of the handle bar and replacing the accelerator and brake has been envisaged. Therefore the following functions are required for driving theself-balancingvehicle. In this special purpose two wheeler, a joystick will replace the conventional method of driving.

1.5 Objectives

- To design and develop a joystick for controlling the self-balancing the vehicle.
- To develop a working prototype of a joystick.
- To perform Failure mode effective analysis to the joystick assembly.

1.6 Methodology

- Data collection is done by user study
- Concept generation of joystick.
- Develop CAD models and fabrication of joystick
- Performance and testing

1.7 Organization of the Paper

Chapter1 briefly explains about the general introduction to joystick, drive by wire system, problem definition, objectives and methodology.

Chapter2 includes the brief survey done with general procedure for a product development, three different principles used in joystick operation, different areas of application of joystick and brief introduction of companies using joystick for driving application.

Chapter3this Chapter deals with the concept development process by identifying customer needs, idea screening, generation of different concepts, and selection of the concept using Pugh Matrix.

Chapter4this chapter includes the specifications, 3D model of selected concept, the detail drawings of the components to be manufactured, calculations for safe design, and assembly procedure for major components.

Chapter5this chapter is about fabricating prototype. It deals with the material selection, process selection, and different stages of manufacturing.This chapter also deals with the cost estimation for the working prototype by considering all kind of costs.

Chapter6 includes the testing and the inference of the project testing is discussed in this chapter.

Chapter7 This chapter gives the conclusion of the project and discusses about the scope of future work the project.

CHAPTER2-LITERATUREREVIEW

2.1 General Study on Product Development Process

A product development process is the set of activities beginning with the perception of a market opportunity and ending in the production, sale and delivery

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of a product. Product development is an interdisciplinary activity requiring contributions from nearly all the functions of a firm however Marketing, Design and manufacturing are almost always central to a product development project.

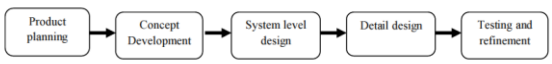
2.2 An Overview of the Product Design Process

A step by step approach for the design process when designing individual products as well as for complex systems are as follows

1. Need identification of the new design and problem identification for redesign of an article.
2. Analysis of existing similar products and collection of relevant information on products of a similar nature. Literature on the subjects should be reviewed.
3. Identification of the need of the users, to know exactly, what is wanted and to set up the objectives of the product development and determined what is required to be incorporated into the product.
4. A research methodology should be setup on what could be done to fulfil the objectives, including incorporation of user's information.
5. Planned research, and arrival at feature specifications.
6. Creative design with alternates.
7. Final design concept and prototype development.
8. Verification of its feasibility through feedback from probable users and experts.
9. Refinement of the design.
10. Final product design and prototype.

Product design is the process by which the needs of the customer or the marketplace are transformed into a product, satisfying needs. [3]

This is possible by following the stages of Product Design Process shown in Fig2.1



2.3 Operating Principle of Joystick

It is based on the principle of conversion of physical movement into a digital signal which when accepted by the device produce same results on the screen. The joystick starts working only when it is connected to the computer or the gaming device. While playing the game, every time the user makes a movement on the joystick, the wires in the device connects a circuit with one another and the computer to produce the same movement in the virtual body in the game or the application.

The Joystick can be operated by using three principles

a) Potentiometer
b) Optical systems
c) Magnetic systems

Joystick systems of the above types are necessary, to measure the angular position of the joystick shaft without introducing errors due to the linear motion. The drawback of optical and magnetic systems are generally have embedded Joystick Control position sensor. These sensors are expensive and also difficult to procure for replacement. For this reason, modern Joystick Control position requires technologies with even lower failure rates.

2.4 Ergonomics of the Design of ProductsErgonomic Design Practice by Debkumar Chakrabarti states thata range of products that structurally supports the human body in a comfortable posture allowing it to work comfortably in a sitting, standing, and supine, semi-lying and in any position that specific tasks may demand may be termed as Ergonomic based design.

The user mode of use of the intended product i.e. how he is supposed to hold it, what type of operation are likely to be performed to get the anticipated functions out of that product, the dimensioning can be provided accordingly, taking into account the natural advantages and limitations of human beings. These dimensions could be incorporated properly into the design process to make the final product useable and acceptable by the users with the facility of using it freely, safely and satisfyingly.

The human geometry of the product must be suitably fitted together for safety as well as for functional reasons. Hence appropriate anthropometric and biomechanical applications are necessary for a "human compatible" deigned product.

2.4.1 Ergonomic Principles

A product should ensure the basic principles of human compatibility through:

- A product user friendly relationship
- An anthropometric and behavioral match between the user and the product
- Ease of handling
- Proper semantic applications
- Product reliability and safely through
- Designing the overall form, shape, size of the product and layout of the parts for operational ease
- Removing unnecessary things
- Guarding unsafe things
- Warning about portable hazards while using the same and
- Training by specific instructions on how the system efficiently works

2.4.2 Ergonomic Criteria-While designing a product the following aspects along with the important Ergonomic criteria may be considered

- If there is any movement or if force has to be applied while using a part of an article or the whole, the direction for force applications should go with the configuration of the human body, i.e. it should synchronize with the human natural movement axis so that maximum mechanical advantage could be achieved.
- Consider the physical, structural and biomechanical nature of human beings, sex and age variation, along with the context and intended methods of use.
- Overall appearance of product should be such that it should be convenient to use.
- Product must be durable, repairable and have multipurpose facilities for manipulator use.
- Obviously the cost factor should be considered with a view to satisfying the intended class of customer. If the above considerations are taken care, the product would appear compatible for human use and its acceptable facilitated. Incorporating ergonomic criteria in a product would obviously be beneficial for the direct

users as well as for the manufactures the employers, who may provide the products to the employee-use, and the others connected commercially with it. The ergonomic design is considered in the development of joystick which are shown in the fig 1.3

Safety has always been a priority. This commitment is demonstrated that the vehicle should use first-ever window airbag. It inflates across the side walls and considerably reduces the risk of head injuries in side crashes and rollovers. Since the coupé study does not have a steering wheel, the front airbags are incorporated in a kneepad underneath the dashboard.

Different types of ergonomic concept development in joystick

2.5 Different Types of Joysticks

There are various types of joystick available in market in that some are listed and explained with figures.

2.5.1 Finger Operated Joystick

2.5.2 Thumb Operated Joystick

2.5.3 Hand Operated Joystick

2.5.4 Desktop Operated Joystick

2.7 Literature Search

.Anup S Deshpande [12],studiedthe desirability of developing an autonomous vehicle.The rising demand for efficient use of energy in automobiles motivate the research on optimum solution to computer control of energy efficient vehicles. This thesis work describes three control methods - mechanical, hydraulic and electric those have been used to convert an electric vehicle into a 'drive by wire' vehicle using computer control. It also describes a vehicle tracking system used to track the route taken by the vehicle. Computer interfacing and control of basic automobile operations like steering, braking and speed have been implemented and will be described in detail. A computer system with a joystick and a Galil three axis motion controller are used for this purpose. The motion controller is interfaced with a computer software program on the input side and with actual hardware (speed motors, steering system, and braking system) on the output side. WSDK (Windows Servo Design Kit) serves as an intermediate tuning layer between the motion controller and the computer program for tuning and parameter settings. The software program for this is developed in C#.NET. Voltage signals sent to the motion controller can be varied through the software program to control the steering motor, activate the hydraulic brakes and vary the vehicle's speed. A 1000 mile test while running in a hybrid mode has also been conducted successfully. The vehicle was also tested in computer control mode with a keyboard and joystick as input devices. Currently the vehicle is being tested in various safety studies and is being also used as a test bed for experiments in control courses and research studies.

Daniel J. Brooks and Holly presented in the Yanco Department of Computer Science University of Massachusetts Lowell [13], Traditional two degree of freedom (DOF) joysticks inherently provide users with some amount of hap tic (sense of touch) feedback in the form of a constant spring force and hard stops. The spring force is felt as a small amount of constant pressure as springs inside the base of the unit push the handle back towards the centre resting point. This pressure provides several important functions. First, feeling any amount ofpressure informs the user that the joystick is not centred. Also, the direction of the pressure is inversely related to the direction in which the joystick is pressed. Finally, the joystick will automatically centre itself when the user relaxes his/her pressure on the unit. The physical layout of the device provides a limited range of motion in which the joystick can move. Thus, the user is informed when the device is at its limit when the device comes to a hard stop. They believe that this kind of feedback should also be present in the hap tic joystick. Therefore, interaction with the hap tic joystick should feel like a traditional joystick and also have the ability to provide information in a hap tic manner. They hypothesize that it will be possible to isolate the act of enabling various types of hap tic feedback.

JoakimÖstlund,[14]presentedworkthe analysis and aim of the report is to describe and analyse commercially available joystick systems in Sweden. Furthermore, general considerations to be taken in the design of alternative primary levers (for driving) are emphasised. A small group of people with severe disabilities regain an essential part of their mobility thanks to joystick operated cars. People currently requiring joystick-operated cars have disabilities resulting in limited mobility and/ or strength in arms and legs. A joystick includes accelerator, brake pedal and steering wheel in one lever. The analysed joystick systems have a joystick with spring-feedback and do not have the mechanical connection with the steering wheels and brake system. The result is that much information fed back to the driver in a conventional car by means of steering wheel and pedals is lost. Since the joystick is designed as a lever, fastened at one point and with two control directions, lateral and longitudinal controls may interfere. Further shortcomings can be identified for joystick operated cars but their influence on traffic safety is difficult to decide. Information and knowledge have been gathered to the knowledge survey through literature studies in the field and contacts with vehicle adapters, driving license instructors and drivers with disabilities.

Youngwoo Kim, Member, IEEE, TakamasaOyabu, GoroObinata, Member, IEEE, and Kazunori Hase,[15]In thisaperpresent some results from the study on the impedance characteristics of a human arm during the execution of vehicle steering control tasks by using a joystick-type steering device. They propose a new model of human–machine interaction where the damping coefficient of the interface device can be tuned to match the impedance characteristics of the human arm. To verify the proposed model, we developed a special experimental setup. They used a robot and force/torque sensors to simulate the joystick operation. They explored human–machine interactions when the operator uses only one hand to control the vehicle. The reaction forces of the joystick were simulated by a virtual impedance field tuned to match human arm impedance.

PakoMaruping, Courses ENG4111 and ENG4112 Research project university of southern queensland faculty of engineering and surverying[16], The design and construction of the joystick in this paper is aimed at helping stroke patients in rehabilitation, the joystick will help exercise the wrist muscles. The joystick will have assistive behavior. This assistive behavior will work such that a patient will follow a target and if they go off course the joystick will act as to assist them to go back on course.The motors were be programmed to move back and forth in a straight line and the force feedback will be applied so as the motors to help the patient move in the right direction a PID was be incorporated in to the control system so as to correct the errors in the shortest time possible. If time permits the joystick will be programmed to move in a rotational motion so as to get the total wrist exercise. The design of the casing for the joystick, the hardware and software were completed, testing was completed as well.

Mohammad Reza Sirouspour and Septimiu E. Salcudean,[17]presentsthere are many manual control tasks in which the operator's action is fed back to the input device, usually a joystick, through the operator's body dynamics excited by the base motion. This can lead to instability and reduced performance. This paper proposes a novel approach to the cancellation of such "biodynamic feed through." A prototype single-degree-of-freedom task in which the operator uses a force-reflecting joystick to position his/her base is considered here. A model-based approach is used to formulate -synthesis-based controllers that coordinate the motions of the joystick and the base. The solution is obtained by iterations. The resultant controllers are robustly stable with respect to variations in the arm/joystick and biodynamic feed through parameters. They also provide a desired level of performance based upon position tracking between the joystick and the base and admittance shaping of the joystick. Experimental studies demonstrate the effectiveness of the proposed methods in the suppression of feed through induced oscillations. The approach developed in this Paper, with some modifications, can be generalized to tele operation from movable bases.

Brad E. Dicianno, Donald M. Spaeth, Rory A. Cooper, Fellow, IEEE, Shirley G. Fitzgerald,Michael L. Boninger, and Karl W. BrownRRD JRRD Volume 46, Number 2, 2009 Pages 269–276 Journals of Rehabilitation Research &Development [18]. In this paper Innovations to control interfaces for electric powered wheelchairs (EPWs) could benefit 220 000 current users and over 125 000 individuals who desire mobility but cannot use a conventional motion sensing joystick (MSJ). We developed a digital isometric joystick (IJ) with sophisticated signal processing and two control functions. In a prior study, subjects' driving accuracy with our IJ was comparable to using an MSJ. However, the observed subjects using excessive force on the IJ possibly because its rigid post provides no positional feedback. Thus, this paper examines the time-series data recorded in the previous study to characterize subjects' force control strategies since weakness is a concern. Eleven EPW users with upper limb impairments drove an EPW using an IJ with two different control functions and an MSJ in a Fitts' law paradigm. Subjectsrelied upon positional feedback from the MS J and used appropriate force. In contrast, subjects using the IJ with either control function applied significantly higher force than necessary.

2.8 Summary of Literature Survey

The researchers and developers have incorporated already well- proven concepts and technologies which are not yet available today, but for which basic research has shown great potential, and therefore a realistic chance of implementation in future models. From the literature survey it is concluded that many companies have tested joystick by installing in four wheeler. Although steering, braking and accelerating with side sticks requires the driver to think differently, it opens up new dimensions in driving, ride comfort and handling safety. It's the driver is less distracted from the traffic situation, meaning that the system has a role to play in the further improvement of active safety.Hence a joystick operated controlling system can also be used in a special type of two wheeler.

CHAPTER 3-CONCEPTDEVELOPMENT

In this section some of the ideas that are required forthe development of the Joystick is analysed. Also it is required to know the schematic of vehicle and working of joystick is necessary which are described in this chapter.

3.1 Schematic of Vehicle

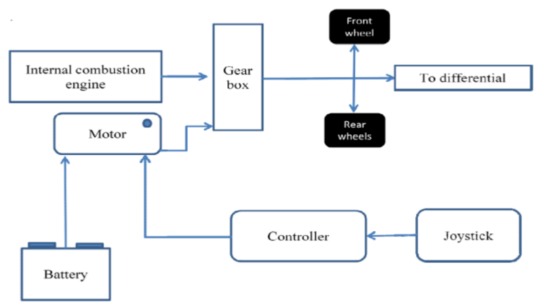


figure 3.1 Schematic Diagram of Vehicle

Fig 3.1 shows the schematic diagram of self-balancing vehicle which showthe transmission of energy in the vehicle, when the mechanical force is applied to joystick, the mechanical energy is converted to electric signals with the help of potentiometer and these electrical signals through the controller to run the motor. The output of motor connected to the transmission is used to run the differential which in turn propels the wheels.

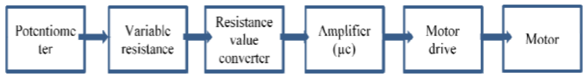


Figure 3.2 Schematic Dig Of Joystick

The schematic diagram of joystick explains the process flow of mechanical energy to electric signals. These signals run the motor which propel the vehicle. This is open loop control system no feedback. This schematic explains the transmission of energy in the vehicle, when the joystick is moved which produce the variable resistance this resistances value is sent to the resistance value converter to convert the signals from analog to digital. As this signals are very low so they are sent to amplifier to amplify these low signals here amplifier is nothing but the microcontroller (embedded system) programme is needed which control the signal and can be used for our required application.

3.2.1 Potentiometer
3.2.2 Amplifiers
3.2.3Micro Controller
3.2.4 Motor Drive
3.2.5 Motors

3.3 Concept Development Process

In the concept development phase the problem is defined and ideas are generated by the interaction with expert from the different department like design, manufacturing &the user of the product. The concepts were generated & screened to get single and promising concept to fulfil the objectives.

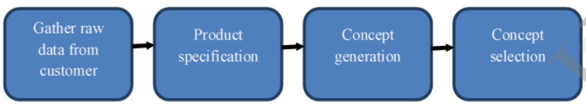


Figure 3.3 Concept development process

3.3.1 Requirements for concept generation for a joystick

After a series of brain storming sessions with the technical personnel and with the customer survey(which is shown in the appendix)the following requirements are considered

(1) The joystick must be designed in order to optimize the possibilities for controlling the vehicle.

(2) The driver's control movements are transmitted via the joystick to the vehicle in order to guarantee its reliable function with a minimum risk of interruption

(3) The exchange of information take place between the vehicle and the driver via the joystick in order to facilitate the task of driving and make it as simple, comfortable and safe as possible.

(4) The operator wants to uses only one hand to control the vehicle.

Based on the above requirements the following parameters are considered for concept generation:

(1) Ease of implementation
(2) Four functions of driving should be controlled by joystick.
(3) Simple mechanisms to be used
(4) Automatic controlled system
(5) Low price

3.3.2Concept Generation

A product concept is an approximate description of the technology, working principles and form of the product. It is a concise description of how the product will satisfy the customer needs. A concept is usually expressed as a sketch or as a rough three-dimensional model and is often accompanied by a brief textual description.

The concept generation process begins with a set of customer needs and target specification and results in a set of product concepts from which the team will make a final selection. Four different concepts are generated and these different concepts are explained in detail below.

3.3.2.1 Concept A

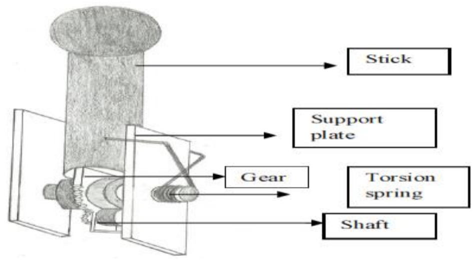


figure 3.4Concept A

Fig 3.4shows the type of joystick concept which has the following features

- When the stick is moved big gear meshes with small gear as small gear is fitted with potentiometer it rotates and produce variable resistance. Torsion spring is used for the return mechanism.

Drawbacks

- In this concept that, there is only one side movement of stick because of gearing arrangement. Hence two joysticks are required.
- But position of this joystick in vehicle is difficult.
- There is no closed body for this concept.
- Since gear mechanism is used for potentiometer actuation, again there may be chances of getting jammed.

3.3.2.2 Concept B

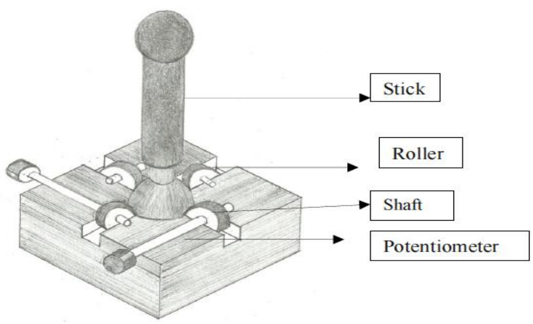


Figure 3.5Concept B

Fig 3.5 shows the type of joystick concept which has the following features

- Simple concept as compared to the first concept and there is no need of two joystick because this joystick rotate in two direction.
- This concept is different from the first, as here rollers are used for actuation of potentiometer. When stick is moved sphere meshes with rollers and force is transmitted to move the potentiometer which produce variable resistance.

Drawbacks

- The potentiometer, shaft and roller are placed in the slots. Where these four slots are provided with the cuts for the movement of roller because of these gaps there is a chance of entering the dust which reduces the motion of shaft.
- In this concept again the position of potentiometer is difficult which is placed outside the assembly.
- In this concept, the main drawback is providing a housing to place the parts.

3.3.2.3 Concept C

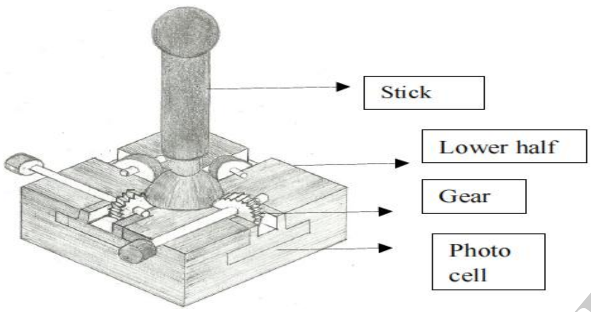


Figure 3.6 concept C

Fig 3.6 shows the type of joystick concept which has the following features

- When light from each LED shines through one of the slots, it causes the photocell on the other side of the gear to generate a small amount of current. When the gear rotates slightly, it blocks the light and the photocell doesn't generate current.
- In this concept gears with the photo cells are used.
- This causes the photocell to generate rapid pulses of current.

Drawbacks

- The main drawback of this concept is depends on the environment conditions.
- When the power is switched off the original reading shows as zero.

3.3.2.4ConceptD

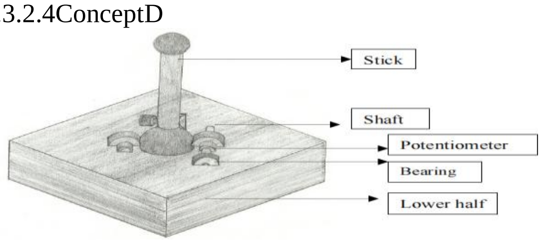


Figure 3.7 Concept D

Fig 3.7 shows the type of joystick concept which has the following features

- In this concept the numbers of slots are reduced.
- The positions of the component are placed in between the upper and lower half so that meshing of components with the sphere is made easy.
- Main advantage of this concept is for the return mechanism of stick helical spring is provided.
- Small steel ball is placed in between sphere and spring for the free movement of sphere.
- Rollers are replaced with bearing, a circular rubber is provided on the surface of bearing to create small friction while meshing components which helps in actuation of potentiometer to show values.
- Two side holes are provided for passing of wires which are connected to the potentiometer.
- This concept overcomes the all above concepts.

Through process of elimination a suitable design was selected. The final design was created From all the initial ideas they were analysed and some concepts from the ideas were used to Make the final design.

3.3.3 Concept Selection

Concepts should be presented at the same level of detail for meaningful comparison and unbiased selection. The selection criteria are listed along the left hand side of the screening matrix, as shown in the table above. These criteria are chosen based on the customer needs in the survey as well as on the needs of the enterprise, such as low manufacturing cost or minimal risk of product liability. A relative score of A, B, C and D is to be place in each cell of the matrix to represent how each concept in comparison to the reference concept relative to the particular criterion.

The concept which is ranked more is selected depending on customer survey as well as with the technical experts which are shown in appendix and the outcome of the entire concept development phase is to select a best concept and finally by taking the average of all survey at a conclusion of this phase is that concept “D” is has been selected as the final concept by the survey conducted with the technical experts of company. Major factors affecting the decision are given below. All team members should be comfortable with the outcome.

- Ease of handling
- Degrees of freedom
- Easy of fabrication
- Ease of operation
- cost
- Easy maintenance

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Table No 3.1 Pugh matrix for concept selection

		CONCEPTS			
Sl. No.	Selection Criteria	Concept A	Concept B	Concept C	Concept D
1	Ease of use/ Handling	5	3	4	5
2	Degree of freedom	5	5	4	2
3	Ease of fabrication	5	1	3	5
4	Ease of operation	4	1	3	5
5	Cost	2	1	3	5
6	Robust Design	1	5	3	5
7	Easy to install	2	1	2	3
	Over-all Score	24	17	22	30
	RANK	II	IV	III	I

SCORING

1. Poor
2. Not so Good
3. Good
4. Very good
5. Excellent

The concept selection is made by taking the average of all the concepts in this Pugh matrix final selected concept is consider as a reference concept which has high score and ranked first.

CHAPTER 4-DETAIL DESIGN

The detail design phase includes the complete specification or the detail of the geometry, for all the unique parts in the product. The output of this phase is controlled documentation for the product – the drawings or computer files describing the detail dimensions of each part and its templates which will acts as tools

4.1 The Technology Used In the Joystick-Generally joysticks are operated by using friction and resistive technologies. In friction technology ball is used for the return mechanism but in resistive technology the spring return mechanism is used. In this project work resistive technology is used for the joystick.

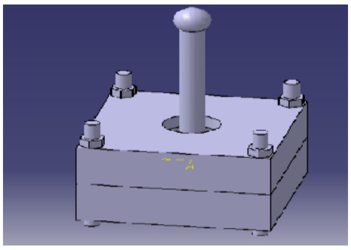
Resistive Technology The resistive joystick use potentiometer mounted to spring loaded ball that are moved by a deflection of the joystick handle. Typically one potentiometer is used for each axis(x and y) the output of the potentiometer is read as either a change in velocity or change in electrical resistance depending on how they wired.

4.2 Specifications-With the existing literature and by consulting with the technical personnel the following specifications are considered.

Table 4.1 specification table for mechanical and electrical is shown below

Mechanical (For X and Y).		Electrical	
Break out force	5N	Supply voltage	5V
Operating force	15N	Supply current	13mA
Mechanical angle of movement	35°	Resistance	1.2ohm
Material	Nylon		
Lever action	self-centring through the spring		

4.3 3D Modelling of Selected Concept



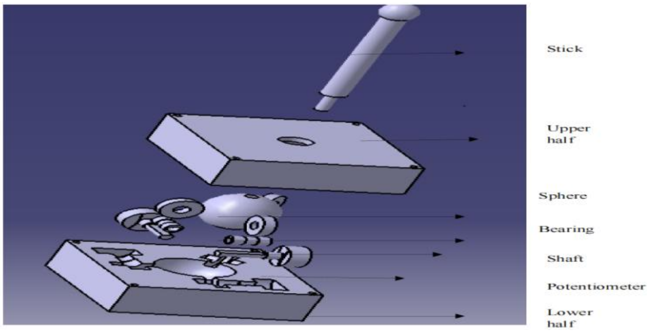


Figure 4.1 exploded view of the joystick

The Joystick Assembly Mainly Consists Of Following Components:

4.4 Part Details of Selected Concept

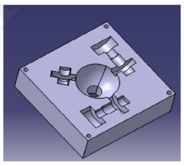


Figure 4.2 upper half

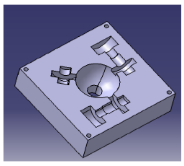


Figure 4.3lower half

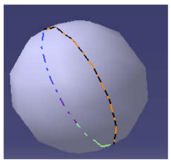


Figure 4.4 ball

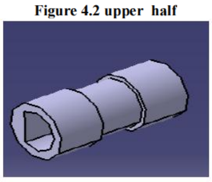


Figure 4.5 shaft

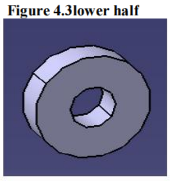


Figure 4.6bearing

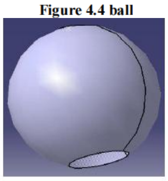


Figure 4.7 sphere

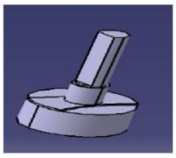


Figure 4.8potentiometer

Figure 4.9springs

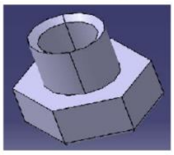


Figure 4.10special bolt

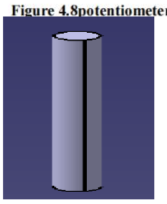


Figure 4.11bolt

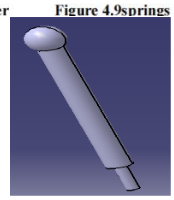


Figure 4.12 Stick

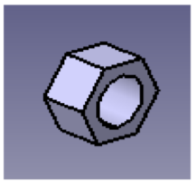


Figure 4.13 Nuts

Upper half:Figure 4.2 shows the upper half, the frame of joystick is made up of two halves called as upper half and lower half. The dimensions are 75*75*25mmlength,breath and thickness. Which consist of three slots in which potentiometer are placed in two slots and another slot is for the support of sphere. Centre cut out is made for the placing sphere which is 15mm diameter and four holes at the ends to place bolts for fixing two halves. Centre throughout cut of 23mm diameter is made to pass the stick.

Lower half:Figure 4.3 shows lower half,the frame of joystick is made up of two halves called as upper and lower half of measurement75*75*25mm length, breadth and thickness. Here also same procedure as the upper-half but throughout cut is made with threading to place the special type of bolt which acts as the housing of the spring.

Ball:Figure 4.4 shows ball, which is made up of mild steel having 10mm diameter. This is placed in between the Sphere and the spring, for the free movement of the stick and selection of ball is made same as the outer diameter of the spring so that it shouldn't fall inside the spring or out.

Shaft: Figure 4.5 shows,the shaft is made of mild steel and cut-out is made at the centre of the shaft to Place the bearing this helps in rotation of shaft. Through cut is made inside the shaft to place knob of the potentiometer.

Bearing:Figure 4.6 shows,the bearing which is mounted on the shaft the ratio of bearing and the sphere is 1:3.which is up of the material mild steel which meshes with the sphere & helps in the rotation of the shaft the rubber is placed on the bearing for the friction between sphere and bearing

Sphere:Figure 4.7 shows the sphere, which is the sphere, is made up of mild steel having 30mm diameter. At the bottom small circular cut out is made for the movement of small ball and on the head straight cut out to place the stick. Here the tight fit is made in between stick and sphere.

Potentiometer:Figure4.8 shows a potentiometer, which is a three-terminal resistor with a sliding contact that forms an adjustable voltage divider. If only two terminals are used, one end and the wiper, it acts as a variable resistor or rheostat. This is a readymade part, which vary the resistance. The resistance value is converted and sent to amplifier for amplification of low signals. These signals are sent to motor through motor drive.

Compression Spring:Figure 4.9 shows the helical spring placed in the housing of bolt for the return mechanism of the stick. This is made up of the material used is carbon steel wires. The mechanism most joysticks use for automatically resetting the shaft to neutral. Thicker and larger springs make the reset stronger and movements more affected. A part is often added to secure the spring below the pivot.

Special Bolt:Figure 4.10 shows the special Bolt is placed at the bottom of the lower half which acts as a housing of spring,so that spring should not come out. Which is made up of the material mild steel and this is hexagonal bolt.

Bolt :Figure 4.11 shows the bolt which is used for the fixing up of upper and lower half.

Nut :Figure 4.12 shows thenut, which is also made of mild steel which helps thight fit in fixing of two halves of the joystick.

Stick: Figure 4.13 shows the stick,which is used for the lever mechanism in joystick. This is made of mild steel material.The stick is made up of mild steel with 90mm height with 15mm circular structure on the head of the stick and circular cut out 10mm diameter at the bottom.

Figure 4.14,E-clipFigure,4.15 guides,Figure 4.16 wire harness

E-clip:Figure 4.14 shows the E-clip which is a small, flat curved plate of metal shaped like the letter "E"; it is a type of retaining ring which is a type of fastener. It attaches to the bottom of the shaft, aligning and securing the parts along it. This also puts some compression and tension in the spring so the joystick has and returns to a neutral position.

Restrictor guide:Figure 4.15 shows the guide which is a restrictor gate is a plate with a specifically shaped hole, like a square or circle that determines physically where the joystick can be moved. It is generally attached on the bottom of the joystick, restricting the bottom of the shaft. Many joysticks do not come with restrictor gates and are always circularly restricted.

Wire Harness:Figure 4.16 shows the wire harness joysticks potentiometer have attached to a PCB into which a wire harness (wires aligned along a plug) is inserted instead of having to wire each of the micro switches around the bottom of the joystick.

4.5 Design Considerations Of Joystick

The joystick is more function based not strength based so torque at various position, spring design and safety of joystick is calculated.

4.5.1 Torque calculation

Torque is calculated at various portions of stick.

Table 4.2:Torque at various positions

SI.NO	Torque	Force applied	T=F×L	Results
1	Nil torque	0kg	F ×L =0	0 N.m
2	Min torque	0.5kg	F ×L =.5×0.09×9.8	0.441N.m
3	max torque	1kg	F ×L =1×9.8×0.09	0.882N.m

The joystick has to be designed for kinematic considerations and ergonomic considerations.

4.5.2 Kinematic Consideration

Joystick can be approximated as a second type of lever. The joystick can be assembled easily without any complication since it's made symmetric. Also the assembly is easier as there is no complex mechanisms involved. Henceit is considered as a lever.

A lever is a rigid rod or bar capable of turning about a fixed point called fulcrum. it is used as a machine to lift a load by the application of a small effort.The load W and the effort P may be applied to the lever in three different ways as shown in Fig. 4.17. In the second type of levers, the load is in between the fulcrum and effort. In this case, the effort arm is more than load arm; therefore the mechanical advantage is more than one.

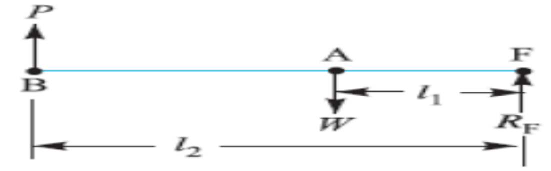


Figure 4.17second type of lever

1. Load (*W*), 2. Effort (*P*) and3. Reaction at the fulcrum *F* (*R*F)

4.5.3 Design of joystick

Considering the stick as a lever the reaction at point Q and R are calculated.

Diameter of the Rod, D=10mm

Force at point p=F_P= 5N

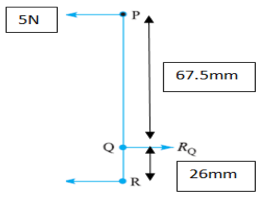
R_R= Reaction at R

Taking moment at R,

R_Q ×26=5×93.5

R_Q =233.75N

Since the forces at P and Q are parallel and opposite as shown in Fig. therefore reaction at R



4.18 Lever

R_R=R_Q-5=233.75-5=228.5N

Considering these above reactions the following equation is considered to calculate the stressM = Bending Moment of column

Y= length of stick

σ = Normal Stress acting on a member

I = Moment of Inertia

$\frac{M}{I}=\frac{\sigma}{Y}$,

I = $\frac{\pi}{64}D^4$= 490.8 mm^4

M =I/2 × F ×X=1/2 × 233.75 × 67.5= 7889.06Nmm

Y =$\frac{D}{2}$ =5mm

$\sigma = \frac{MY}{I} = \frac{7889.06*5}{490.8}$ = 80.36 M N/M^2

Factor of safety = ultimate stress / working stress= 234 / 80.36= 2.8

Since the factor of safety is 2.8 so the design of joystick is safe.

4.5.4 Determination of circular hole on the upper half

The circular hole is needed on the surface of the upper half so the following specifications are considered

s=circular area

r=distance from the ball

θ=angle between reference line

to the deviated position of stick

S = R × θ(radians)

Converting degree to radians

θ =35×3 /180 =0 .583

S=45×0.583=26.25mm

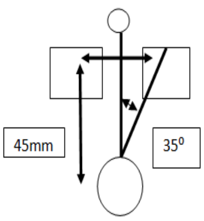


Figure 4.19 hole on upper half

4.5.5 Spring calculation

On applying 4.905 N (0.5 kg)

And the required stiffness be k= 2.96 N/mm

Step 1: measure deflection –

Deflection= δ = load/ Spring constant = 4.905/2.96= 1.65385 mm

Step 2: Material selected

s_{ut} = ultimate tensile strength

= 1210 N/mm^2

Permissible shear stress=τ= 0.5* s_{ut}

= 0.5*1210 = 605 N/mm^2

Step 3: spring index(C)

Assume C=9.5

Step 4: Wahl factor ‘K’

$$K= \frac{4C-1}{4C-4} + \frac{0.615}{C} = 1.152972$$

Step 5: wire diameter (d)

$$d^2 = \frac{k\,(8\,P\,C)}{\pi\tau}$$

d = 1 mm

Step 6: mean coil diameter (D)

D= c*d

D= 9.5 mm

Step 7: no. of active coils (N)

$$N=\frac{\delta \times G \times d^4}{8 \times P \times D^3} = 4$$

Step 8: total length

Assumed length of the spring is 16 mm (as per requirement)

Step 9: pitch

Pitch = total length / (Nt-1)= 4 mm

Nt = total no. of active and non-active coils= 4 +1 = 5

Step 9: total gap = (Nt-1) × gap between two adjacent[19]

4.6 Detail Drawing of the Each Component

The detail dimensions of the each component are set according to the anthropometric data where the selection of the percentile or the respective components is already explained in earlier section.

The component drawings are created using CATIA V6 and later it was edited by importing it in AutoCAD 2006. The 2D drawings of different components are shown in appendix

4.7 Assembly Procedure of Joystick

The joystick can be assembled easily without any complication since it’s made symmetric. Also the assembly is easier as there is no complex mechanisms involved.

The main assembly can be divided into different sub-assemblies. Fig 4.20 (a) to Fig 4.20(d) shows the assembly procedure of Joystick.

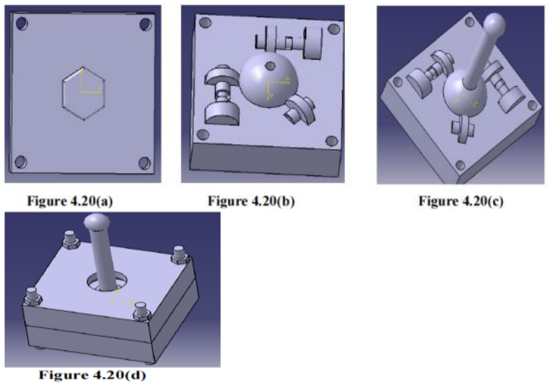


Fig4.20 Assembly procedure of Joystick

CHAPTER 5-FABRICATION OF JOYSTICK PROTOTYPE

Raw material is transferred into the finished product in this activity generally, during fabrication. Each part of the product is manufactured by referring to their respective design drawings. Before taking up fabrication, the product drawings are studied and process plan for each part is prepared. Attention is bestowed on fabric ability during design stage itself.

During product fabrication following procedure is followed

5.1 Material selection-Information about several Suitable materials is selected depending on their application and their properties. In this manufacturing process the nylon material is selected.

Table 5.1: Properties and cost of available material

MATERIAL	Modulus Of Elasticity E, GPa	Ultimate strength MPa	Cost per kg Rs.
NYLON	450	750	500

5.2 Process Planning-Systematic determination of the detailed methods by which parts can be manufactured economically from initial to finished stage is taken up. The process sequence is determined for a particular part based on the availability of specific machines. Plans are presented in the form of process sheets, giving sequence of operations, machine tool employed and an estimate of time for each operation and related details

5.3 Manufacturing-According to process plan presented in the form process sheets, manufacturing of each component are carried out.

The machining operation can be classified into the following categories:

Pre tooling:-Raw material is cut to overall profile considering machining allowances. This operation is carried out generally sawing and flame cutting. This is also called as pre-tooling.

Conventional tooling:-According to drawing and process sheet the raw material is rough machined to the geometric features and size of the part by providing sufficient allowance for finishing. Conventional machining is generally carried out by Lathe, Milling and shaping machines.

1.4 Failure Mode Effective Analysis (FMEA)process

Process FMEA is performed on the manufacturing processes. They highlight possible failure modes in the manufacturing process, limitations in equipment, tooling gauges, operator training, or potential sources of error.

5.4.1 Failure Mode Effective Analysis (FMEA)-FMEA process is performed on all the components to be manufactured. They highlight possible failure modes in the manufacturing process, limitation in equipment, tool gauges, operator training, or potential source of error. This information can then be used to determine the corrective action that need to be taken.

The objective of an FMEA is to look for all of the way a process or the product can fail. A product failure occurs when the product does not function, as it should or when it malfunctions in some ways. Even the simplest product have smany opportunities .Ways in which a product or process can fail are called failure mode has a potential effect and some effects are more likely to occur then others. In addition, each potential effect has a relative risk associated with it. The FMEA process is a way to identify the failures, effects and risks with in a process or product and then eliminate and reduce them.

5.4.2 Evaluated risk of Failure in FMEA work sheet-The FMEA work sheet gives the complete information of individual failure mode .the table shows FMEA worksheet, the column 1 describes the part number, the column 2 describes part name, the column 3 describes the function of each component, the column 4 describes potential failure mode, the column 5 describes the potential effects of failure, the column 6 describes, the column 7 assigns severity number depending on that the rating is given to the process. The column 8 describes potential cause or the mechanism of failure, the column 9 describes occurrences scale depending on that rating is given to that process, the column 10 describes current design controls or verification, the column 11 assign the rating is given depending on detection scale, the column 12 assign the RPN ratings for the individual potential failure modes respectively. Column 6, 9 and 11 assigns severity ranking criteria, occurrences ranking criteria and detection ranking criteria after action taken for the individual potential failure modes.

5.4.3 Evaluating the risk of failure

The relative risk of a failure and its effects is determined by three factors-

Severities (S) - the consequence of the failure should it occur.

Occurrence (O) –the probability of frequency of the failure occurring.

Detection (D) –the probability of the failure being detected before the impact ofthe effect is realized.

Once action has been taken to improve the product or process, new rating for severity, occurrence and detection should be determined and a resulting RPN calculated.For the failure modes where action was taken, there should be a significant reduction in RPN.There should expect at least a 50% or greater reduction in the total RPNs after an FMEA.That RPN depends on the industry and the seriousness of failure.

5.5 Bill of Material-The bill of material gives description of each and every components and the quantities of each used to manufacture an end product. The bill of material is generally abbreviated as BOM. Bill of materials are hierarchical in nature. During assembly and final inspection, BOM plays an important role.The details are shown in the appendix

5.6 Cost Estimation-Cost estimation aims at determining the cost of manufacturing a component (Product Assembly). It should be carried out in such a way that all factors affecting the cost are properly considered. Thus it is the probable cost of an article before manufacturing starts. By compiling statement of the quantities of the material required and production time required, the probable cost is computed. The various constituents of the costs like material cost, tooling cost, machining cost, non-productive cost (factory expenses, administrative expenses, selling expenses etc.).

5.7 Material Cost-Cost incurred on raw material used in making product. They are direct and indirect materials

Table 5.2 Materials use for the product and its cost

Sl.no	Part	Quantity	Cost(Rs)
1	Shaft	3	225
2	Stick	1	100
3	Upper half	1	75
4	Lower half	1	75
5	Sphere	1	175
6	Ball	1	50
7	Special bolt	1	100
Total			800

5.8 Process Cost-Cost of shaping the raw material in to finished products. For this, machining time is to be calculated for each part. Machining time can be calculated by using following formulae.

1. Turning, $T_m = L / (S \times N)$ Where, L= Length of the job in mm

   S= Feed rate in mm/rev

   N= RPM

2. Drilling, $T_m = L / (S \times N)$ Where, L= Depth of the job in mm

3. Milling, $T_m = L / S$ Where, L= Length of travel in mm

In practice machining cost is fixed based on the experience considering the handling time, set up time etc.

5.9 Standard Components Cost:Cost incurred on purchasing the standard component used is indicated in

Table 5.3 Standard Components and its Cost

Sl NO.	Part	Quantity	Cost per piece	Cost
1	Potentiometer	4	25	100
2	Bearing	3	75	225
3	Spring	1	15	15
4	Nut	1	25	25
5	Bolt	1	25	25
6	Small Ball	1	35	35
7	IC LM 393	2	10	20
8	Resistor	18	0.56	10
9	LED's	4	1	4
10	General purpose PCB board	1	20	20
11	Battery	1	30	30
12	Wire	-	-	10
	Total			519

5.10 Total Machining Cost:

Table 5.4 Machining and its Cost

Sl. No	Machining Operation	No. of hours taken	Cost per hour (in Rs)	Machining cost (in Rs)
1	Turning	1	125	125
2	Drilling (on metal)	2	160	320
3	Tapping	0.75	175	132
4	Other operations on wood Like drilling, cutting etc	30	50	1500
	TOTAL			2077

5.11 Prime Cost

Prime Cost = Material Cost + Cost of Standard Items + Total Machining Cost

= 800 + 519 + 2077

Prime Cost = Rs. 3396/-

5.12 Overhead Charges

Overhead Charges = 25% of Prime Cost

= Rs. 849 /-

5.13 Indirect Expenses

Indirect Expenses = 15% of prime cost

= Rs. 509.5/-

5.14 Total Manufacturing Cost

Foot Switch cost= Prime Cost + Overhead Charges + Indirect Expenses

= 3396 + 849 + 509.5

= Rs. 4754.5/-

CHAPTER 6-TESTING

6.1 Testing Objective

The Joystick is tested for its performance. Its performance will be done by using PCB and LED's in testing the performance will be assessed by relating the movement of the joystick with the glowing of LED's.

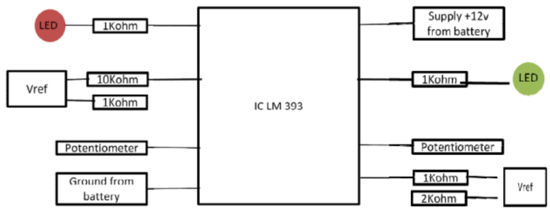


Figure 6.1 PCB Board

Figure 6.1 shows the connections required for testing the joystick using the PCB board.It consists of an amplifier to amplify the voltage output from the potentiometer which is in millivolts up to 12V. Two PCB's are built for two directional movement of joystick and four LED's are used to test the four directional movements of the joystick. Different potentiometer outputs, i.e. output from two LED's for acceleration - brake (front-back) and other two LED's are for steering (left -right)are provided. By moving the joystick the resistance of the potentiometer will be varied through the variable resistance which can predict the position of the joystick.

A comparator is a device that compares two voltages and switches its output to indicate which is larger. They are commonly used in devices such as analog-to-digital converters (ADCs).Potentiometer is connected to a comparator as a input, to get the position of the joystick. In the comparator by giving a reference voltage(V_{ref}) will be set. As the position of the joystick is varied and when it comes to its maximum position i.e when $V_{ref} \leq V$ pot, the corresponding LED will glow. Here two comparators are used for getting the position of front,back, left side,and right side position of the joystick. To indicate the positionfour LED's are used.

In the table 6.1, shows by taking various test cases the position of joystick is tested for forward turn at max position which shows the blue light in LED's, Backward at max shows green light in LED, Right turn at max at max speed which ON's red light in other LED and finally Left turn at max at max speed ON's yellow light. But light cannot be seen in LED's at low speed and the operating range of LED's are mentioned in the appendix. Whereas the variable resistance in the potentiometer is measured by connecting it with Multimeter with the movement of stick which is mentioned in the table below.

Voltage divider –V_{refs}

6.2 VoltageDivider for a Particular Resistance Value

Output of the voltage (V_{out}) is calculated for the different resistance value which shows how the voltage value is divided fora particular resistance.

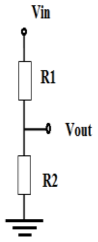


Table no.6.1Voltage divider for different resistance value

SI.NO	RESISTANCE (KΩ)	Vou (V)
1	1	6 *
2	2	8
3	10	10.

* specimen calculation

$V_{out} = R_2 \times V_{in} / (R_1+R_2)$

Table6.2 shows the list of testing criteria

SI. NO	Test cases	Forward movement	Backward movement	Turn right	Turn left
1	Forward turn at max position	ON(Blue)	-	-	-
2	Backward at max position	-	ON(Green)	-	-
3	Right at max position	-	-	ON(red)	-
4	Left turn at max position	-	-	-	ON(Yellow)

Figure6.2 Left movement of joystick

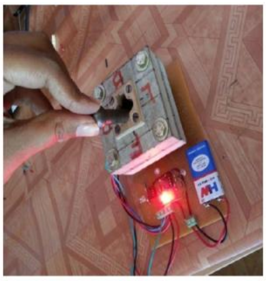


Figure 6.3 Right movement of joystick

Figure 6.4 Forward movement of joystick

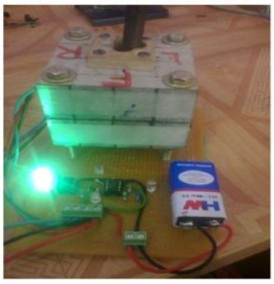


Figure 6.5 Back movement of joystick

6.3 Angular Movement V/S Resistance

The main aim of testing is to produce variable resistance at the required angle.The joystick assembly is connected to multimeter to note the variable resistance value for different position of joystick.

Table 6.3 angular movement vs variable resistance

SI.NO	θ	Resistance(kΩ)
0	0	5
1	-7	5.5
2	-14	6
3	-21	6.5
4	-28	7
5	-35	8
6	0	5
7	7	4.7
8	14	4
9	21	3.5
10	28	3
11	35	2

CHAPTER 7-CONCLUSIONS AND SCOPE OF FUTURE WORK

7.1 CONCLUSIONS

An attempt is made to design, develop and prototyping a joystick for a special purpose driving applications for two wheelers. Only the proof of concept is developed using simple mechanisms for the actuation of the stick in both the directions. Multiple concepts of mechanisms are generated and screened to single workable concept.

The Design and development of a joystick for controlling the self-balancing the vehicles, working prototype of a joystick, Failure mode effective analysis to the joystick assembly and Finally the Testing is made to determine its performance.

7.2 Scope of Future Work

The future work can be suggest to generate and evaluate the concepts of the joystick by benchmarking the prototype of this dissertation work or by evaluating the uncertainties of this prototype and also by trying to make

- Software has to be build
- Drive train
- Extensive testing
- Integration with control system
- Electronic hardware

REFERENCES

1. T. Limpibunterng and T. Fujioka, “Bilateral driver model for steer-by-wire controller design,” in Proc. of 18th IAVSDSymp. Dyn.Vehicles Roads Tracks/Extensive Summ. IAVSD, 2003, pp. 129–131.
2. Daimler,The future of the original“The research cars of Mercedes-Benz”Prof. Dr.Thomas Weber Member of the Board of Management of Daimler AG Group Research & Development Mercedes-Benz Cars.
3. Product Design and Development - Karl.T.Ulrich, Steven D Eppinger - Irwin McGrawHill– 2003thirdedition.
4. Joystick Control Position Sensing with Linear Hall Sensors,Edition 2009-0 Published by Infineon Technologies AG, Am Campeon 1-12, 85579 Neubiberg, Germany © Infineon Technologies AG 2009. All Rights Reserve (www.infineon.com).
5. L. Duran, M. Fernandez-Carmona, C. Urdiales, J.M Peula, and F. Sandoval “Conventional Joystick vs. Wiimote for Holonomic Wheelchair Control”Copyright is held by the author/owner(s). CHI 2006, April 22–27, 2006, Montréal, Québec, Canada. ACM 1-59593-298-4/06/0004.et al
6. Integrating Isometric Joysticks into Mobile Phones for Text Entry,Copyright is held by the author/owner(s). CHI 2006, April 22–27, 2006, Montréal, Québec, Canada. ACM 1-59593-298-4/06/0004.
7. Honda AC-X Uses Joysticks to Steer,Japantimes.co.jp Concepts Transportation Honda Hondahybridacxjoystick. October 21, 2009 - By Kevin Parrish –Source: Tom’s Guide US

8. NeelamBarua, Ashok C.Meti, B.N.Shobha and Ronald E.Haas, “Design and development of human machine interface for an automotive application” by Vol.8 No.1,april 2009.
9. Joystickwww.hzqs.com High-performance, professional and trustworthy. Made in china.[Caldaro]
10. www.yamahamotors.com
11. http://www.linelin.org/../uploadeds/2007/03/ scl500 06.jpg, last accessed on 14/11/2008.
12. Anup S Deshpande “Computer Joystick Control and Vehicle Tracking System in Electric Vehicles” department of Mechanical, Industrial and Nuclear Engineering of the College of Engineering and Applied Science August 2010.
13. Daniel J. Brooks and Holly A. Yanco“Design of a Haptic Joystick for Shared Robot Control” Department of Computer Science University of Massachusetts Lowell, Lowell MA {dbrooks, holly}@cs.uml.edu
14. JoakimÖstlund,“Joystick-controlled cars for drivers with severe disabilities” 1999 project code 40209 VTI rapport 441ASwedish National Road Administration, the Vehicle Standards Division
15. Youngwoo Kim, Member, IEEE, TakamasaOyabu, GoroObinata, Member, IEEE, and Kazunori Hase IEEE transactions on systems, man, and cybernetics—part a: systems and humans, “Operability of Joystick-Type Steering Device Considering Human Arm Impedance Characteristic”, vol. 42, no. 2, march 2012.
16. PakoMaruping“The Design and Construction of a Large Scale- Force Feedback Joystick for the use in Physiotherapy” by, Courses ENG4111 and ENG4112 Research project university of southrenqueenslandfuculty of engineering and surverying.
17. “ Suppressing Operator-Induced Oscillations in Manual Control Systems With Movable Base”s by Mohammad Reza Sirouspour and Septimiu E. Salcudeanieee transactions on control systems technology, vol. 11, no. 4, july 2003.
18. Brad E. Dicianno, Donald M. Spaeth, Rory A. Cooper, Fellow, IEEE, Shirley G. Fitzgerald, Michael L. Boninger, and Karl W. Brown, RRD JRRD Volume 46, Number 2, 2009 Pages 269–276 Journal of Rehabilitation Research & Development.
19. Machine Design Data Handbook-K.Lingaiah, 2nd Edition, McGraw Hill publications.