

Design of hand operated control knobs based on various kinds of hand grips

Submitted in partial fulfilment of the requirements
of the degree of Master of Design

by

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Approval Sheet

This dissertation entitled “*Design of hand operated control knobs based on various kinds of hand grips*” by P Sri Hari is approved for partial fulfilment for the post graduate degree in Industrial Design

Supervisor

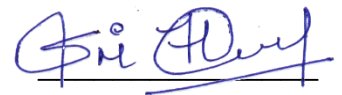


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Abstract

Human beings have demonstrated amazing ingenuity in designing machines for accomplishing things with less wear and tear upon themselves. Since most machines require human control, they must include control devices through which people make their presence known to machines. These controls must be designed to be suitable for desired control actions in terms of sensory, psychomotor and anthropometric characteristics of the intended user. The design of these controls involve many product components such as shape, size, force required to operate, resistance and grip. The choice of grips is dictated less by size and shape but by task that is to be accomplished. Hand adopts different grips to adjust changing force or torque conditions. A single control knob design doesn't serve all the purposes and the design must evolve based on the application. This project aims at designing hand operated control knobs based on different kinds of hand grips to enable the user to sustain productive work in a safe manner.

KEYWORDS: Control knobs, grips, sliders, joysticks, precision, feedback, control response ratio, thumb grip, two finger grip, spherical grip, modified spherical grip, single finger grip, two finger grip, lateral pinch, power grip

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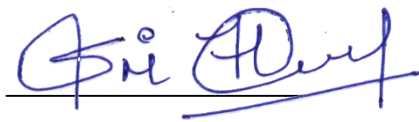
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Lastly, I would also like to specially thank that studio staff for helping me out with prototypes and my family and friends for being my support during project time.

A handwritten signature in blue ink, appearing to read 'P Sri Hari', is written over a horizontal line.

P Sri Hari

Chapter 1

Introduction

1.1 Background

Humans have demonstrated amazing ingenuity in designing machines for accomplishing things with less wear and tear upon themselves. Some of these machines perform more efficiently than the humans. Since most of the machines require human control, they must include control devices such as wheels, push buttons or levers. It is through these control devices that people make their presence known to machines. These devices must be designed to be suitable for the desired control actions in terms of sensory, psychomotor and anthropometric characteristics of intended users.

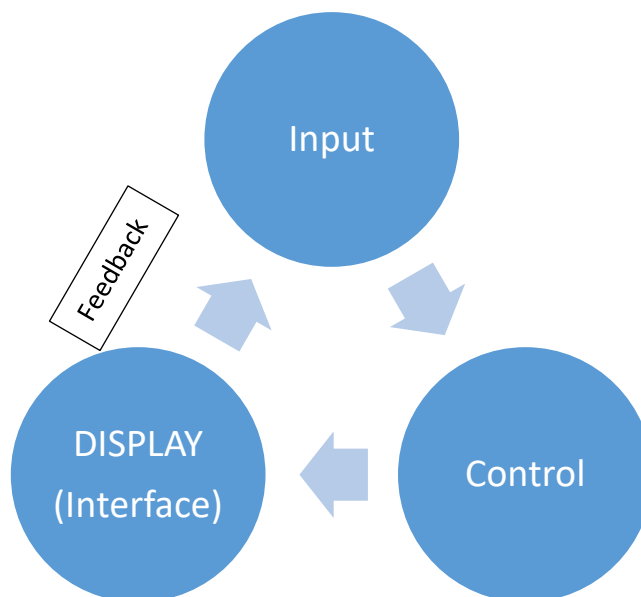


Figure 1.1 Interaction with control

1.2 Purpose

The primary function of a control is to transmit control information to some mechanism or system. The type of control information can be discrete or continuous. There are numerous types of control devices available today. Certain type of controls are best suited for certain applications. Although certain types of controls might be considered more appropriate for certain applications than others, the overall utility of the control can be greatly influenced by factors like size, ease of identification, control-response ratio, resistance, backlash, dead space and grip. The two hands forms a system of two organs which is incredibly versatile and fascinating. Although technology has developed other interfaces with humans through voice, eye movement and even electroencephalography (EEG or brainwaves), the human hand will be a dominant feature of humans for millennia to come. Since human hands have lot more significance in communicating with machines, focus on hand operated controls is of utmost significance. The use of hand operated controls often requires us to grip it in a certain way. The hand postures required creates different product design considerations.

This project aims at creating hand operated control knobs based on various kinds of hand grips by considering how the design of the hand operated control knob fits the capabilities of a particular hand grip so that comfort and ease of the control in use is maximized and performance is enhanced.

1.3 Delimitations

The project is limited to developing of only certain kinds of hand operated controls using one of the control design attribute i.e. Types of hand grips. All the dimensions considered for designing the controls are in the Indian context (*after Chakrabarti, Debkumar [9]*).The testing of control knobs designed is purely based on qualitative assessment based on four factors namely intuitiveness of the grip, force, precision, time of operation. A total of 15 users are considered for testing. The conclusions drawn are solely based on the feedback given by the user participated in the testing.

Chapter 2

Literature Survey

Products are becoming increasingly complex, therefore designers are forced with a challenging task to incorporate new functionality, higher performance and optimal shape design. Anthropometric data is incorporated to design products with optimal shape for best fit to the target population. Design is a very complex task even for an experienced designers. Technology innovation pushes the creativity to new limits and therefore designers are forced to design new products with new functions with even shorter time to market deadline.

Human factors efforts in instrument design specification help to ensure that features of controls procured for use in machines support required task performance. Effective control design facilitate reliable information transfer between personnel and sensor or actuation elements in equipment components. Control movement relationships are compatible with personnel expectancies. Scales represented on continuous displays or controls are easily translated and appropriate coding enables rapid recognition of the acceptability of displayed values.

2.1 Human factors objectives in control design

The primary human factors objective in contributing to control design specifications is to promote reliable information transfer between personnel and the sensor or actuation elements in equipment components. Recommendations regarding display/ control movement relationships are aimed at reducing potentials for confusion that can result from incompatibility with personnel expectancies. While enabling reliable information transfer is the main objective, other concerns include providing features that promote ease of instrument use and maintenance. Design features displays and controls are specified not only to meet system functional requirements but also to reflect human factors principles and criteria, helping to ensure reliable interactions between personnel and display/ control instruments.

2.2 Functions of controls

It is through control devices that people make their presence known to machines. The primary function of a control is to transmit control information to some mechanism or system. The type of information can be divided into:

- *Discrete*: Information that can represent only one of a limited number of conditions.
Ex: On – Off; High – Medium – Low
- *Continuous*: Assumes the value on a continuum
Ex: Speed; Pressure; Temperature

2.3 Types of controls

There are numerous types of control devices available today. Certain type of controls are best suited for certain applications, and the design of control evolves based on the application and their classification is made based on the following factors:

2.3.1 Type of Control information

The classification based on the type of control information carried by the control devices in order to communicate with the system:

- *Discrete*: Push button, push- pull control, toggle switch, rocker switch, rotary selector, J- handle
- *Continuous*: Rotary knob, lever, thumbwheel, ball control, joystick, slider

2.3.2 Force required for manipulation

The classification based on the force required to manipulate the control devices in order to communicate with the system:

- *Electric and hydraulic systems*: Require small forces to actuate controls
- *Mechanical linkage systems*: Require large forces to actuate controls

2.4 Factors involved in control design

Certain types of controls might be considered more appropriate for one application than for another, the overall utility of the control can be greatly influenced by the following factors:

2.4.1 Ease of identification

Correct identification of control is critical in some situations. The identification of controls is essentially a coding problem. The primary coding methods include shape, texture, size, location, operational method, color and labels. The choice of coding methods depend on detectability, discriminability, compatibility and meaningfulness of the code selected.

2.4.2 Control- response ratio

In continuous control task, a specified movement of the control will result in a system response. Control-response ratio is defined as the ratio of control device to the movement of the system response.

$$C/R \text{ ratio} = \frac{\text{Movement of control device}}{\text{Movement of system response}}$$

2.4.3 Size

Size coding of controls is appropriate in instances where different sizes are discriminable from one another.

2.4.4 Resistance

All control devices have some resistance. Resistance can of course, serve as a source of feedback. The primary types of resistances are as follows:

- *Elastic resistance*: Varies with the displacement(the greater the displacement, the greater the resistance as in the case of spring loaded controls)
- *Static friction*: Resistance to initial movement and drops off sharply once the movement of the control begins.
- *Coulomb (sliding) friction*: Continues to have resistance to movement and not related to either velocity or displacement.
- *Viscous dampening*: Related to the velocity of the movement. The faster you move, more resistance experienced.
- *Inertia*: Resistances caused by mass of the mechanism involved. It varies in relation to acceleration.

2.4.5 Deadspace

Deadspace in a control mechanism is the amount of control movement around the null position that results in no movement of the device being controlled. Deadspace of any consequence usually effects control performance and with the amount of effect being related to the sensitivity of control system.

2.4.6 Grasps:

The relationship between task requirements, object shape and adopted grasp leads to a taxonomy that makes it possible to identify a particular grasp, to trace how it derives from more generic grasps types and to illustrate the role of part geometry and task requirement in choosing the grasp. The taxonomy also provides a systematic way to find a grasp that will satisfy a particular set of task requirements and a particular object shape. Perhaps more importantly, it allows us to identify sets of grasps that satisfy set of requirements and geometric constraints.

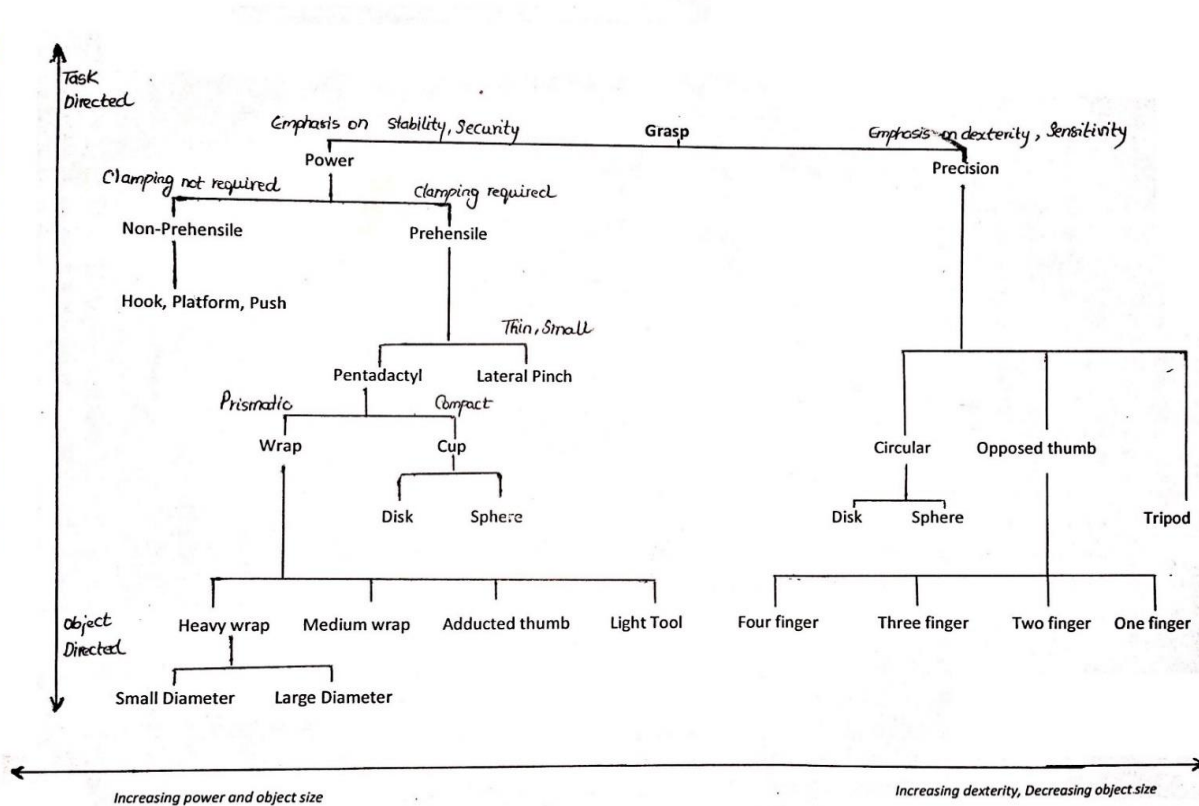


Figure 2.1: Taxonomy of grasps (after Cutkosky, Mark, and Paul Wright [5])

2.4.7 Direction of display and control movements:

People have certain expectancies about directions of movements between controls and corresponding displays. Such expectancies are referred as “popular stereotypes.” Some expectancies are shared by almost everyone based on common previous experiences. Such expectancies must be compatible with expectancies of control operations.

Table 2.1: Summary of common expectations regarding direction of control movement

System function	Control movement
On	Up, Right, Forward, Pull
Off	Down, Left, Rearward, Push
Right	Clockwise, Right
Left	Counter clockwise, Left
Up	Up, Rearward
Down	Down, Forward
Increase	Up, Right, Forward, Clockwise
Decrease	Down, Left, Rearward, Counter clockwise

2.5 External factors influencing the control design

The following are the external factors that influence the controls design and has a significant effect on the usability of control devices.

- *User Characteristics:* Persons age, body dimensions, dexterity, hand size, hand strength, fine motor skills and training
- *Work place:* Location of the work (Light, Sound etc..), physical layout
- *Work Organization:* Type of task, frequency of work cycles and quality of work required

2.6 Ergonomic principles for hand operated devices

All the principles for good ergonomic design rest in five fundamental requirements that apply to any hand operated devices. The requirements are that the device should:

Minimize high surface contact forces

Minimize static postural loading and pinch points when using the device

Minimize awkward joint positions and maximize natural postures

Minimize repetitive forceful finger action when hands are in a deviated posture

Minimize the extent to which device vibrates the hand

Minimize the wrist deviations

Minimize the shoulder abduction away from the body during the normal operation

2.7 Guidelines for display/ control relationships

General guidelines address broad issues that should be explored before detailed design features of the displays and controls are specified. Specifications for display/ control relationships involving direction, amount and time of movement should be first established. Finally, appropriate application of techniques for supporting check reading performance should be defined.

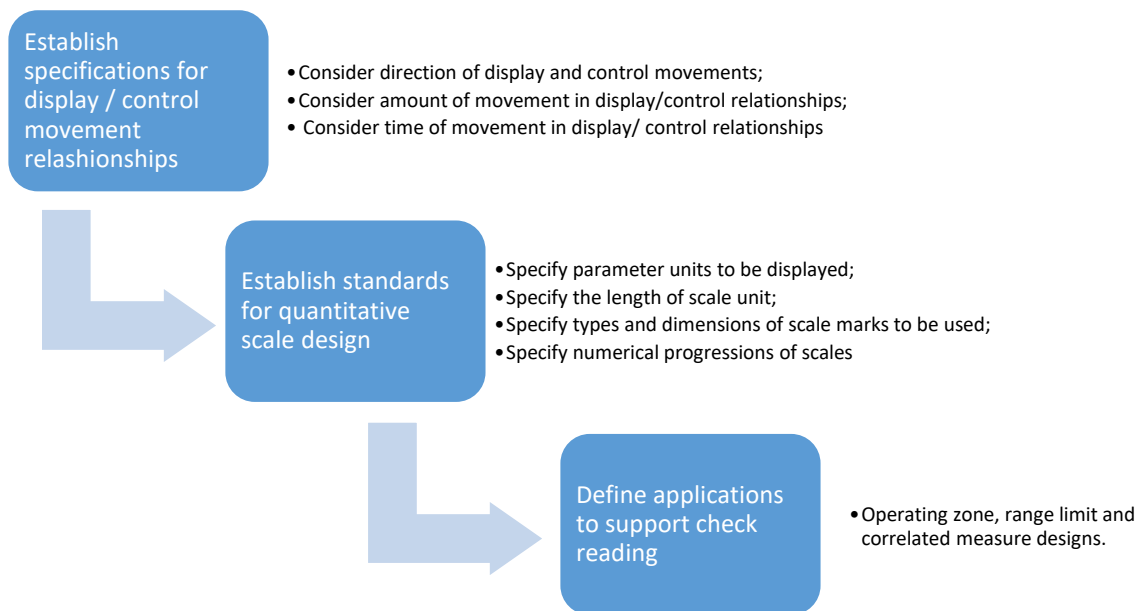


Figure 2.2 Steps involved in addressing considerations for display and control specifications

2.8 Recommend design specifications for discrete selector controls

Base specifications for discrete selector control designs on features needed to satisfy response requirements, strategies for protecting against accidental activation and control coding decisions. Control design specifications should be accessed against specific needs identified in the development process.

Discrete control selectors are categorized based on how the force is applied to adjust the controls. These controls include pull and/or push, linear (up-down or left-right), or rotary controls. Categorizing of controls facilitates analysis of biomechanics involved in operating controls when developing specifications.

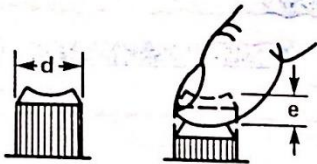
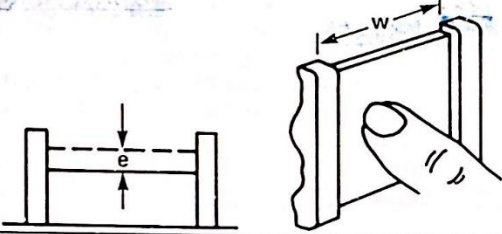
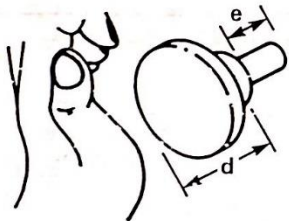
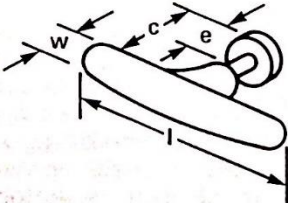
ILLUSTRATIVE VARIETY	DIMENSION	PREFERRED RANGE	
		MINIMUM	MAXIMUM
FINGER OPERATED PUSHBUTTON 	Diameter (d) Displacement (e) Resistance	3/8 in. 1/16 in. 5 oz.	1 in. 1/4 in. 20 oz.
INDICATOR SWITCH LIGHT 	Width (w) Displacement (e) Resistance	3/4 in. 1/8 in. 10 oz.	1-1/2 in. 1/4 in. 60 oz.
HEEL-OF-HAND OPERATED PUSHBUTTON 	Diameter (d) Displacement (e) Resistance	3/4 in. 1/8 in. 10 oz.	4 in. 1/2 in. 40 oz.
LOW FORCE PUSH-PULL CONTROL 	Diameter (d) Clearance (c) Displacement (e) Resistance	3/4 in. 1 in. 1/2 in. 10 oz.	2 in. 1-1/2 in. 3/4 in. 40 oz.
HIGH FORCE PUSH-PULL CONTROL 	Handle width (w) Handle length (l) Clearance (c) Displacement (e) Resistance	5/8 in. 4 in. 1-1/2 in. 1/2 in. 20 oz.	1-1/2 in. 6 in. 3 in. 3/4 in. 80 oz.

Figure 2.3 Preferred ranges in dimensions for varieties of discrete controls that require push/ pull forces for selection of command signals (after Kinkade, R.G [2])

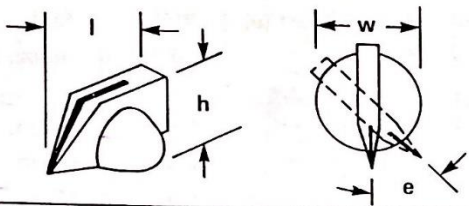
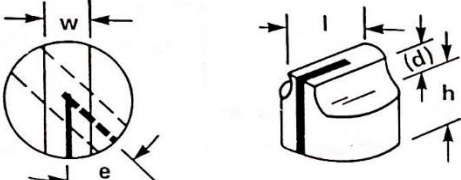
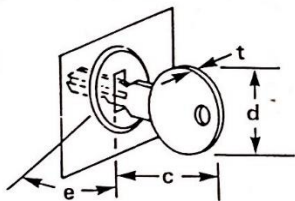
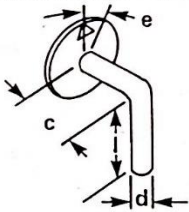
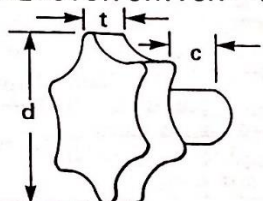
ILLUSTRATIVE VARIETY	DIMENSION	PREFERRED RANGE	
		MINIMUM	MAXIMUM
MODERATE TORQUE THUMB AND FINGER OPERATED ROTARY SELECTOR SWITCH 	Knob width (w) Knob height (h) Knob length (l) Displacement (e) Resistance	1/2 in. 5/8 in. 1-1/2 in. 15° 1 in.-lb.	1 in. 3 in. 4 in. 60° 6 in.-lb.
LOW TORQUE THUMB AND FINGER OPERATED ROTARY SELECTOR SWITCH 	Knob width (w) Knob height (h) Knob length (l) Depth (d) Displacement (e) Resistance	1/4 in. 5/8 in. 3/4 in. 1/2 in. 24° 1/4 in.-lb.	1/2 in. 1 in. 2 in. 3/4 in. 60° 1/3 in.-lb.
KEY OPERATED ROTARY SELECTOR SWITCH 	Key size Diameter (d) Thickness (t) Clearance (c) Displacement (e) Resistance	1/2 in. 1/16 in. 3/4 in. 30° 1 in.-lb.	3 in. 1/8 in. 1-3/4 in. 90° 6 in.-lb.
HIGH TORQUE HAND OPERATED ROTARY SELECTOR SWITCH – J HANDLE 	Handle diameter (d) Handle length (l) Clearance (c) Displacement (e) Resistance	5/8 in. 4 in. 1-1/4 in. 24° 6 in.-lb.	1 in. 6 in. 2 in. 60° 12 in.-lb.
HIGH TORQUE HAND OPERATED ROTARY SELECTOR SWITCH – KNOB 	Diameter (d) Thickness (t) Clearance (c) Displacement Resistance	2 in. 3/8 in. 1/2 in. 24° 4 in.-lb.	4 in. 3/4 in. 1-1/2 in. 90° 12 in.-lb.

Figure 2.4 Preferred ranges in dimensions for varieties of discrete controls that require rotary forces for selection of command signals (after Kinkade, R.G [2])

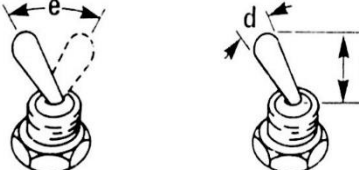
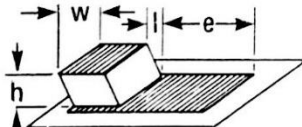
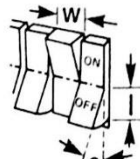
ILLUSTRATIVE VARIETY	DIMENSION	PREFERRED RANGE	
		MINIMUM	MAXIMUM
TWO-POSITION TOGGLE SWITCH 	Arm length (l) Arm diameter (d) Displacement (e) Resistance	1/2 in. 1/8 in. 30° 10 oz.	2 in. — — 60° 40 oz.
SLIDING SWITCH 	Width (w) Height (h) Length (l) Displacement (e) Resistance	1/4 in. 1/8 in. 3/8 in. 1/4 in. 10 oz.	1/2 in. 1/4 in. 5/8 in. 1/2 in. 40 oz.
ROCKER SWITCH 	Width (w) Length (l) Displacement (e) Resistance	1/4 in. 1/2 in. 30° 10 oz.	1-1/2 in. 3/4 in. 120° 40 oz.

Figure 2.5 Preferred ranges in dimensions for variety of discrete controls that require vertical/horizontal force for selection of command signals (after Kinkade, R.G [2])

2.9 Recommend design specifications for continuous selector controls

Base specifications for continuous selector control designs on features needed to satisfy both adjustment precision and time requirements, control coding conventions and protection from accidental activation strategies. Although some detailed guidelines and representative guidelines and representative dimensions for continuous adjustor controls are provided, control design specifications should be developed in response to specific needs identified in the development process.

Representative preferred size, length of scale unit and resistance for some varieties is of continuous adjusters controls are shown in figure 2.5. Varieties include rotary control knobs, thumb and finger operated levers, and hand operated levers and continuous thumbwheels.

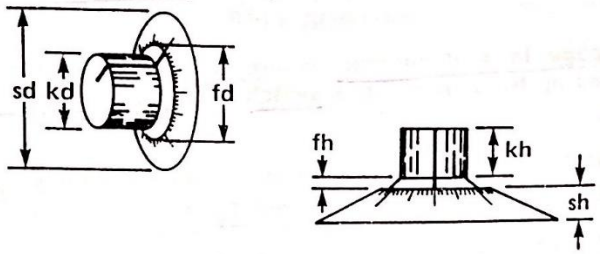
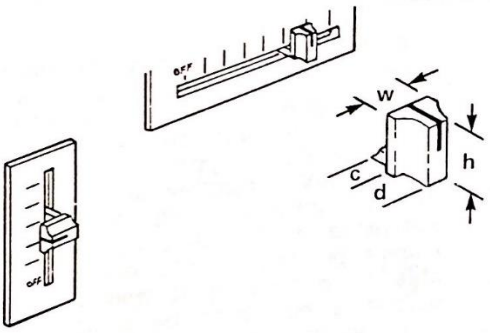
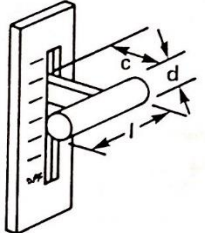
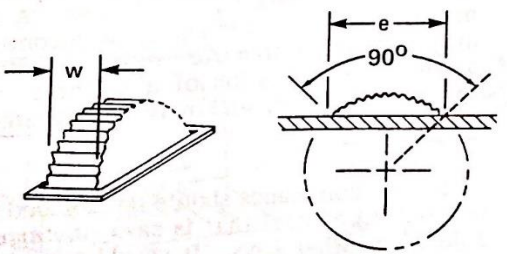
ILLUSTRATIVE VARIETY	DIMENSION	VALUE
SINGLE ROTATION ROTARY KNOB 	Knob diameter (kd) Knob height (kh) Finger-stop diameter (fd) Finger-stop height (fh) Skirt diameter (sd) Skirt height (sh) Length of scale unit Resistance	3/4 in. 1/2 in. 1-1/4 in. 1/4 in. 2 in. 1/4 in. 1/16 in. 1/4 in.-lb.
THUMB AND FINGER OPERATED LEVER 	Head height (h) Head width (w) Head depth (d) Clearance (c) Length of scale unit Resistance	1/2 in. 1/4 in. 1/2 in. 1/16 in. 1/4 in. 10 oz.
HAND OPERATED LEVER 	Handle diameter (d) Handle length (l) Clearance (c) Length of scale unit Resistance	5/8 in. 3 in. 1-1/2 in. 1/2 in. 20 oz.
CONTINUOUS THUMBWHEEL 	Rim width (w) Rim exposure (e) Resistance	1/8 in. 1 in. 1/4 in.-oz.

Figure 2.6 Preferred ranges in dimensions for variety of continuous adjustor controls (after Kinkade, R.G [2])

2.10 Flow of human factors applications in panel design

Panel design starts by recommending conventions for the use of color in panels followed by detailed conventions for panel labelling. Then spatial separation of instruments in panel is identified to help the specification of lines of demarcation and mimic designs. It is followed by specifying coding convention for instruments. After conventions have been established, produce recommendations for preliminary panel layouts.

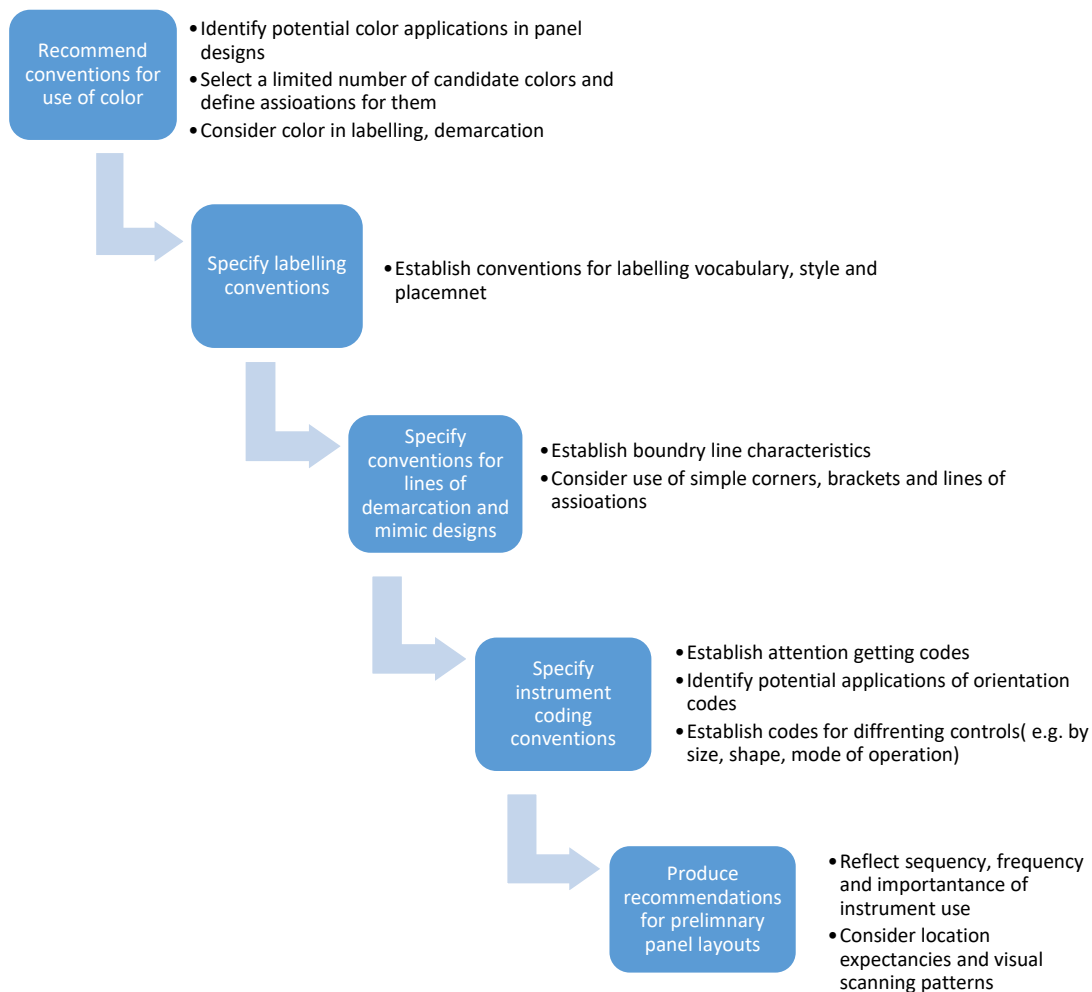


Figure 2.7 Flow of human factors applications in panel design

Chapter 3

Design of hand operated control knobs

3.1 Hand controls design principles

A fundamental requirement for all the hand controls is that a grip surface needs to be provided. A well designed control can enhance the functionality of the control by increasing grip stability and comfort. A well designed hand control should achieve the following:

- The hand controls should be shaped to avoid extremes of wrist deviations
- The control shape must assist the grips
- Use of universal design that can accommodate ambidextrous operations and use by different groups such as children
- Using design that minimize shoulder abduction away from the body during normal operation.

3.2 Types of Hand operated controls

There are numerous types of control devices available today. Certain types of controls are best suited for certain applications. Following are the hand operated controls used for various purposes:

- *Push button*
- *Push – Pull control*
- *Toggle switch*
- *Rocker switch*
- *Rotary selector switch*
- *J – Handle*
- *Key operated rotary selector*

- *Rotatory knob*
- *Levers*
- *Thumb wheel*
- *Ball control*
- *Joy stick*
- *Sliders*

3.3 Design specifications for Joystick controls

A joystick is an input device consisting of a stick that pivots on a base and reports its angle or direction to the device it is controlling. A joystick, is the principal control device in the cockpit of many civilian and military aircraft, either as a center stick or side-stick.

Joysticks must return to the point of origin when not in use. It may offer more resistance to reduce inadvertent activation. Joysticks are also used for controlling machines such as cranes, trucks, underwater unmanned vehicles, wheelchairs, surveillance cameras, and zero turning radius lawn mowers. Miniature finger-operated joysticks have been adopted as input devices for smaller electronic equipment such as mobile phones. The following are the various categories of joysticks in the market:

- *Finger operated*
- *Thumb operated*
- *Hand operated*



Figure 3.1 Various kinds of Joy sticks

(Reference: <http://www.intertech-austria.at/joystick/index.php/en/> accessed on 14-july-2018)

3.4 Design specifications for Slider controls

Use levers when a rapid adjustment is required but precise control isn't. For thumb and finger operated levers, precision in setting is enhanced if support is provided for the forearm. The control head must be easy to grasp and located close to scale to avoid parallax. Provide a reference line on the control head. For hand operated sliders, side-to-side orientations should be avoided. Precision in setting is enhanced when such controls are located between the operator's waist and shoulder. The control handle must accommodate at least three fingers, the index fingers on one side of the shaft and two fingers on the other side. A position pointer should be provided on the shaft so that it is visible at least during right-handed operation. The following are various types of sliders:

- *Thumb operated slider*
- *Finger operated slider*
- *Hand operated slider*



Figure 3.2 Various kinds of sliders

(Reference: <http://www.intertechautria.at/sliders/index.php/en/> accessed on 14-july-2018)

3.5 Significance of Hand grips

The two hands from a system of two organs which is incredibly versatile and fascinating. Although technology has developed other interfaces with human through voice, eye movement and even electroencephalography (EEG or brainwaves), the human hand will be dominating feature of humans for millennia to come. A series of ergonomic standards must be taken into consideration when designing hand operated controls, focusing on how the design of the product fits the

capabilities of the hands so that the comfort, ease and safety of the product is maximized and performance is enhanced.

3.5.1 Spherical grip

Fingers enclose the ball end of the handle like in heavy convex grip. Finger entraps the part and uses friction to sustain most of task-induced forces. Sensation at finger tips is minimal. Major angular movements made at wrist. It is power counterpart of precision spherical grip.

3.5.2 Modified spherical grip

Forces are light and high degree of sensitivity is used. Finger tips enclose the ball end of the handle and has degree of sensitivity. Extra control and sensitivity to responses. Since fingers are more gentle more sensitive to small changes and vibrations. Fingers manipulate the control and actively adjust stiffness of the grasp. Used when task induced forces are high.

3.5.3 Thumb grip

Thumb is used to control the object. It requires some amount of friction between the thumb and the object. High degree of sensitivity can be achieved but cannot handle high force factors.

3.5.4 Single finger grip

Thumb or index finger tip is used to manipulate the object. High degree of sensitivity can be achieved with low degree of force requirement. Usually suitable for achieving sliding motion.

3.5.5 Two finger grip

A grasp in which one presses the thumb against the fingers of the hand and does not involve the palm. Thumb and index finger roll against part or tool to twist it rapidly. The grip is often used when tip of the part or tool is touching another object. The contact becomes a third finger like constraint upon the object which permits relative rotation but no translation between the two objects. This grip provides more control because the thumb joint is highly movable and precise.

3.5.6 Lateral pinch grip

Thumb and side of the index finger are used to hold the object but the remaining fingers add degree of support. Used when object is small and task induced forces are high, so that a powerful grip is required. Thus, the lateral pinch becomes the grip of choice for turning key in a lock.

3.5.7 Power grip

Fingers and thumb wrap tightly about the tool handle with the handle running parallel to the knuckles and protruding on either side. Swing motion is made with the arm. Fine motions are made with the wrist and fingers are passive. The grip will generally maximize the power on the part of the worker. Minimal control is associated with the power grip as the fingers move as one entity and only in one direction (flexion).

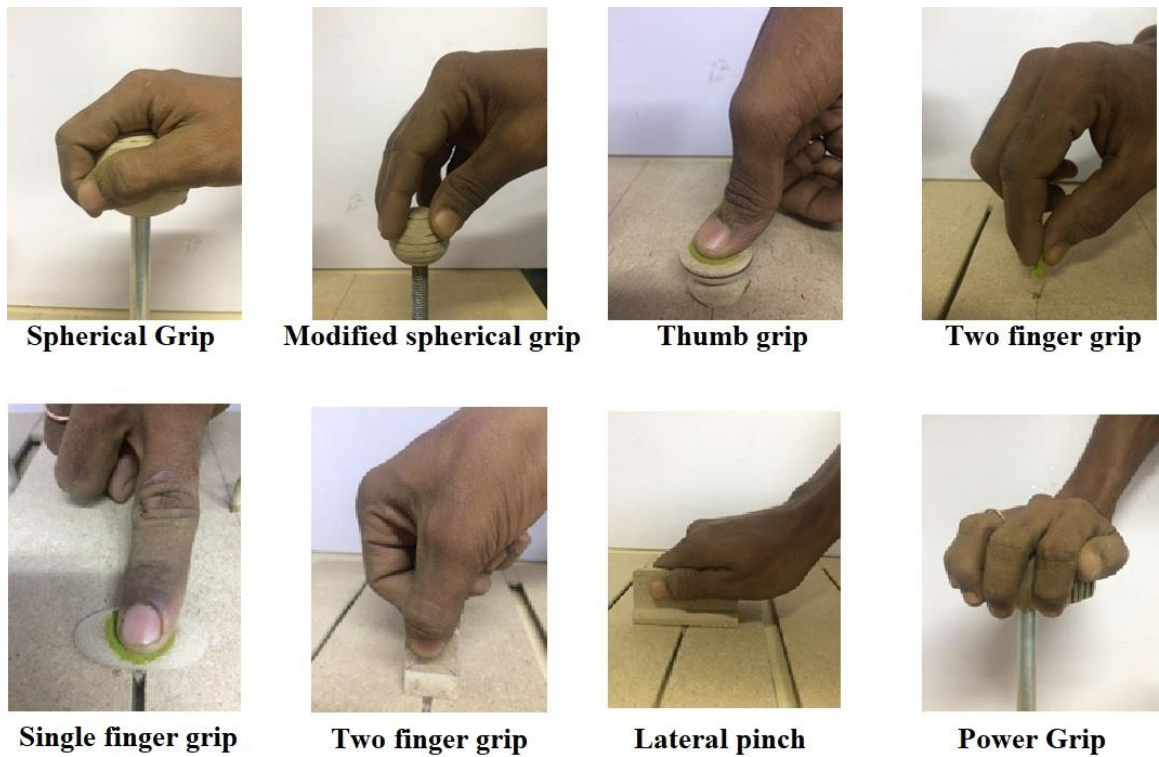


Figure 3.3 Types of hand grips

3.6 Control knob designs based on hand grips

Taking hand grips as basic design criteria the following are the designs of few hand operated controls. These designs focus on how the design of controls fits the capabilities of the hands so that comfort, ease and product use is maximized and performance is enhanced.

3.6.1 Joystick controls

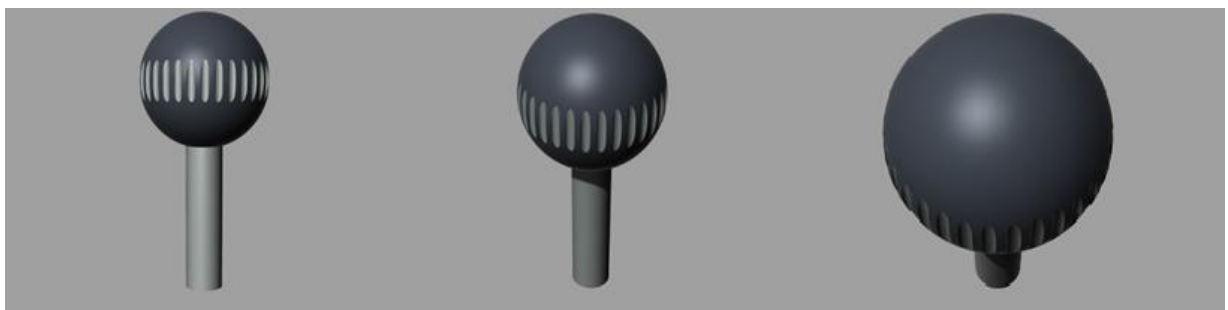


Figure 3.4 Spherical grip joystick



Figure 3.5 Modified spherical grip joystick



Figure 3.6 Thumb grip joystick

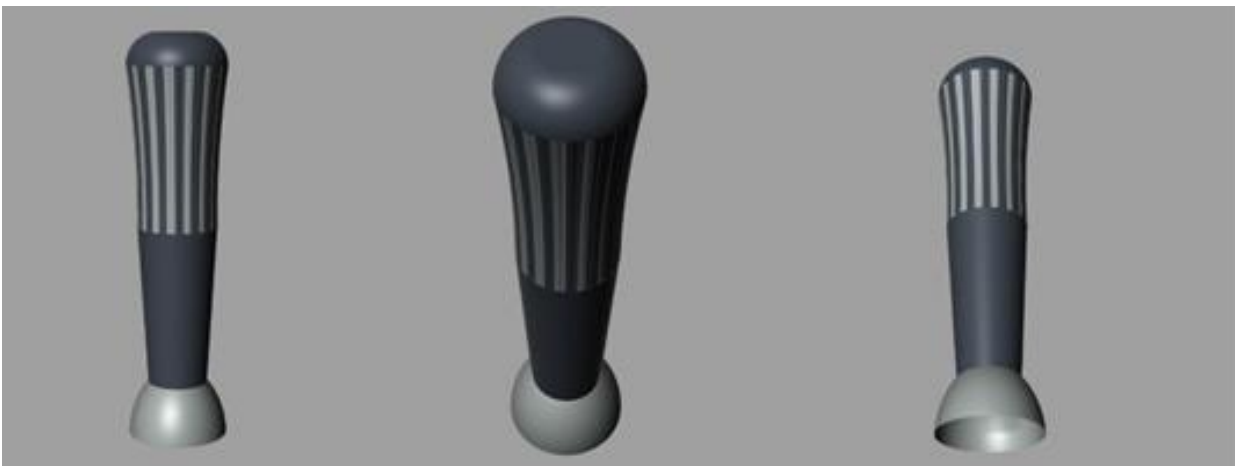


Figure 3.7 Two finger grip joystick

3.6.2 Slider controls

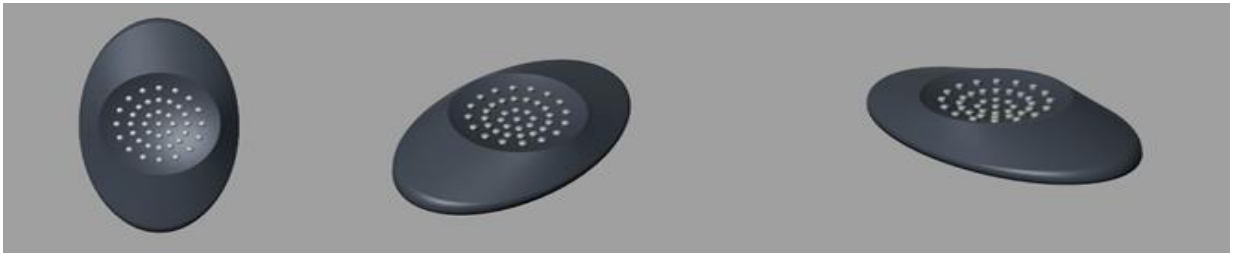


Figure 3.8 Single finger slider



Figure 3.9 Two finger slider



Figure 3.10 Lateral pinch slider



Figure 3.11 Power slider

3.6.3 Dimensional drawings

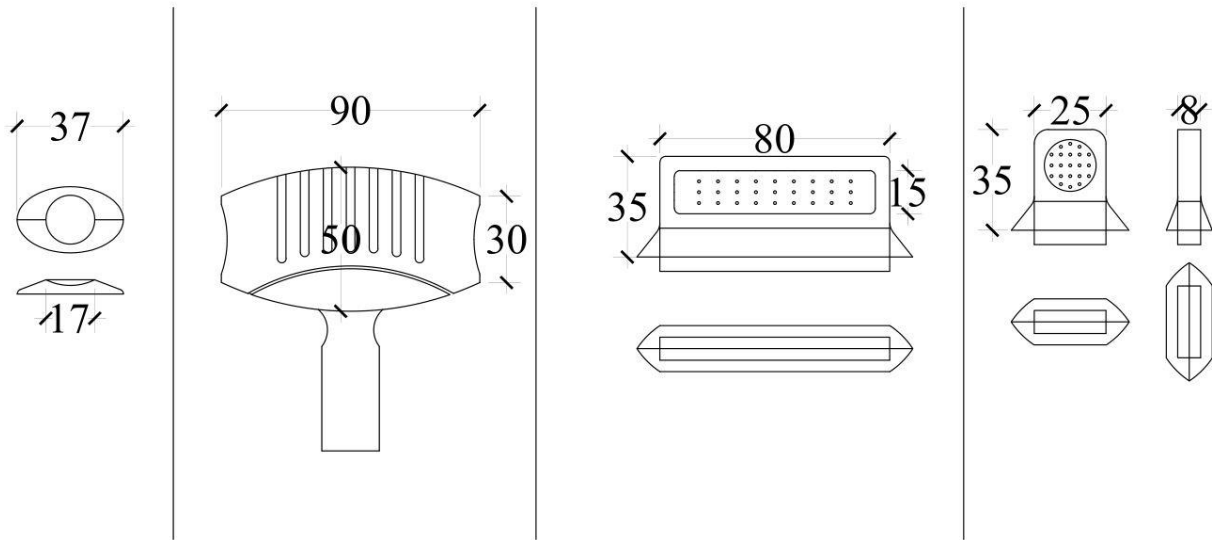


Figure 3.12: Dimensions of slider controls

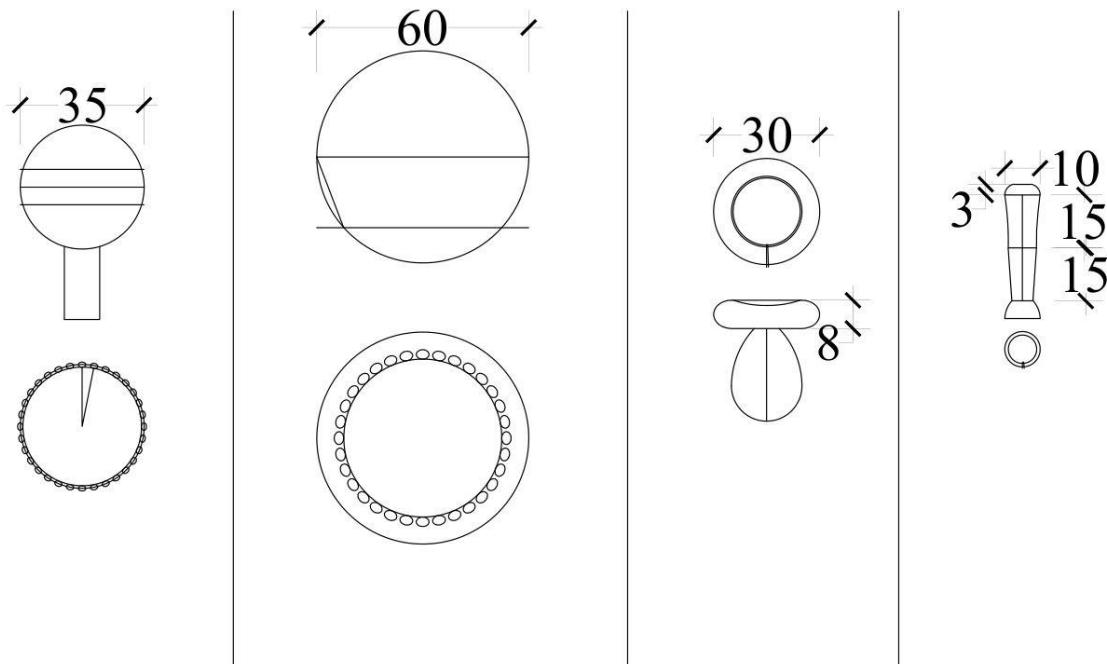


Figure 3.13: Dimensions of joystick controls

Note: All dimensions are in millimeters

3.7 Testing

All the dimensions considered for designing the controls are in the Indian context (*after Chakrabarti, Debkumar [9]*). The testing of control knobs designed is purely based on qualitative assessment based on four factors namely intuitiveness of the grip, force, precision, time of operation. A total of 15 users are considered for testing to discover 100 percent of usability problems (*after Nielsen, Jakob [10]*). The conclusions drawn are solely based on the feedback given by the user participated in the testing.

Prototypes of all the controls are made and set up as a testing rig. The testing rig is placed at the elbow height of the each users participated in testing to create neutral testing environment.

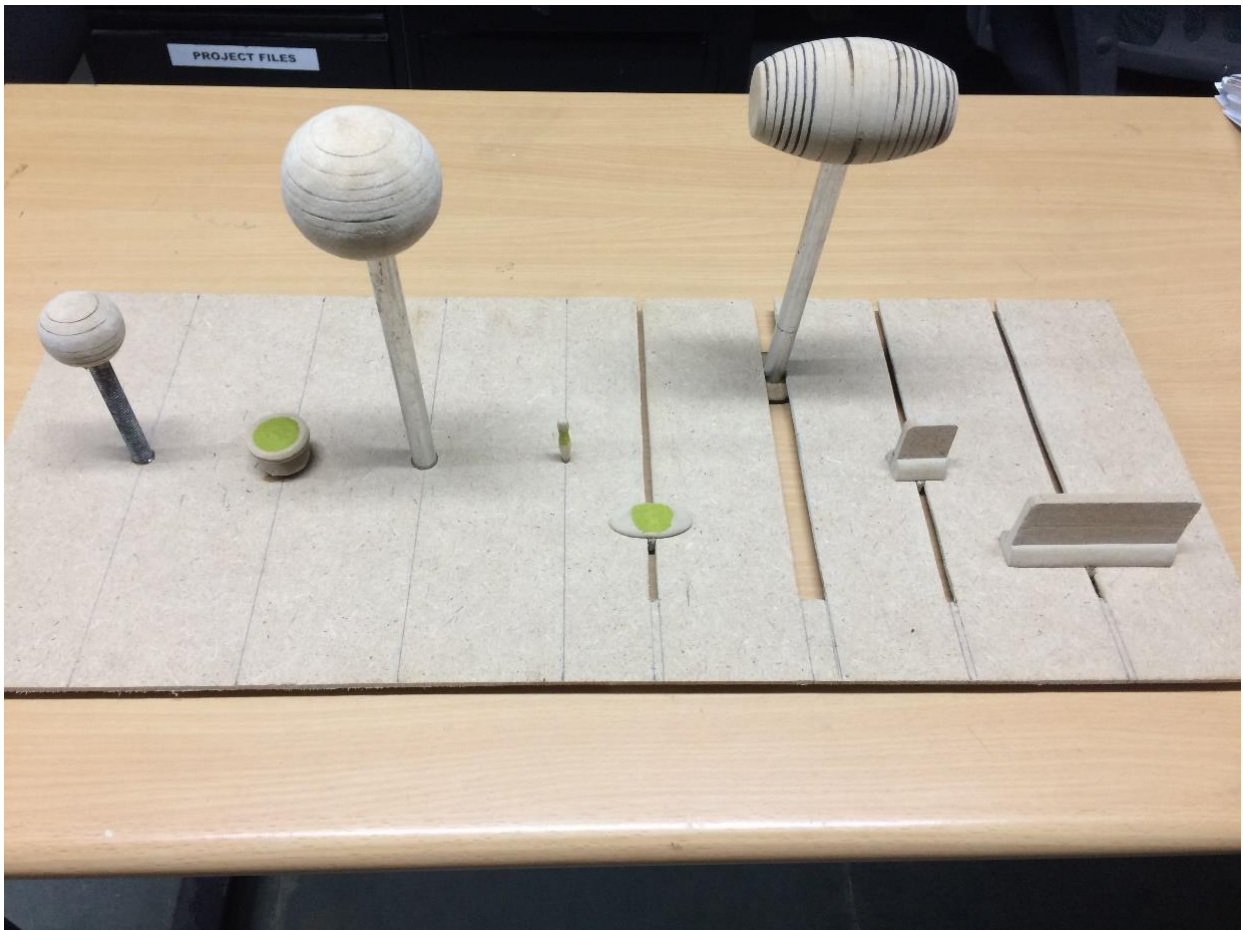


Figure 3.14: Testing rig

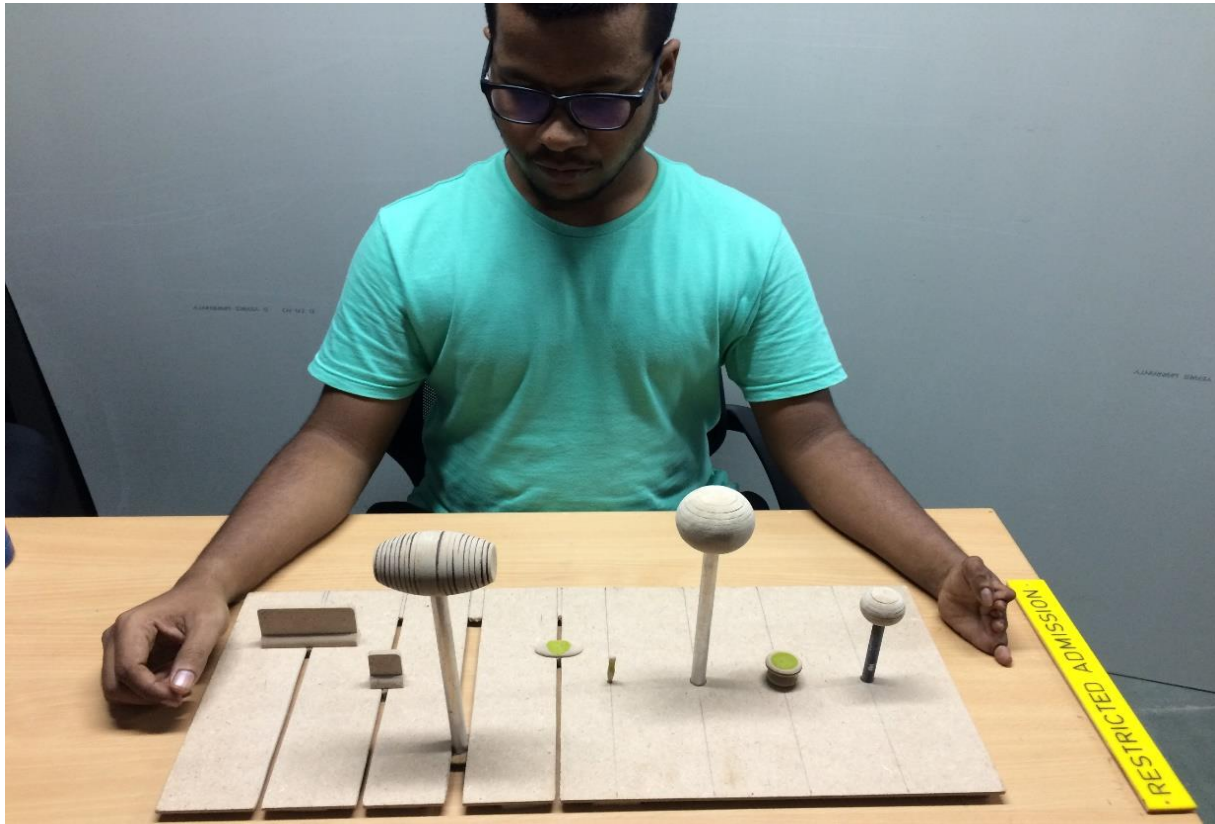


Figure 3.15: User interacting with the testing rig

3.8 Evaluation and results

The evaluation of the controls is purely based on qualitative assessment on the following four factors:

Intuitiveness of the grip: How intuitive is the grip to hold in the anticipated manner of the design.

Force: The amount of force needed to operate the control

Precision: The degree of precision in operating the control

Time: How long the control can be used without any discomfort

The intuitiveness of the grip is quantified based on the percentage of people holding the control in the anticipated manner as per design. Force, precision, time are quantified based on ranking within the family of controllers (Joysticks and sliders).

Table 3.1: Results for joystick controls

GRIP	GRIP INTUTIVENESS (%)	FORCE (RANK)	PRECISION (RANK)	COMFORT (RANK)
THUMB GRIP	66%	3	2	2
TWO FINGER GRIP	87%	4	1	1
SPHERICAL GRIP	93%	1	4	3
MODIFIED SPHERICAL	87%	2	3	4

Table 3.2: Results for slider controls

GRIP	GRIP INTUTIVENESS (%)	FORCE (RANK)	PRECISION (RANK)	COMFORT (RANK)
SINGLE FINGER	100%	4	1	1
TWO FINGER	87%	3	2	3
LATERAL PINCH	87%	2	3	4
POWER GRIP	100%	1	4	2

Chapter 4

Discussion and conclusion

The purpose of the project has been fulfilled, a set of control knobs are designed based on various kinds of hand grips and a qualitative tests have been carried out. However the functionality of the control knobs, with all the other attributes, needs to be incorporated in the final control knob design and a rigorous quantitative tests has be to carried out. The final output has eight control knob designs, perhaps if not for the lack of time, some additional grips would have been implemented.

The data collection and research stage, preparing for the development of framework, was the most time consuming part of this project work. This is because that research found that hand ergonomics and grip types are very general and partly diffuse, and therefore the decision of what grips, kinds of controls to use was the hardest judgment.

At times it felt that designing the hand operated control knobs solely based on hand grip as attribute seemed impossible as most of the attributes for controls are interlinked. Since the work involved a new approach in designing of controls, many complications were experienced. The work consisted of trial and error mostly since it was new approach in designing the controls.

The grasp taxonomy discussed allows streamlining of hand control designs and construction. Thus in a form follows function approach, consideration of how the control fits the capabilities of the hands so that ease, comfort and safety are enhanced will be useful. The hand grip criteria can be used to evaluate the degree to which the design of the existing products can be judged to be ergonomic. This criteria should be used to assist in the development of new products to ensure that the requirements of an ergonomic product are met.

From the analysis as well as the preliminary testing the following conclusions may be drawn with reference to the superiority of control knobs designed based on hand grips to the existing conventional control knobs. Shape of control knobs changes drastically for same mode of operation for different force and precision requirements. Grasp changes if the amount of force, precision required changes. The two hands form a system of two organs which is incredibly versatile and fascinating. The human hand will be a dominant feature of humans for millennia to come.

References

1. Sanders, M. S., & McCormick, E. J. (1993). Human factors in engineering and design (7th ed.). New York, NY, England: McGraw-Hill Book Company
2. Kinkade, R.G. (1985). Human factors guide for nuclear power plant control room development. United States: IEEE Service Center.
3. Hunt, Darwin P. The coding of aircraft controls. AIR FORCE AEROSPACE MEDICAL RESEARCH LAB WRIGHT-PATTERSON AFB OH, 1953.
4. Patkin, Michael. "A checklist for handle design." Ergonomics Australia On-Line 15.Suppl (2001).
5. Cutkosky, Mark, and Paul Wright. "Modeling manufacturing grips and correlations with the design of robotic hands." Robotics and Automation. Proceedings. 1986 IEEE International Conference on. Vol. 3. IEEE, 1986.
6. Loughborough, ICE Ergonomics. "Consumer products-more by accident than design?." Human Factors in Consumer Products (1997): 127.
7. Harih, G., and A. Čretnik. "Interdisciplinary approach to tool-handle design based on medical imaging." BioMed research international 2013 (2013).
8. Lewis, Winston G., and C. V. Narayan. "Design and sizing of ergonomic handles for hand tools." Applied ergonomics 24.5 (1993): 351-356.
9. Chakrabarti, Debkumar. Indian anthropometric dimensions for ergonomic design practice. National institute of design, 1997
10. Nielsen, Jakob. Mathematical model of usability problems. Elsevier, 1994