MANUFACTURING OF HEADFORM CONFORMING TO THE INDIAN STANDARD FOR TESTING OF HELMETS

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Abstract

Headform is necessary for the testing of protective helmets. Making a headform conforming to the testing standards is a critical task. This work sufficiently highlights all the important literature referring to the Indian Standard relating to the manufacture of the headforms for helmet testing and then goes on to present a methodology for the manufacture of the conventional head form. Various suggestions are made keeping in mind the complexity and accuracy aimed to be achieved. This chronological sequence if applied by the reader, will be helpful in manufacturing any headform of the various sizes compliant to the Indian standards for manufacturing of headforms. These steps are formulated such that if applied to a modelling software would help to a certain extent in the modeling of a headform for virtual testing and analysis. Establishment of a correlation between the actual and virtual testing using the respective headforms for testing of helmets could thus, be a relevant subject for further increasing the scope of this paper for future works.

Index Terms: Head form, Helmet Testing, Manufacturing, Standard.

I. INTRODUCTION

Helmet is one of the most important items of personal protective equipment used by many users for protection against the hazards connected with various fields.

A 'form' of a product is a base model utilized for the manufacturing of any product, mostly wearable. Similarly, a headform is the base model which simulates a human head for the manufacture and testing of different types of head wear mostly helmets.

For testing of helmets, it is important to specify precisely a range of headforms to ensure a close fit for the helmet under test, thereby avoiding inaccuracies to the measurement of transmitted force. The dimensions and other details of the headforms used for testing of helmets are provided and are referred to, from the Indian Standard IS 7692 [1].

Internationally, there are two types of headforms used for impact attenuation testing of motorcycle helmets. These two types of test headforms follow specifications established by the International Standard Organization (ISO), or the US Department of Transportation (DOT). Both headforms are low resonance, rigid castings, but they differ in size, shape and weight. During testing the headforms are supported by a rigid guide assembly that limits their motion to the vertical direction only. Different impact locations are obtained by adjustment of the headform on a spherical ball joint [2].

The objective of this paper is achieved by proposing guidelines for the complete manufacture of the headform from wood material. The paper can be found divided mainly into two sections overall, firstly, the study of details regarding headform reference planes and dimensions as mentioned in the Indian Standard IS-7692 are presented, and secondly, steps

developed for the manufacture of the headform are highlighted, which proposes a methodology for the manufacture, lists the interpolated and surveyed data tables and also the material requirements.

Various parameters like market availability, problems during manufacture, etc. are attempted to be covered to the fullest, and the methodology if followed would lead to the development of a headform for testing and manufacture purposes.

II. IMPORTANT TERMS AND NOMENCLATURE

Fig. 1 illustrates all the important axes and planes to be understood with their geometric positions. All the other data measured and the sizes of standard headforms available are always measured with respect to one or more of these geometries [1].

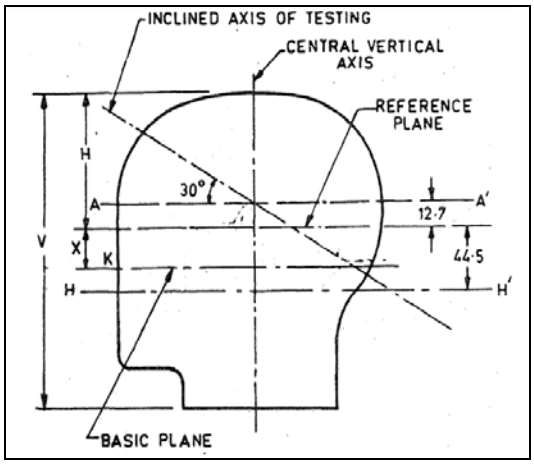

Fig. 1 Terms and Nomenclature

All the terms and some other distance nomenclatures are listed as follows:

- Vertical Axis
- Zero Plane
- Reference Plane
- Basic Plane
- H Distance (in mm)
- V Distance (in mm)
- X Distance (in mm)

The standard sizes used for the manufacture are shown in Table 1, along with their H-Distance and V-Distance. The circumference values refer to the internal circumference of the helmet measured at the head band level [1].

Table 1 Standard sizes of headforms and other distances

Code Letter of the Headform	H (mm)	V (mm)	Circumference (mm)
0	89.5	216.4	500
1	95.0	223.4	540
2	102.5	232.4	570
3	107.0	249.0	600

The dimensional details of the headform above and below the basic plane is illustrated in the Fig. 2 and Fig. 3, and the corresponding values of the dimensions on each plane are tabulated in Table 4 and Table 5 in the appendix section of the paper.

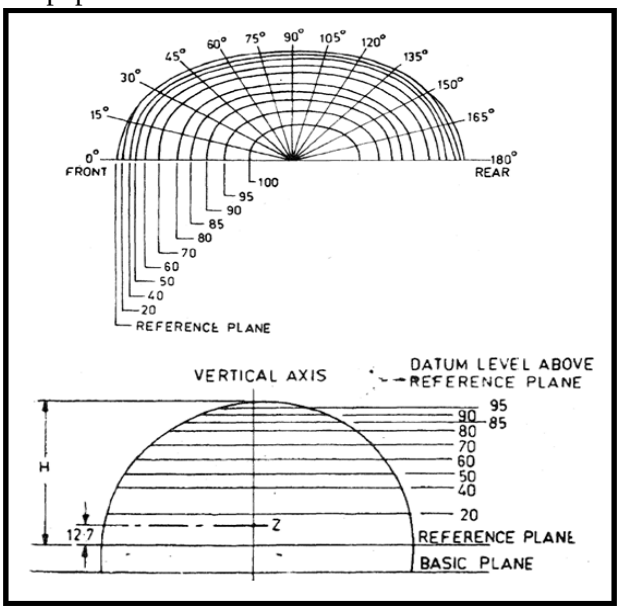

Fig. 2 Headform Details (Above Basic Plane) [1]

III. MATERIALS

The Headform is built up from layers of hard wood.

Although the Indian Standard IS-7692 suggests that the use of any alternative material is permissible, but in our work plywood or MDF (Medium Density Fibre-board).

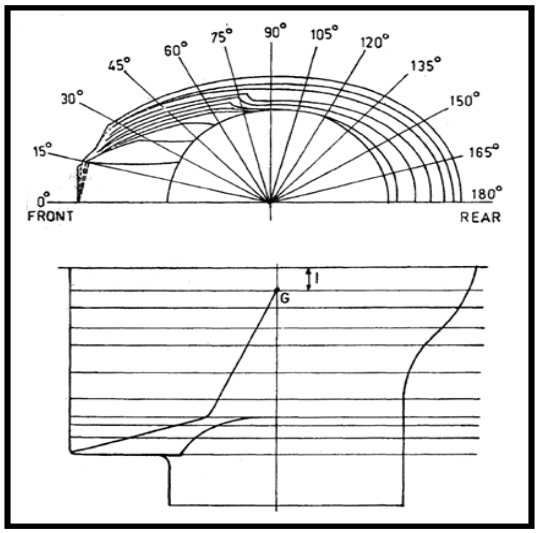

Fig. 3 Headform Details (Below Basic Plane) [1]

Material is particularly used for the following reasons:

a) It is easily available as scrap material from any interior decoration or furniture manufacturing workshops.
b) They are readily available in different standard sizes of thickness.
c) It is easily machinable that is the various processes like cutting, grinding, polishing, etc. can be performed on it to suit our needs.

A. Market Survey for the Availability of Materials

The hard wood material is readily available in two basic forms in the market:

a) *Plywood:* It is a sheet material manufactured from thin layers or "plies" of wood veneer.
b) *MDF (Medium Density Fibre-board):* It is engineered wood product from the family of manufactured boards made by breaking down hardwood or softwood residuals into wood fibres. It is generally higher in density than plywood.

Fig. 4 Plywood

Fig. 5 MDF Wood

The MDF wood material can be differentiated from the normal plywood by its lighter color and smooth finish. This makes the MDF wood more suitable for application in our work. The MDF material is also available in the same standard thickness as that of the plywood material.

The standard sizes of thickness available in the market are summarized in Table 2.

Table 2 Availability of different thickness sizes

Thickness Size (mm)	Availability	Comments
18	Yes	*Used for doors*
16	No	*Manufactured for military*
14	No	
12	Yes	*Most Commonly available*
10	No	
8	Yes	
6	Yes	
4	Yes	

B. Materials Requirements

The material required for the manufacture of the headform, i.e. Headform code 3 of 600mm circumference, should satisfy the following conditions:

1. The wooden plates selected should be exactly 23 in number:

a) 0 Plate: Reference Plane.
b) 1 to 11: The Plates above the reference plane, i.e. The 0 plate.
c) -1 to -11: The plates below the reference plane, i.e. the 0 plane.

2. The Total Height of the headform should be approximately 249mm:

a) 107 mm - Above the reference plane.
b) 142mm - Below the reference point.

3. All the 23 plates should be of 1ft x 1ft in dimensions.

C. Specifications and Optimization Interpolations

The thickness order, in which the plates are selected to meet the above constraints, can be obtained by simple numerical or methodological calculations. One such thickness order of the plates selected for this work is listed in the Table 3(a & b), and is suggested for use to the reader as it is based on the most commonly and readily available standard thickness sizes in the market (Refer Table 2).

IV. MANUFACTURING

Once the materials are procured as mentioned in the earlier section, the respective plates are arranged in order of their thicknesses as listed in Table 3 (a & b).

Each plate is labeled with its corresponding plate number. The construction methodology developed is listed in eight steps, to comprehensively cover all the points relating to the papers purpose.

A. Step 1 - Marking on the Plates

- Mark the horizontal and vertical axes in each of the 1ftx1ft plate and plot the center.
- Mark these as the quadrant lines, i.e. 0^o, 90^o, 180^o, 270^o and 360^o (same as 0^o). Refer Fig. 6.
- Mark equiangular lines of 15^o each starting from the 0^o line. Refer Fig. 7.
- Plot the markings for the headform from Table **4** and Table 5. The table shows the markings for a Code 3 Headform of circumference 600m and Join them with a smooth curve.

Ensure that these markings are correct and accurate and the curves are smooth enough before going out to the 2nd step. Any errors produced here will get carried forward in the further steps and result in an inaccurate shape of the headform.

B. Step 2 - Cutting the Plates

- The plates are cut along the marked curves using a vertical blade cutter machine as shown in Fig. 8.
- Select a particular degree line, supposing 0^o line and start entering towards the curve along that line in all the plates to avoid confusion.
- A half inch blade should be used for the thicker plates (i.e. 18mm and 12mm thickness) and finer blade sizes for the thinner ones (i.e. 4mm, 8mm thickness).
- Care should be taken to provide a tolerance of about +0.5mm to +1mm.

Table 3 Thickness Order of Plates Upward and Downward from the Reference Plate

(a.) Plate Number (Above Reference Plate from Top)	Thickness Size (mm)
11	6
10	4
9	6
8	4
7	6
6	8
5	12
4	12
3	12
2	18
1	18
0 (Reference Plane)	12

(b.) Plate Number(Below the Reference Plate)	Thickness Size (mm)
0 (Reference Plane)	12
-1	12
-2	12
-3	12
-4	12
-5	18
-6	8
-7	8
-8	6
-9	12
-10	12
-11	18

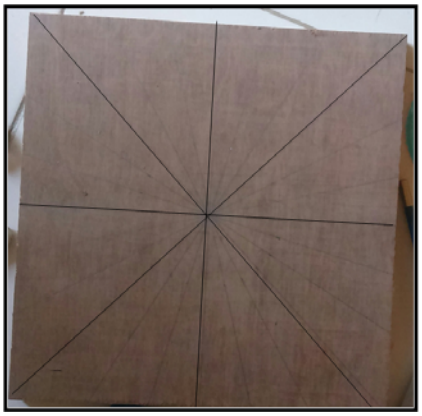

Fig. 6 Step1 - Quadrant and Angled Lines Marked

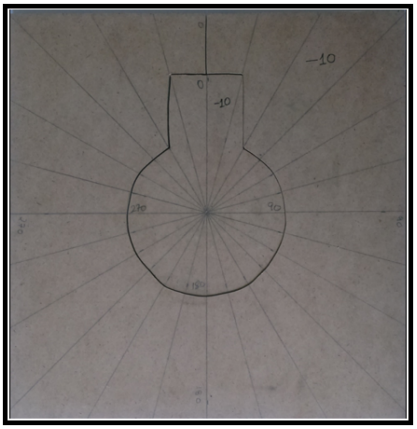

Fig. 7 Step1 - Curves drawn along the Markings

C. Step 3 - Markings for Grinding

- Take two consecutive plates starting from the reference plate upwards. For example, consider plate 0 and plate 1.
- Keep the smaller plate over the bigger plate and align their axes carefully. (Here, plate 1 over plate 0).
- Now, trace the curve of the smaller plates on the bigger plate's surface using it as a stencil.
- Now, repeat the steps for the plates below the reference plate, just taking care that here the smaller plate should be kept below the bigger plate (example plate -1 under plate 0) and take the markings on the lower surface of the bigger plate.

D. Step 4 - Grinding along the Curves

- Grind the plates along the edge starting from the bigger edge of one face of a plate towards the smaller curve drawn on the opposite face.
- A variable speed grinding machine should be use to obtain a smoother finish, better handling and accuracy on the wooden plates.
- The grinding machine is sometimes difficult to handle, so it would be recommended that the grinding machine be clamped onto a table fixed *Clamp* tightly and the grinding done in consecutive strokes on the grinding blade.
- Ensure a tight fix of the grinding machine without damaging it, or else it may fall loose and cause damage to the user or the surrounding equipment.

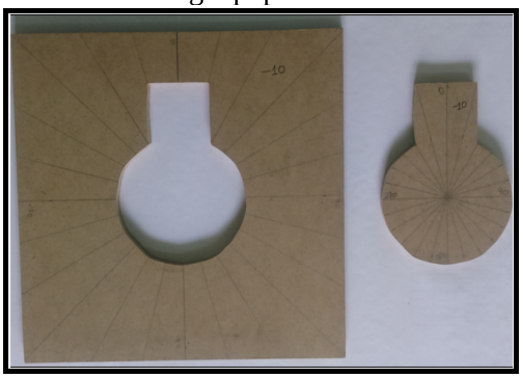

Fig. 8 Step2 - Cut and removed part of a Plate

Fig. 9 Step4 - Edges grinded according to markings in Step3

E. Step 5 - Rearranging and Aligning

- Mark the four quadrant angles with lines on the side surface or edges grinded in the previous step for aligning purpose.
- Rearrange the plates in order from bottom to top (from plate no. : -11 to 11).

F. Step 6 - Joining the Plates to Shape the Headform

- The plates in the step 5 are then joined one by one from the bottom upwards.
- The joining is done by applying glue (fevicol) between two plates and sticking then together in the form of a sandwich.

- Nails are hammered from the upper plate into the lower plate to strengthen the bond.
- Nails size should be selected keeping in mind the thicknesses of the two plates to be joined.
- The process should be repeated up till the topmost plate of the headform.

Fig. 10 Step6 – Joining done using glue and nails

G. Step 7 - Final Grinding

A final grinding is done in certain places of the headform to smoothen out the edges and give the headform a more accurate finish and curvature.

Fig. 11 Step6 - Headform takes shape after joining all Plates

H. Step 8 - Plaster and Painting

- A coating of plaster of paris (POP) is done on the headform for a smoother finish covering all the burrs and fractures in the headform surface.
- Then a coating of paint is done over it for a more aesthetic and glossier look.
- The thickness of the layers of POP and paint combined, should be justifiable to the standard size of the helmet selected.

Fig. 12 Step7 - Plastered and painted for a finished look

V. CONCLUSION

Helmet is one of the most important items of personal protective equipment. For testing of helmets, it is important to specify precisely a range of headforms to ensure a close fit for the helmet under test, thereby avoiding inaccuracies to the measurement of transmitted force. Here the reader is introduced to the types of helmets used for two different standards, which in way conform to each other. The paper sufficiently highlights all the important literature referring to the Indian Standard relating to the manufacture of the headforms for helmet testing and then goes on to develop and present a chronological methodology for the manufacture of the same. Various suggestions are made keeping in mind the complexity and accuracy aimed to be achieved. These steps are formulated such that if applied to a modelling software like Catia or Creo would also help in the modeling of a headform for virtual testing and analysis. Establishment of a correlation between the actual and virtual testing using the respective headforms for testing of helmets could thus, be a relevant subject for further increasing the scope of this paper for future works.

REFERENCES

[1] IS 7692, 1993: Indian Standards for headform testing of helmets—Specifications (1st revision).

[2] David R. Thom, Hugh H. Hurt Jr., Terry A. Smith, "Motorcycle Helmet Test Headform and Test Apparatus Comparison," Head Protection Research Laboratory, Unites States, Paper Number 98-S10-P-29.

APPENDIX

Table 4 Polar Coordinates of Horizontal Half Sections (for Plates Above Reference Plane)[1]

Height Above Reference Plane (mm)	0º	15º	30º	45º	60º	75º	90º	105º	120º	135º	150º	165º	180º
0	106.0	104.0	101.0	93.5	87.0	84.5	84.0	86.5	91.0	96.0	102.0	106.0	106.0
20	103.5	102.5	99.5	93.0	87.0	84.5	84.0	86.5	91.0	96.0	101.5	105.5	105.5
40	99.0	98.5	96.5	90.5	85.0	82.5	82.0	84.0	88.5	93.5	96.0	100.5	100.5
50	95.5	94.5	93.0	87.5	82.0	79.5	79.0	81.5	85.5	90.0	93.0	97.0	97.0
60	89.5	89.5	88.0	83.0	77.5	75.0	75.0	77.0	81.5	86.5	91.0	92.0	92.0
70	82.0	82.0	81.0	77.0	72.0	69.5	69.5	71.5	75.5	81.0	84.0	85.5	85.5
80	71.5	71.5	71.0	68.0	64.0	61.5	61.5	64.0	67.0	72.0	76.0	77.0	77.0
85	64.5	64.5	64.0	61.5	59.0	57.0	57.0	58.5	61.5	66.5	71.0	72.0	72.0
90	56.5	56.5	56.5	55.0	53.0	51.5	51.5	53.0	56.0	60.5	64.5	66.0	66.0
95	46.5	46.5	47.0	46.5	45.5	44.0	44.0	45.5	48.5	53.0	57.5	59.0	58.5
100	32.0	32.0	32.5	33.0	34.0	34.0	34.5	35.5	38.5	43.0	46.5	48.5	48.0
105	12.0	12.0	13.0	14.0	15.0	16.0	17.5	19.5	21.0	25.0	29.5	30.0	30.0
Dimension H: 107mm Measurement around the head: 600mm													

Table 5 Polar Coordinates of Horizontal Half Sections (for Plates Below Reference Plane)[1]

Depth Below Reference Plane (mm)	0º	15º	30º	45º	60º	75º	90º	105º	120º	135º	150º	165º	180º
0	106.0	104.0	101.0	93.5	87.0	84.5	84.0	86.5	91.0	96.0	102.0	106.0	106.0
-13.3	106.0	104.0	98.5	88.5	81.5	79.0	79.0	81.5	85.5	92.0	97.0	100.5	101.5
-23.7	106.0	105.0	98.5	88.0	79.5	75.0	73.5	76.5	80.5	86.5	92.0	95.5	96.0
-36.5	106.0	106.5	96.5	85.0	77.5	74.0	67.0	69.5	73.5	79.5	84.5	87.5	88.0
-47.0	106.0	106.5	94.0	82.5	75.0	71.5	64.0	66.0	69.0	73.5	78.0	80.5	80.0
-62.6	106.0	106.5	92.0	80.0	72.0	64.0	61.5	62.0	63.5	67.5	70.5	71.5	70.0
-78.3	106.0	106.5	90.0	77.0	70.0	62.5	60.0	61.0	61.5	62.5	63.0	64.0	64.5
-88.7	106.0	106.5	87.5	74.5	69.0	60.5	60.0	61.0	61.5	62.5	63.0	64.0	64.5
-94.0	106.0	106.5	85.0	72.0	59.0	59.5	60.0	61.0	61.5	62.5	63.0	64.0	64.5
-100.7	106.0	106.5	83.0	57.0	59.0	59.5	60.0	61.0	61.5	62.5	63.0	64.0	64.5
-110.7	106.0	109.5	56.5	57.0	59.0	59.5	60.0	61.0	61.5	62.5	63.0	64.0	64.5
-142.0	56.0	56.0	56.5	57.0	59.0	59.5	60.0	61.0	61.5	62.5	63.0	64.0	64.5
Dimension l: 13.3mm Measurement around the head: 600mm													