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Thickness measurement and digitising of the SAM phantom head shape

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Head-shell digitising

The SAM head shells are individually digitised on a Mitutoyo test bench model CMM C574 (see Figure 1) to a precision of 0.001mm.

Figure 1: Mitutoyo co-ordinate measurement machine (Model C574)

For the measurement of SAM phantom shells, Mitutoyo were commissioned to write a special measurement program for Indexsar Ltd. The head is mounted on a rotation base and filled with water prior to measurement. When the measurement set-up has been positioned and checked, the head is rotated in 5 degree steps and vertical profiles collected on the outside of the heads at each angle. The raw measurement data consist of x,y,z coordinate sets expressed to a precision of 0.001mm.

Figure 2: Sapphire-tipped probe measuring the head shell

In subsequent data processing, the data are converted into .csv head-shape files of the outside of the phantom. The reference CAD files for the SAM phantom shape are used to deduce the coordinates of the inside of the phantom shape from the measurements taken on the outside. This process removes the ear shape (which is not present on the inside surface).

The resulting head shape file is saved in the resources directory in the SARA2 application folder on the controlling PC.

Shell thickness Measurement

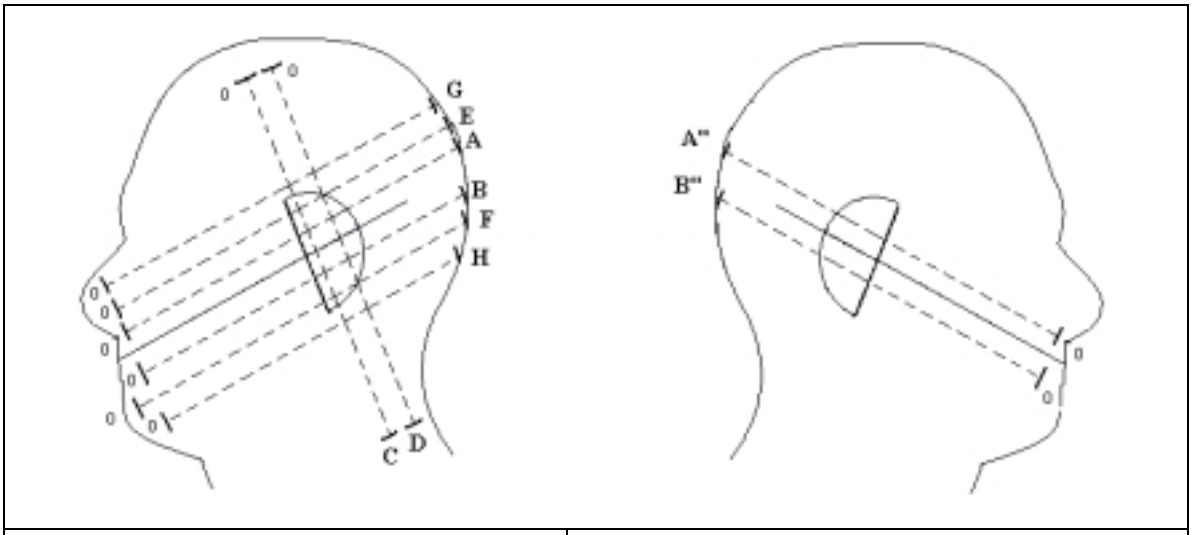
To measure the thickness of the phantom shells, an ultrasonic thickness meter (Krautkramer Model CL3) optimised for the measurement of plastic materials was used. The 'plastic probes option' of this instrument is designed to overcome difficulties due to the low acoustic impedance of many plastic materials.

Figure 3: Showing an ultrasonic thickness measurement being performed

The instrument was calibrated by using sections of the headshells where the thickness could be determined using digital vernier callipers (which read to a precision of 0.01mm). Each head shell has a circular penetration cut out at the top of the head and this can be used for calibration as well as providing a sample for thickness measurement with the callipers.

To obtain good coupling with the shell surface, water was used as a coupling fluid during measurement (Figure 3). Having calibrated the ultrasonic meter, the measurements in Table 1 were made in the positions shown below (Figure 4) on a representative head-shell (S/N FT03).

Before delivery, other head shells are individually checked for conformance using several points in the key regions of the head shell where the phones are positioned.



Lines along which thickness Measurements were taken on the RHS of the SAM phantom	Lines along which thickness measurements were taken on the LHS of the SAM phantom

Figure 4: Approximate locations of points measured on each side of the shell (see Table 1)

Table.1. Thickness values obtained from the SAM phantom S/N FT03 . ('No Meas' indicates that the surface at that point had a too much of a radius to take a suitable measurement. The measurements are in millimetres.

Point	A	B	C	D	E	F	G	H	A"	B"
0	2.33	2.28	1.87	1.9	2.17	2.05	2.12	2.04	2.13	2
1	2.21	2.1	1.97	2.03	2.1	2.15	2.12	2.02	2.18	2.02
2	2.11	2.07	1.91	2.09	2.07	2.05	2.18	2.04	2.04	2.06
3	2.07	2.06	2.02	2	1.95	2.04	2.19	2.01	2	2.05
4	2.08	2.05	2.17	2.01	2.1	2.04	2.09	2.01	2.02	1.99
5	2.09	2.1	2.13	2.03	2.09	2.08	1.94	2.03	1.99	2.04
6	2.12	2.07	1.98	2.05	2.08	2.08	2.03	2.04	1.96	1.98
7	2.07	2.03	1.96	1.96	2.04	2.04	1.99	2.04	1.94	1.98
8	2.05	2.04	1.96	1.97	2.03	2.01	1.98	2.15	1.93	1.94
9	2.06	2.04	1.98	1.98	2.06	2.02	1.98	2.27	1.92	1.94
10	2.03	2.02	No Meas	2	2.02	2.01	1.99	2.31	1.89	1.93
11	2.03	2.01	No Meas	No Meas	2.01	2.01	1.99	2.2	1.87	1.85
12	2.02	No Meas	No Meas	No Meas	No Meas	2.03	1.98	2.12	1.85	1.83
13	No Meas	No Meas	No Meas	No Meas	1.98	No Meas	1.96	2.12	1.86	No Meas
14	No Meas	No Meas	No Meas	No Meas	1.98	No Meas	1.95	2.11	No Meas	No Meas
15	No Meas	No Meas	No Meas	No Meas	2	No Meas	1.97	2.1	No Meas	No Meas
16	No Meas	2.1	No Meas	No Meas	2.02	No Meas	2	2.05	No Meas	No Meas
17	1.98	2.12	No Meas	2.06	2	2.05	2.19	2.04	No Meas	No Meas
18	1.97	2.02	2.11	2.12	1.99	2.08	2.53	2.04	1.84	1.91
19	1.97	1.99	2.12	2.12	1.99	2.05	2.5	2.04	1.9	1.95
20	2.04	2.01	2.06	2.05	2.02	2.02	2.43	2.03	1.94	1.96
21	1.99	2	2.06	2.04	2.01	2.01	2.45	2.01	1.89	1.95
22	2	2	2.06	2.03	1.99	2.01	2.18	2.07	1.84	1.96
23	2.02	1.99	2	2	2	1.99	1.82	2.14	1.87	1.98
24	2.05	1.97	2.04	2.04	1.91	2	1.67	2.16	1.93	1.99
25	2	1.97	2.1	2.08	1.94	2.01	1.79	2.02	1.93	1.99

Discussion of uncertainty implications

If all the measurements listed in Table 1 are included, the average wall thickness is 2.031mm and the standard deviation of the measurements is 0.105mm.

Rows G and H contain a small number of measurements made in thicker regions close to the top and bottom of the ear. Whilst the thickness at these points exceeds the tolerance on thickness of 10%, they are not in regions where the phone will contact the shell. With these points excluded, the average of the remaining readings is 2.020mm and the standard deviation is 0.083mm. In all cases, where it is possible to make vernier calliper measurements of cut portions of the SAM shells, the thickness measurements have all been within 10% of the 2.0mm nominal thickness.

It is unlikely that any significant uncertainty allowance for thickness variability of the SAM shells supplied by Indexsar is required in the overall uncertainty assessment. The shells supplied are unpainted. If they were to be painted, this might represent a significant alteration in terms of the tight tolerances achieved for the moulded shells.