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Note to support corrected jig settings-calculations for off-set fiducial lines of ETM04

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v1	*26th July 2011*	*First draft for review by Ken Strain and Angus Bell*
v2	*12th August 2011*	*Checked by Angus Bell and Ken Strain, for review by Gerardo Moreno and Mark Barton*
v3	*7th September 2011*	*Correct error found in calculations found by Gerardo Moreno and added new measurements of the fiducials on ETM04 and calculations of the jig settings. After dry runs these jig settings do match up with fiducial lines.*
v4	*19th September 2011*	*A few additions to help clarify what is S1, S2, S3 and S4 and x*

1 Introduction

This note explains the re-calculation of the jig settings for bonding on ears to test mass ETM04 based on measurements made by Gerardo Moreno (reported in T1100438) as they are incorporated into the jig-settings calculation sheet E1000265-v10.

2 Reference documents

E1000278	Preparation of an end or input test mass (ETM/ITM) (Hydroxide-Catalysis Bonding of ears)
E1000265	Jig settings calculation spread sheet
D0901591	BASEPLATE - NP-type bonding jig
D0901592	ASSEMBLY DRAWING - ear bonding jig
T1100438	Report on fiducial line position measurements for ETM04

3 Analysing measurement data of fiducial lines

Table 3.1 shows the measurements made by Gerardo Moreno (T1100438) of the vertical offset of the fiducial lines on surface S3 and S4 of ETM04.

As stated in his report the measurement was repeated 5 times on 3 locations on each of the fiducial lines (2 one each surface). The standard deviation of the measurements was less than 0.06 mm for all different locations. To aid with the re-calculation of the jig settings to place the ears in the correct position, two columns have been added into this table when compared to T1100438;

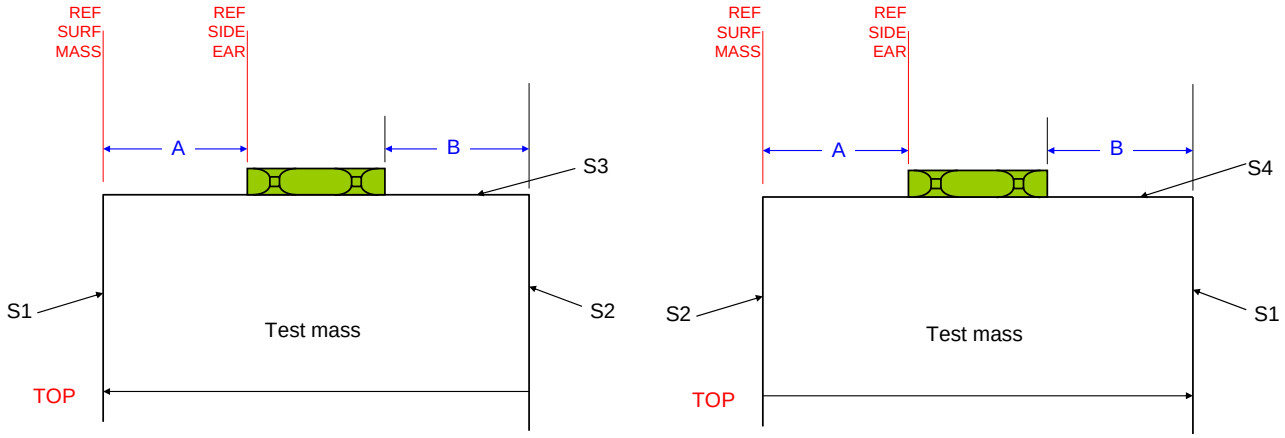
1) the average for each location of the 5 independent measured values (average), and;

2) the approximate x-location of the measurement points on the surface measured (x-loc).

The goal of the analysis of the data tabulated in Table 3.1 is to determine the offset value of the fiducial lines at the x-location of each of the sliders on the ear bonding jig (D0901592). The drawing of the baseplate of the bonding jig (D0901591) shows that the centres of the slider grooves are located 80 mm from the centre of the mass, which means they are centred at 20 mm from surface S1 and surface S2. Figure 3.1 shows the locations of S1, S2, S3 and S4 with respect to the top of the mass and the way the ears are positioned in S3 and S4.

Figure 3.2 shows the graphical representation of the position of the fiducial lines with respect to the cylindrical axis projected onto the vertical plane. The position of the fiducial lines is positive for offsets towards the top of the mass, in other words towards the arrow on the barrel. All data points for each surface S3 and S4 are shown and linear regression lines through each of the data sets seems to indicate that the two fiducial lines on each surface are in line with each other.

One other notable thing is that the location of different points on each individual fiducial lines can vary as much as 0.2 mm as is the case near surface S1 on surface S4. It is therefore important to make sure that the correct section of the fiducial line is measured and used for the slider settings calculation.



a) Ear on S3 **b) Ear on S4**

Figure 3.1 Graphical representation of ear position measurements on the test mass

Table 3.1 Measurement data of the offset of the fiducial lines from the cylindrical axis created by Gerardo Moreno (+ 2 added calculation columns). All values are in millimeters.

	Data from Scribe lines on surface S3							
	Data Sample							
	A	b	c	d	e	St. Dev.	Average	x-loc
near S2	0.56	0.501	0.509	0.514	0.479	0.030	0.5126	6
	0.491	0.488	0.5	0.518	0.402	0.045	0.4798	21
	0.462	0.435	0.436	0.386	0.401	0.030	0.424	35
	0.197	0.18	0.121	0.114	0.141	0.036	0.1506	165
	0.179	0.133	0.13	0.06	0.101	0.044	0.1206	179
near S1	0.149	0.077	0.113	0.026	0.038	0.051	0.0806	194

	Data from scribe lines on surface S4							
	Data Sample							
	A	b	c	d	e	St. Dev.	Average	x-loc
near S2	0.734	0.625	0.684	0.688	0.697	0.039	0.6856	6
	0.714	0.596	0.578	0.651	0.596	0.056	0.6270	21
	0.646	0.592	0.563	0.618	0.513	0.051	0.5864	35
	-0.070	-0.062	-0.068	-0.011	-0.031	0.026	-0.0484	165
	-0.133	-0.144	-0.095	-0.118	-0.082	0.026	-0.1144	179
near S1	-0.187	-0.247	-0.249	-0.211	-0.157	0.039	-0.2102	194

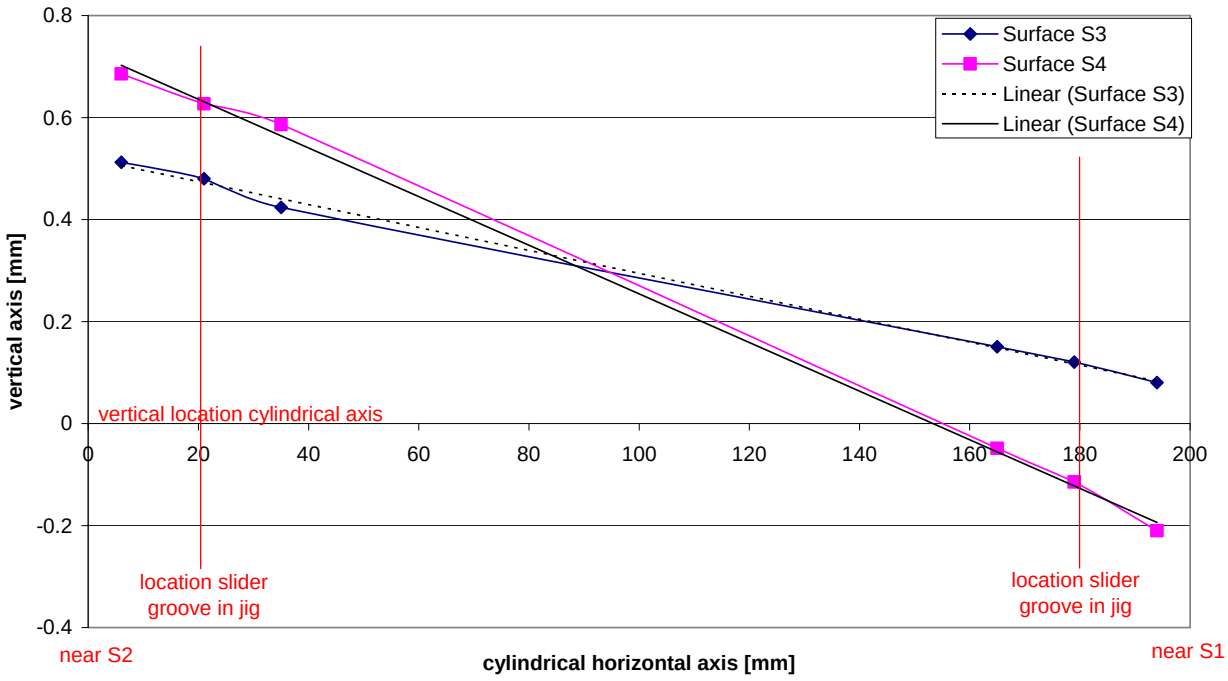


Figure 3.2 Graphical representation of the measured location of the fiducial lines on surfaces S3 and S4. Linear least squares fitted lines through each of the data sets seem to indicate each section of fiducial lines is an extension of the other (as the mismatch is very small). The certical (red) lines indicate the location of the reference slot on the bonding jig.

The location of the slider slot is indicated with the vertical red lines in the figure. As explained above this is 20 mm from surface S1 and S2.

The offset values for the fiducial lines that shall be used for this mass are therefore the averages of the measured values at 21 mm and at 179 mm. These values are highlighted in yellow in Table 3.1.

4 Slider settings calculation

The vertical alignment of the bonding jig is normally achieved by setting two sliders in a groove to a pre-calculated height with respect to a fixed reference pin on the jig. This value is called D_{slider} and is based on the desired flexure point position (d_4), the distance from the tip of the horn to the flexure position ($l_{flex\ horn}$), on the width of the ear (y_h) and the distance between the reference pin and the top reference surface on the jig (y_{pin}). For the test mass a small correction (0.1 mm) is also

included for the off-set of the COM from the cylindrical axis due to the wedge. The bottom of the slider then has to match up with the fiducial lines on the test mass.

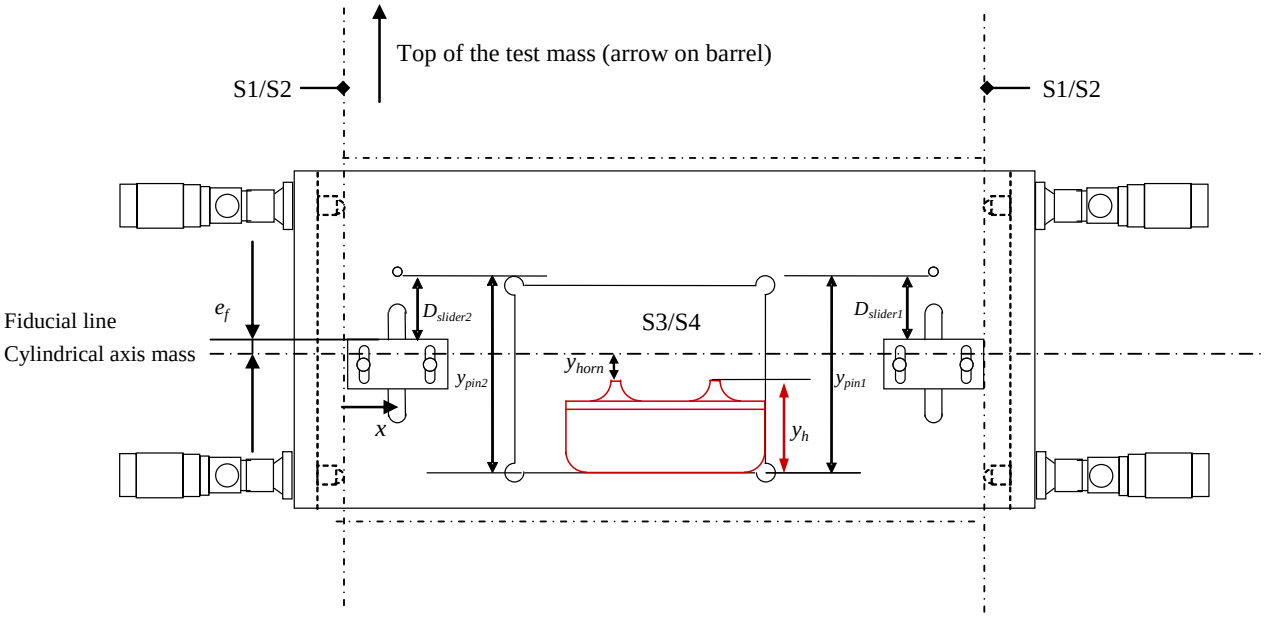


Figure 4.1 Graphical representation of each of the values used to calculated the setting for D_{slider}

Assuming that the fiducial lines are not offset from the cylindrical axis of the optic as projected onto the vertical plane D_{slider} can then be calculated as follows;

$$D_{slider} = y_{pin} - y_h - \left(l_{flex\,horn} - d_4\right) - 0.1 = y_{pin} - y_h - h_{horns} - 0.1$$

If we now include an error for the offset of the fiducial line from the cylindrical axis called e_f this equation becomes;

$$D_{slider} + e_f = y_{pin} - y_h - h_{horns} - 0.1$$
$$D_{slider} = y_{pin} - y_h - h_{horns} - 0.1 - e_f$$

Because e_f is different for each fiducial line, it needs to be calculated and set separately for each slider on the jig. $D_{slider\ 1}$ on the left side of the jig and $D_{slider\ 2}$ on the right side of the jig.

For the bonding the jig with S/N 1 will be used for both ears. For surface S3 ear S/N 48 will be used. For surface S4 ear S/N 46 will be used. The results are shown in Table 4.1.

Table 4.1 Calculation of D_{slider} for ears 48 and 46 on ETM04 using jig S/N 1 including the error of the fiducial line position as reported in T1100438.

Surface	y_{pin} [mm]	Ear	y_h [mm]	h_{horns} [mm]	Location slider	e_f [mm]		
S3	58.205	48	27.490	7.4	Near S1	0.121	$D_{slider\ left}$ =	23.09
S3	58.205	48	27.490	7.4	Near S2	0.480	$D_{slider\ right}$ =	22.74
S4	58.205	46	27.505	7.4	Near S2	0.627	$D_{slider\ left}$ =	22.57
S4	58.205	46	27.505	7.4	Near S1	-0.114	$D_{slider\ right}$ =	23.31

5 Another check and jig settings calculations

Gerardo performed fit check with these jig settings but found that the jig still did not match up in a satisfactory way with the fiducial lines. He made new measurements of the mass ETM04. These are shown in Table 5.1. The datasets of surface S3 agree very closely (to within a few tens of microns). The datasets of surface S4 do agree closely in relative positions (with a few tens of microns) but they are shifted by about 0.1 mm as a whole with respect to each other. This is not considered to be an issue as the biggest error in total vertical positioning of the fibre flexure points will still be introduced by the fibre welding procedure.

Table 5.1 Second measurement data round of the offset of the fiducial lines from the cylindrical axis created by Gerardo Moreno. All values are in millimeters.

	1st Data sample		2nd Data sample		3rd data sample	
	Near surface					
	s2	s1	s2	s1	S2	S1
Data for Surface S3	0.402	0.112	0.503	0.121	0.494	0.129
	0.488	0.147	0.505	0.218	0.395	0.115
	0.446	0.133	0.51	0.208	0.474	0.133
Average offset near S2	0.469					
Average offset near S1	0.146					
Data for Surface S4	0.771	-0.054	0.694	-0.075	0.716	-0.054
	0.765	-0.055	0.679	-0.06	0.741	-0.057
	0.765	-0.001	0.672	-0.065	0.715	-0.038
Average offset near S1	-0.051					
Average offset near S2	0.724					

The jig settings that can be calculated from this second data set are shown in Table 5.2 compared to the initial data set. The new jig settings calculated from this dataset reflect the differences in the mass measurements. Gerardo Moreno has reported that after a dry run with the second dataset jig settings the fiducial lines do match up.

Table 5.2 Calculation of D_{slider} for ears 48 and 46 on ETM04 using jig S/N 1 including the error of the fiducial line position as reported in T1100438 for two separate ETM04 measurement data sets.

		Measurement round 1			Measurement round 2		
Surface	Location slider	e_f [mm]			e_f [mm]		
S3	Near S1	0.121	$D_{slider\ left}$ =	23.09	0.146	$D_{slider\ left}$ =	23.07
S3	Near S2	0.480	$D_{slider\ right}$ =	22.74	0.469	$D_{slider\ right}$ =	22.75

S4	Near S2	0.627	$D_{slider\ left}$ =	22.57	0.724	$D_{slider\ left}$ =	22.48
S4	Near S1	-0.114	$D_{slider\ right}$ =	23.31	-0.051	$D_{slider\ right}$ =	23.25