# ECAL
# Metrologies // T-frame and CF

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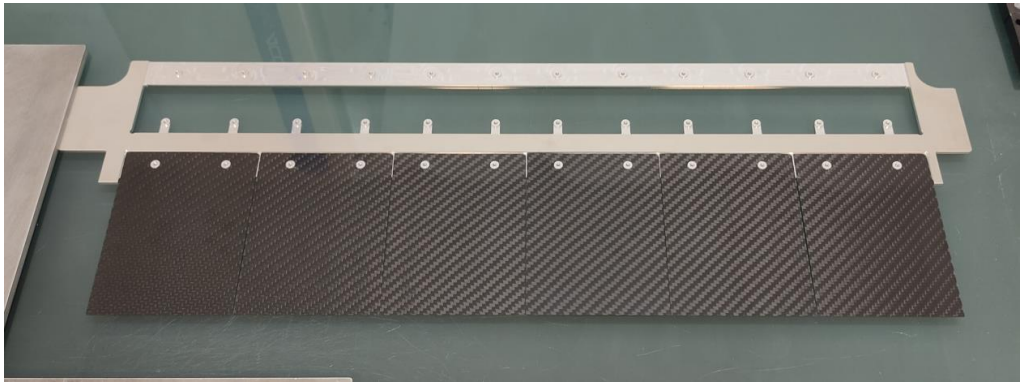
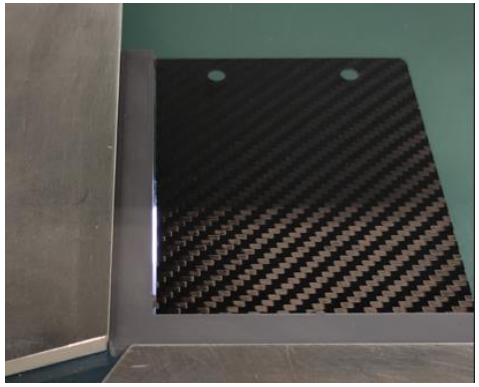
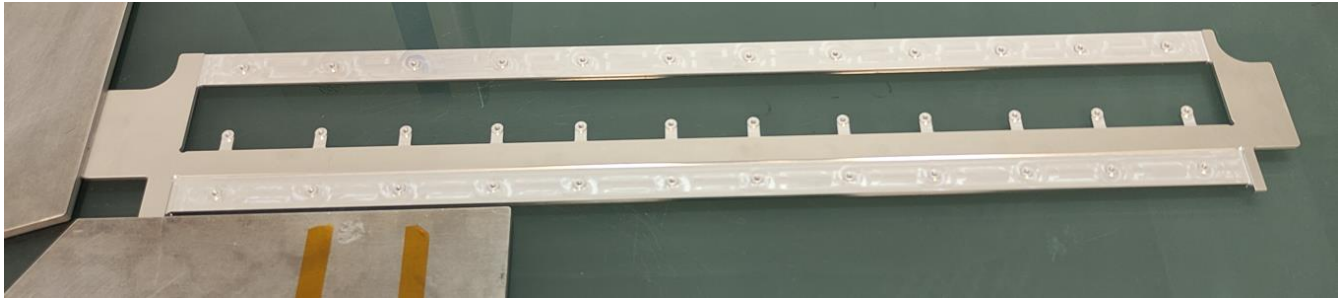
# Metrologies

- T-frame + 6 CF: to measure gap between CF in top and bottom.
- T-frame: 3 rows of 12 tabs (top, middle and bottom)
- CF: HP (“high precision”) and CF LP (“low precision”)

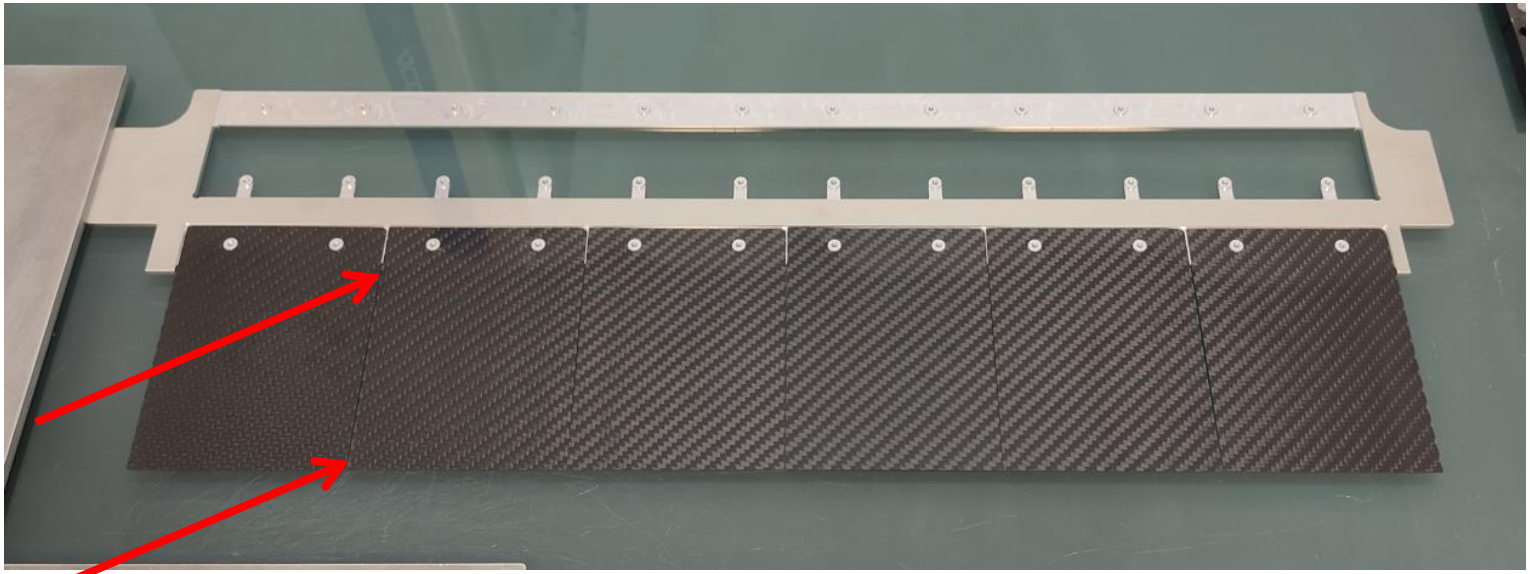




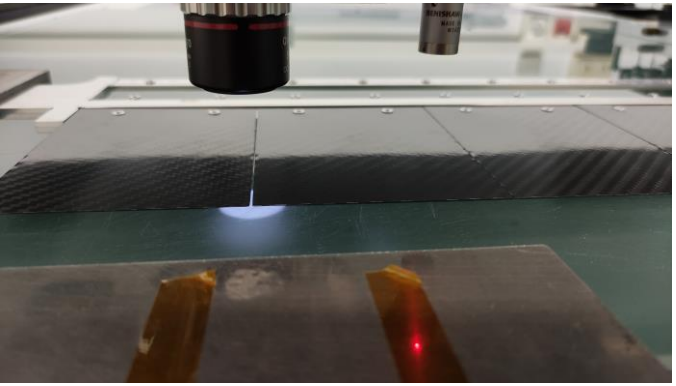


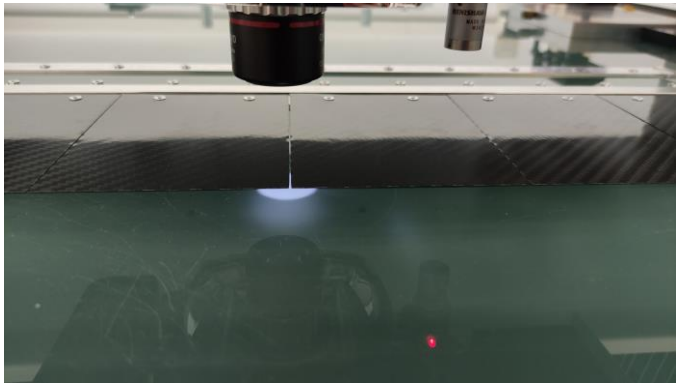
# T-frame + 6 CF (gap between CF)

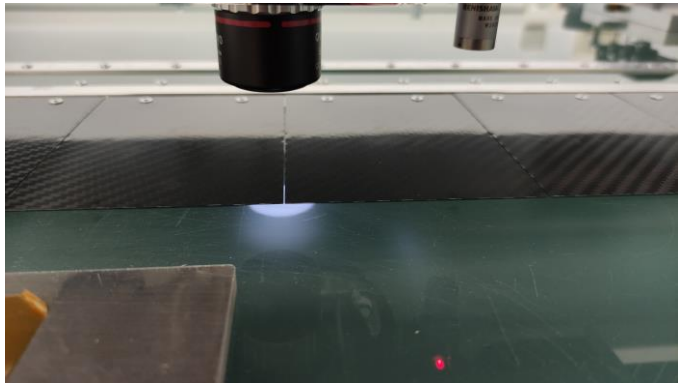
- CF HP1 to CF HP6 mounted on T-frame
- Top gap measured next to T-frame edge.
- Bottom gap measured end of CF.
- CMM equipment has 600 um width. Pictures where taken when both CF where on frame. Gaps bigger than 600um do not have picture.

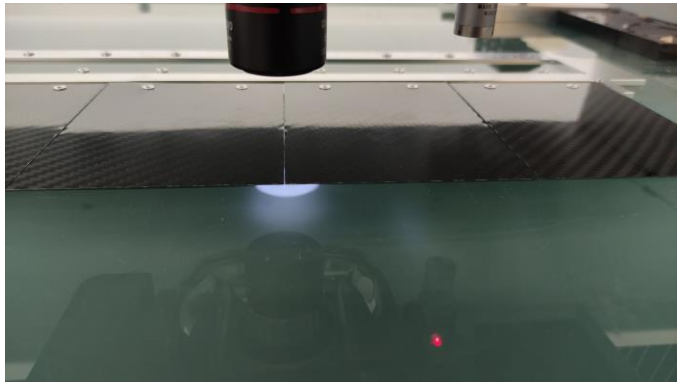


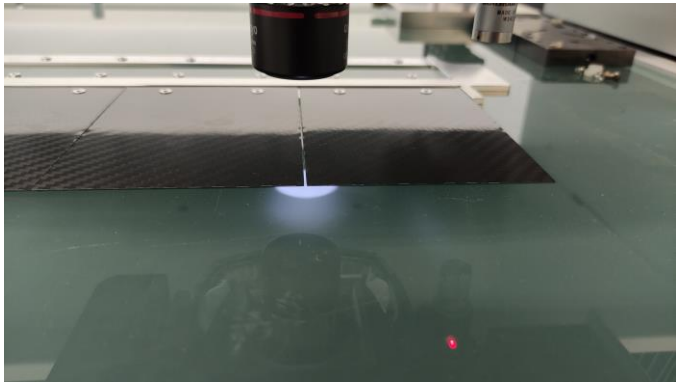
# T-frame + 6 CF (gap between CF)









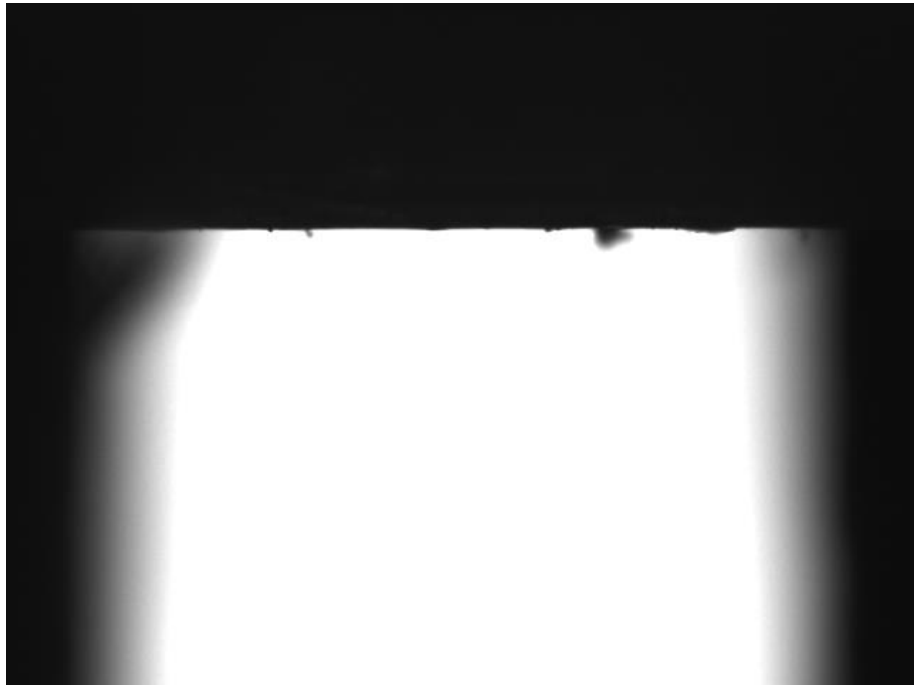


# T-frame + 6 CF (gap between CF)

- GAP_CF2-CF3 // GAP_CF4-CF5

# T-frame + 6 CF (gap between CF)

- TFRAME_1_GAP_CF1-CF2 // TFRAME_2_GAP_CF1-CF2
- This pictures show the same gap (CF1 - CF2) and T frame edge.
  - Left picture T frame edge is blurry: focus adjusted to CF borders
  - Right picture T frame edge is sharp: focus adjusted to edge.



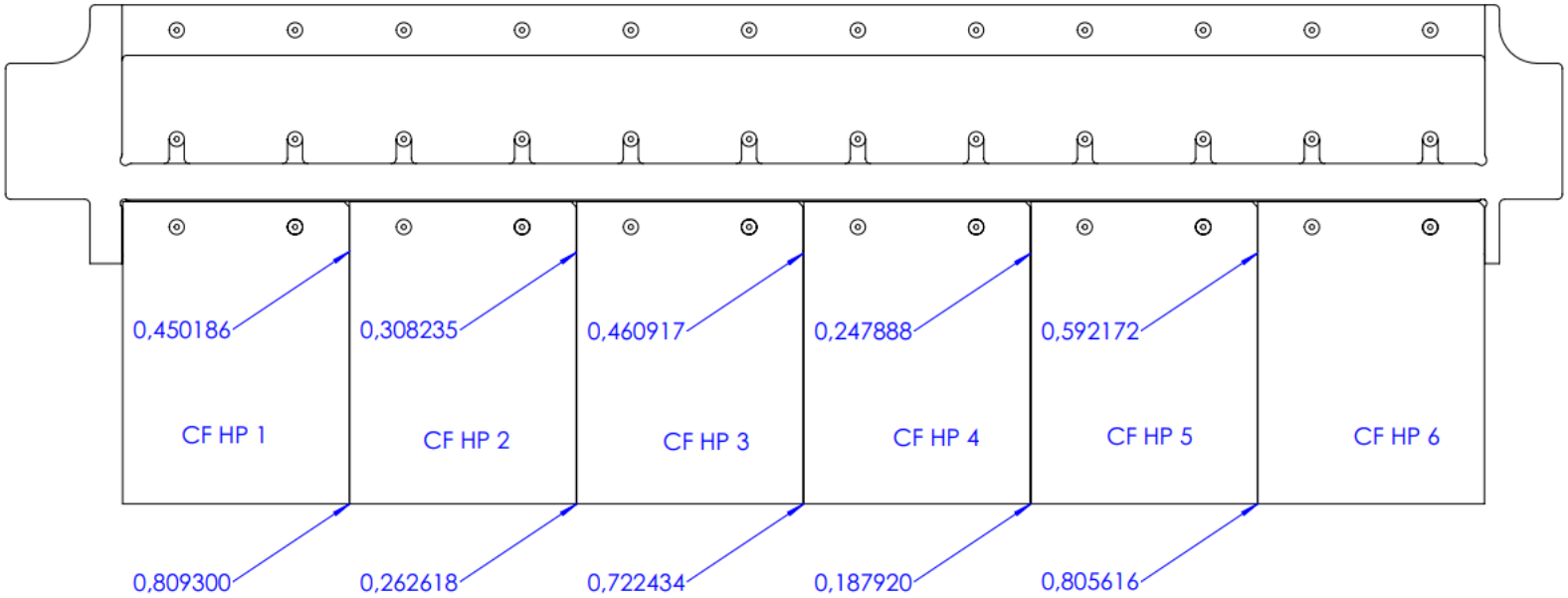
# T-frame + 6 CF (gap between CF)

- TFRAME_GAP_CF1-CF2 // TFRAME_GAP_CF2-CF3 // TFRAME_GAP_CF3-CF4
- TFRAME_GAP_CF4-CF5 // TFRAME_GAP_CF5-CF6

# T-frame + 6 CF (gap between CF)

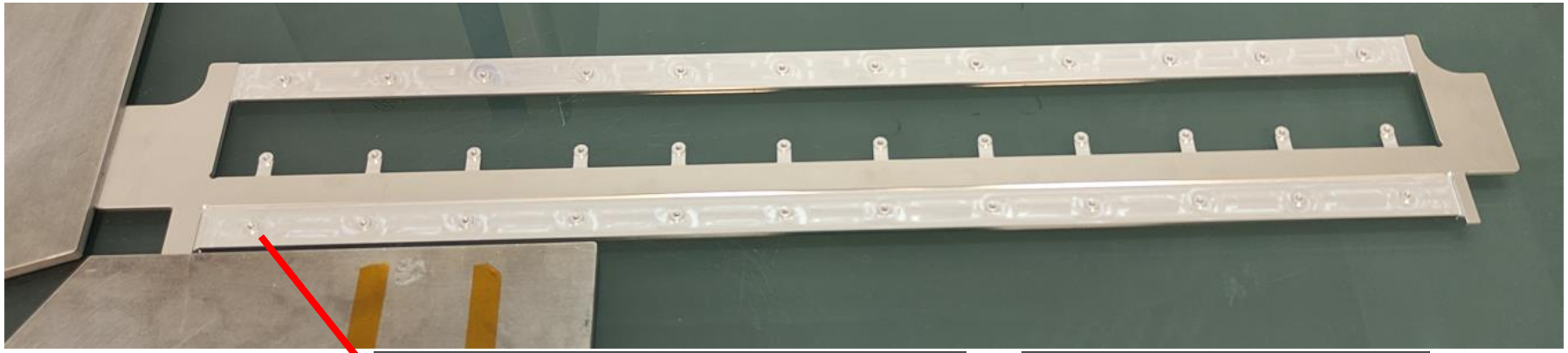
**Results**

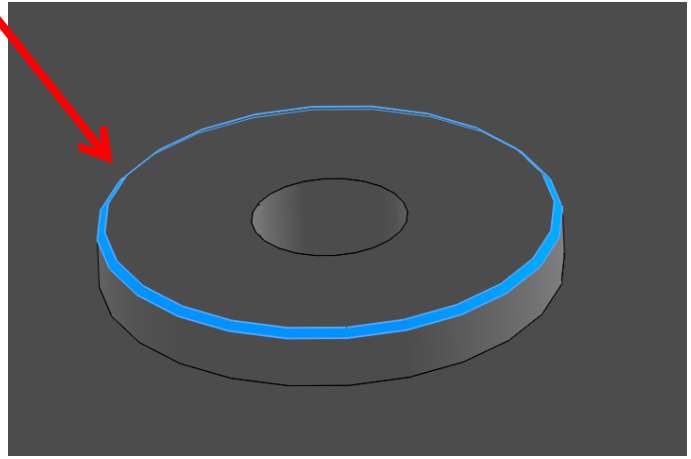
- Very inconsistent gap length and way bigger than nominal.
- Results are coherent with:
  - CF smaller than nominal.
  - CF not located with accuracy (rotated)

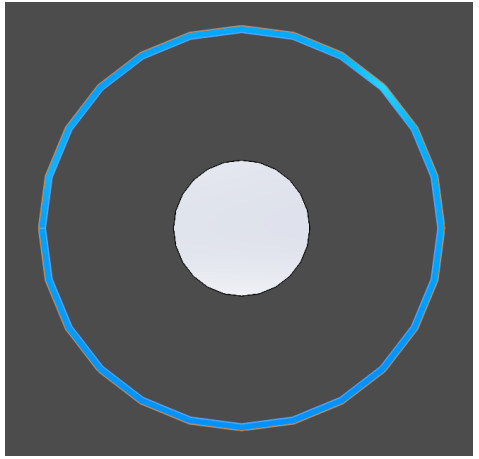


# T-frame

- 3 rows (identified as top, middle and bottom) with 12 tabs each
- Measured with a light setting to be able to see the chamfer on the top of the tab.

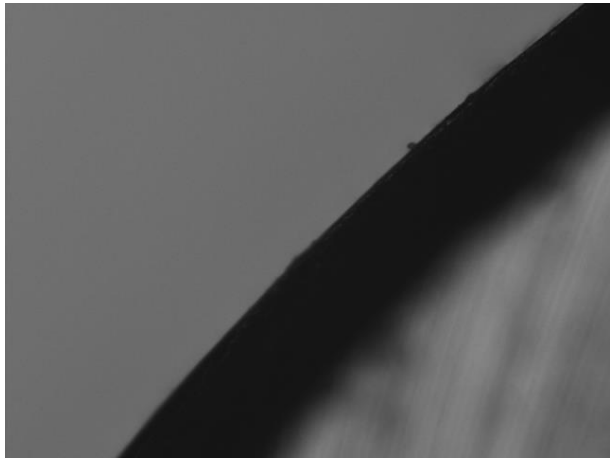


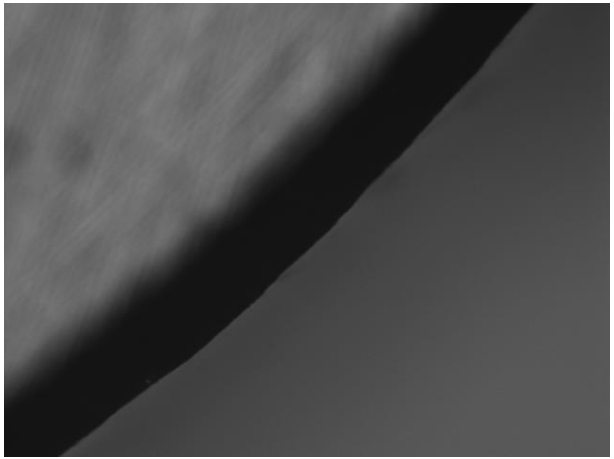


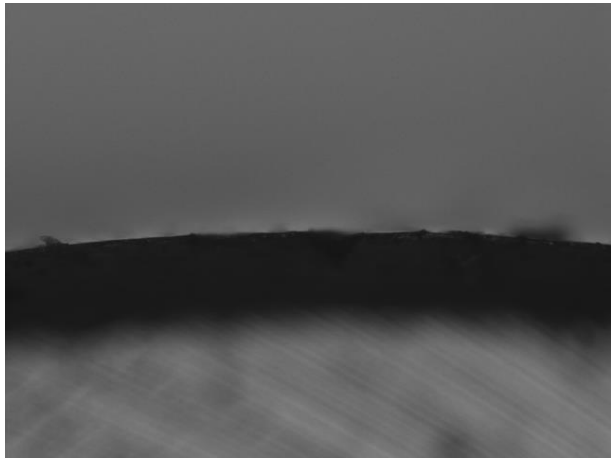


# T-frame

- Measuring 8 points per tab (every 45° angle).
- Fitting those 8 points to a circle least-squares method (Mitutoyo software does it).
- Pictures taken for every point measured.







# T-frame

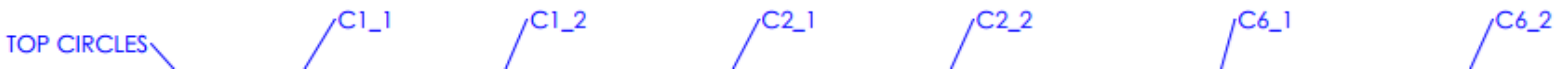
- Pictures will be shared with you to take a closer look.
- 96 pictures of interest (8x12 = 96)
- There are 8 pictures of the points measured to define a PCS (Part Coordinate System): Origin (0,0) at first tab and CMM axes aligned with T frame.

# Title

## Results: VLC-TFRAME_CMM_RESULTS.pdf // VLC-TFRAME_CMM_RESULTS.xlsx

| | TOP CIRCLES | | | | MIDDLE CIRCLES | | | | BOTTOM CIRCLES | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | X coord | Ø | Roundness | | X coord | Ø | Roundness | | X coord | Ø | Roundness |
| 3 | C1_1 | 0.000815 | 5.992096 | 0.009013 | C1_1 | 0.000806 | 5.981617 | 0.009935 | C1_1 | 0.00004 | 5.989821 | 0.010648 |
| 4 | C1_2 | 47.008278 | 5.988629 | 0.00841 | C1_2 | 47.007628 | 5.98047 | 0.005912 | C1_2 | 47.0009 | 5.990876 | 0.016962 |
| 5 | C2_1 | 90.215656 | 5.989385 | 0,011518 | C2_1 | 90.21275 | 5.98105 | 0.00627 | C2_1 | 90.20886 | 5.992143 | 0.008346 |
| 6 | C2_2 | 137.224445 | 5.98948 | 0.010966 | C2_2 | 137.21445 | 5.982547 | 0.01318 | C2_2 | 137.2105 | 5.991259 | 0.010757 |
| 7 | C3_1 | 180.431732 | 5.991298 | 0.009137 | C3_1 | 180.42282 | 5.982943 | 0.006123 | C3_1 | 180.4172 | 5.990562 | 0.008966 |
| 8 | C3_2 | 227.438336 | 5.991234 | 0.011869 | C3_2 | 227.42573 | 5.981387 | 0.009585 | C3_2 | 227.4197 | 5.991301 | 0.004076 |
| 9 | C4_1 | 270.645742 | 5.991297 | 0.010687 | C4_1 | 270.63265 | 5.983326 | 0.009147 | C4_1 | 270.6235 | 5.990273 | 0.009097 |
| 10 | C4_2 | 317.652812 | 5.990488 | 0.007403 | C4_2 | 317.63575 | 5.983877 | 0.006206 | C4_2 | 317.6266 | 5.990786 | 0.010494 |
| 11 | C5_1 | 360.855883 | 5.990204 | 0.00584 | C5_1 | 360.83715 | 5.980677 | 0.006981 | C5_1 | 360.8261 | 5.99127 | 0.006627 |
| 12 | C5_2 | 407.863978 | 5.992189 | 0.009828 | C5_2 | 407.84129 | 5.981909 | 0.005767 | C5_2 | 407.8312 | 5.992601 | 0.008195 |
| 13 | C6_1 | 451.067479 | 5.989243 | 0.008563 | C6_1 | 451.0451 | 5.981157 | 0.00823 | C6_1 | 451.0306 | 5.988075 | 0.008094 |
| 14 | C6_2 | 498.074319 | 5.990329 | 0.009165 | C6_2 | 498.04876 | 5.978079 | 0.005365 | C6_2 | 498.0352 | 5.990173 | 0.010636 |

| | |
|---|---|
| 16 | on spec |
| 17 | out of spec |



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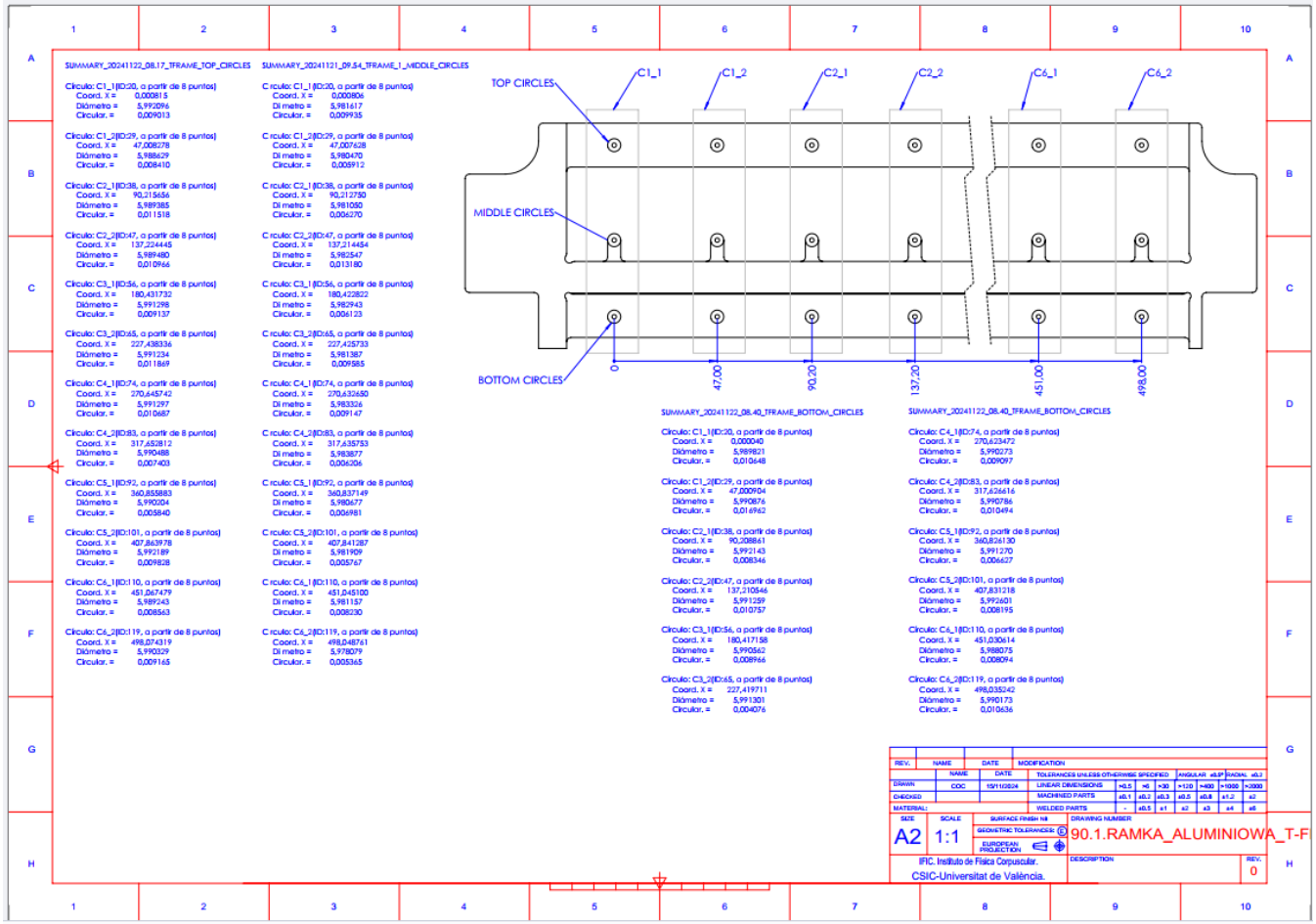
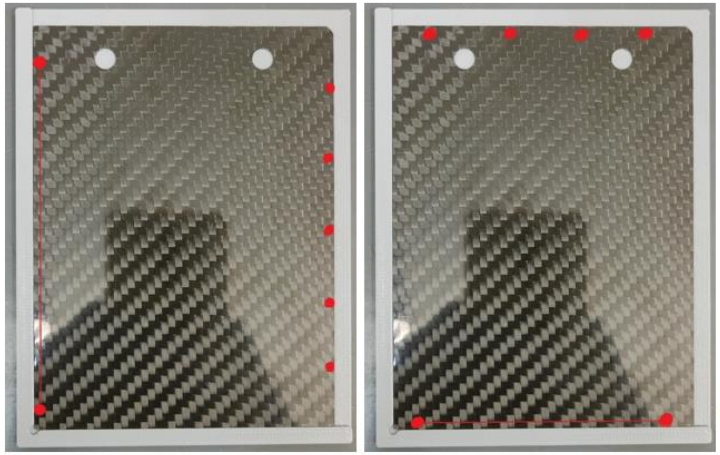
## Results: VLC-TFRAME_CMM_RESULTS.pdf // VLC-TFRAME_CMM_RESULTS.xlsx



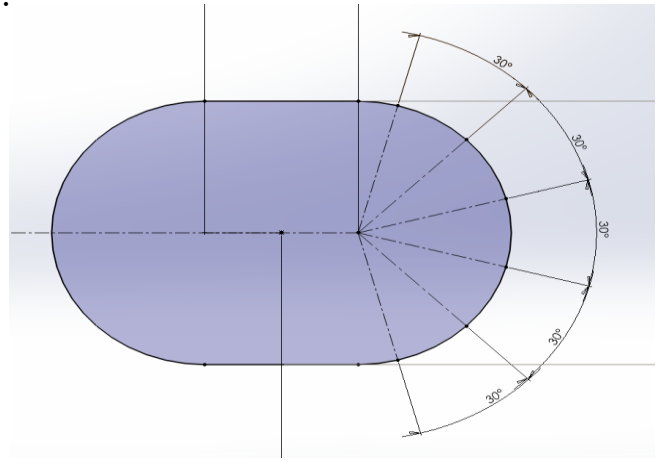
# CF

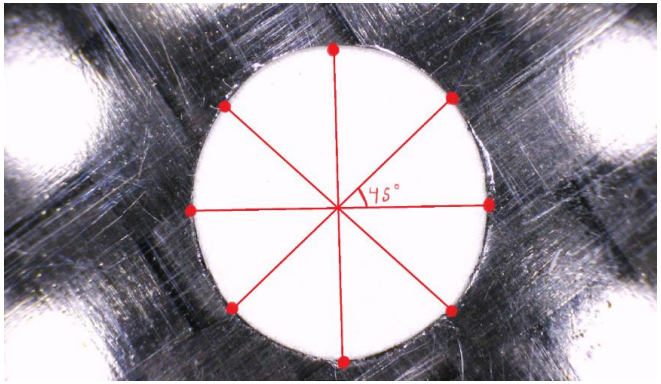
- CF lying flat over CMM glass stage.
- Light coming from the stage (to identify borders) and from top.
- Pictures taken for every point measured.
- 5 points to define an horizontal bottom line: LH
- 8 points to define a vertical left line: LV
- Origin (0,0) set as intersection of LH with LV.
- 5 points measured on top border and distance calculated to LH.
- 8 points measured on left border and distance calculated to LV.

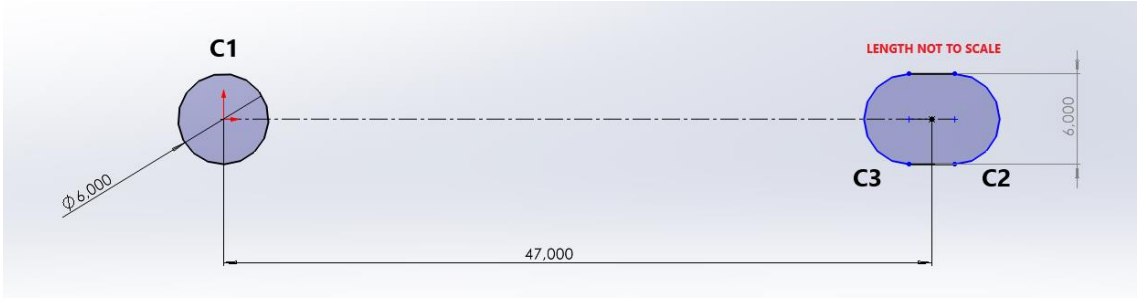


# CF

- C1 (left) measured with 8 points spaced 45º.
- C2 (slotted hole, right part) measured with 6 points spaced 30º.
- C3 (slotted hole, left part) measured with 6 points spaced 30º.
- C2-C3 distance measured as slot length.
- PMC defined as middle point between C2-C3
- C1 distance measured to LH and LV
- C1 to PMC distance measured

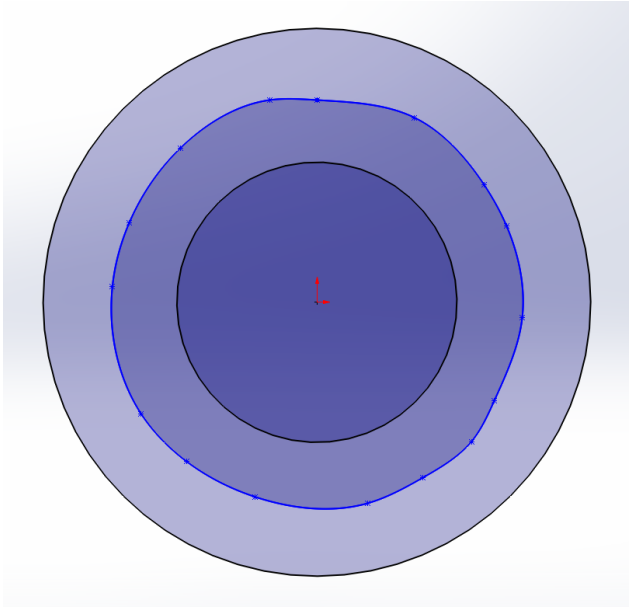


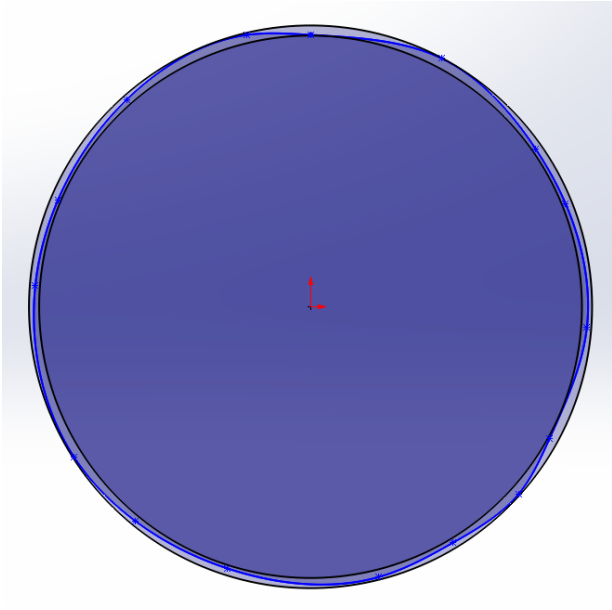



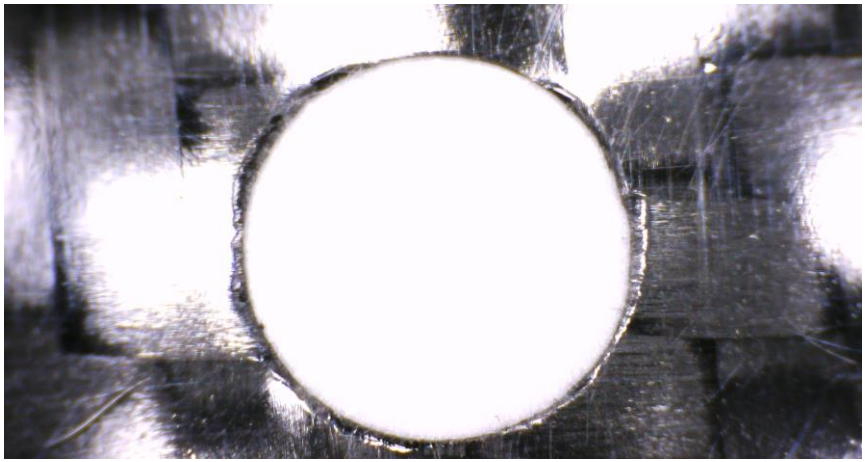
Circularity:

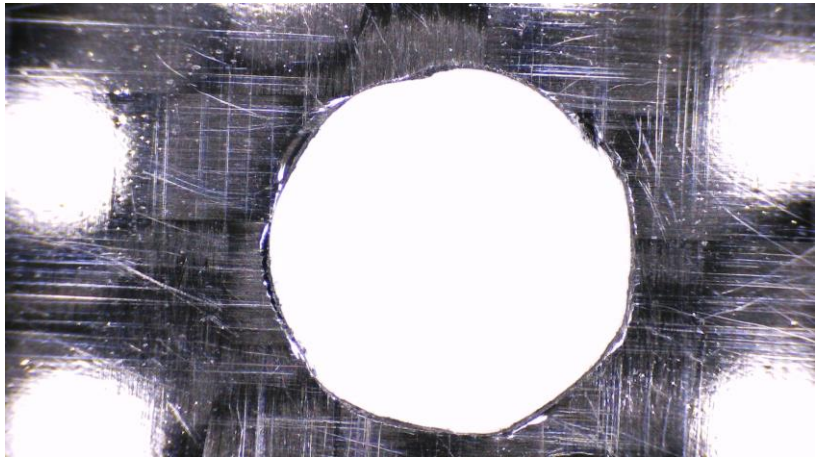
- Circularity controls **the form** of a feature.
- In QVPAK (CMM vision software), circularity is reported as the zone bounded by the two closest concentric circles within which all data points on the surface lie. When all points are at the same distance from the center, the circularity equals zero.
- Circularity is not the error of our measurement.
- Our measurement error is around 1 um - 3 um due to operator and CMM precision.

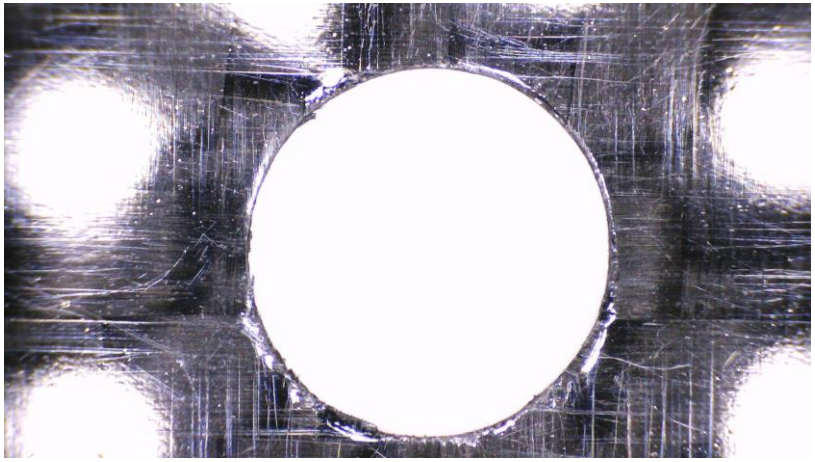


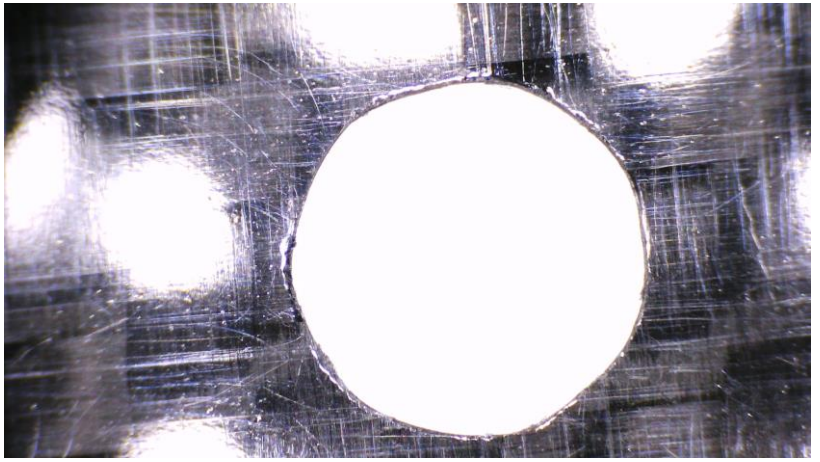


Before showing CMM results, lets see some of the holes without referencing them (very time consuming). These belong to HP samples.

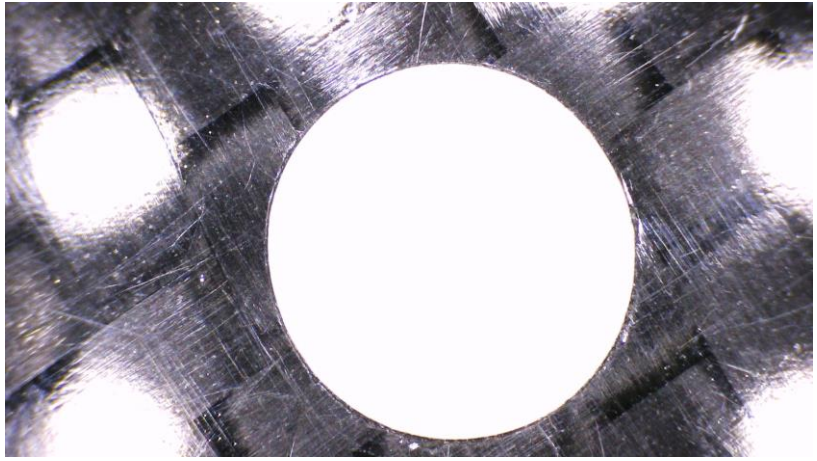


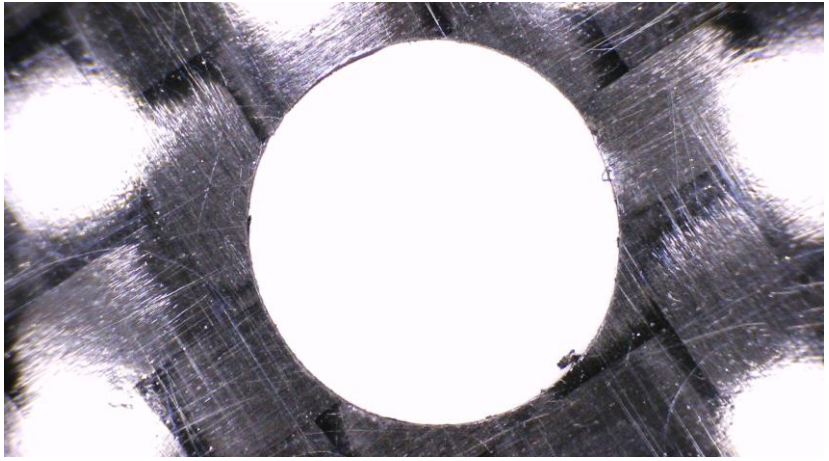


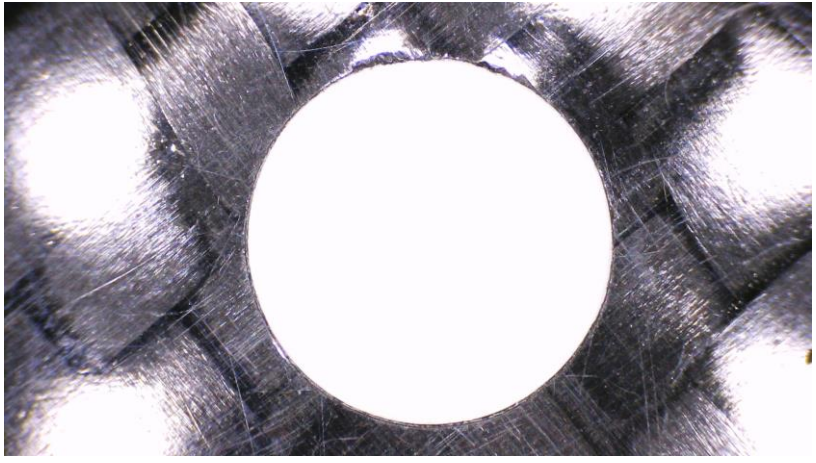


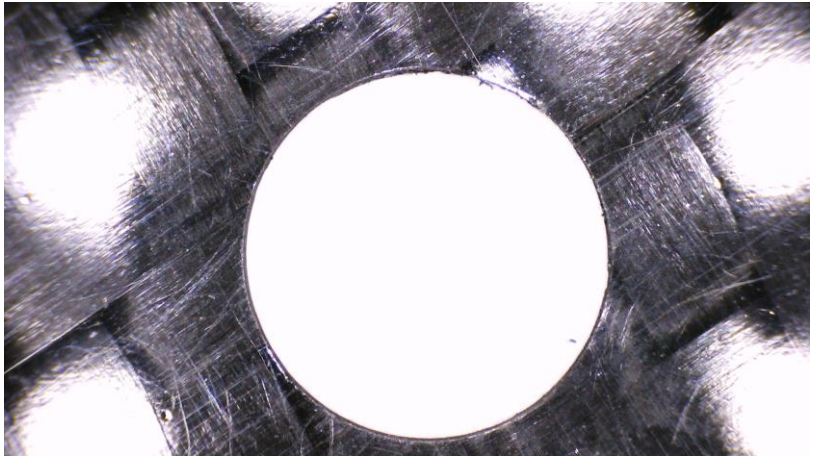


Before showing CMM results, lets see some of the holes without referencing them (very time consuming). These belong to LP samples.









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## LP: low precision results

| | LP1 | LP2 | LP3 | LP4 | LP5 | LP6 | LP7 | LP8 | LP9 | LP10 | $\bar{X}$ | Valor nominal |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Linealidad L1** | 0.015 | 0.032 | 0.074 | 0.081 | 0.05 | 0.095 | 0.085 | 0.044 | 0.041 | 0.072 | 0.059 | |
| **Linealidad L2** | 0.003 | 0.022 | 0.026 | 0.028 | 0.061 | 0.074 | 0.018 | 0.025 | 0.02 | 0.058 | 0.033 | |
| **Distancia L1-PV1** | 89.881 | 89.848 | 89.726 | 89.817 | 89.921 | 89.821 | 89.726 | 89.846 | 89.811 | 89.956 | 89.835 | 90 |
| **Distancia L1-PV2** | 89.907 | 89.844 | 89.778 | 89.842 | 89.922 | 89.782 | 89.676 | 89.806 | 89.836 | 89.915 | 89.831 | 90 |
| **Distancia L1-PV3** | 89.903 | 89.848 | 89.802 | 89.831 | 89.944 | 89.764 | 89.729 | 89.799 | 89.81 | 89.899 | 89.833 | 90 |
| **Distancia L1-PV4** | 89.935 | 89.84 | 89.8 | 89.808 | 89.956 | 89.754 | 89.745 | 89.79 | 89.824 | 89.892 | 89.835 | 90 |
| **Distancia L1-PV5** | 89.938 | 89.81 | 89.821 | 89.796 | 89.947 | 89.712 | 89.737 | 89.749 | 89.822 | 89.873 | 89.821 | 90 |
| **Distancia L1-PV6** | 89.953 | 89.843 | 89.771 | 89.827 | 89.945 | 89.64 | 89.726 | 89.79 | 89.838 | 89.885 | 89.822 | 90 |
| **Distancia L1-PV7** | 89.975 | 89.85 | 89.794 | 89.799 | 89.969 | 89.676 | 89.717 | 89.77 | 89.815 | 89.885 | 89.825 | 90 |
| **Distancia L1-PV8** | 89.96 | 89.828 | 89.785 | 89.833 | 89.959 | 89.76 | 89.76 | 89.809 | 89.804 | 89.869 | 89.837 | 90 |
| **Linealidad PV** | 0.027 | 0.044 | 0.074 | 0.04 | 0.023 | **0.155** | 0.06 | 0.077 | 0.033 | 0.044 | 0.058 | |
| **Distancia L2-PH1** | 119.724 | 119.758 | 119.702 | 119.733 | 119.855 | 119.855 | 119.696 | 119.77 | 119.837 | 119.814 | 119.774 | 120 |
| **Distancia L2-PH2** | 119.729 | 119.785 | 119.729 | 119.703 | 119.807 | 119.86 | 119.684 | 119.805 | 119.828 | 119.765 | 119.769 | 120 |
| **Distancia L2-PH3** | 119.745 | 119.8 | 119.754 | 119.711 | 119.739 | 119.884 | 119.666 | 119.811 | 119.835 | 119.753 | 119.77 | 120 |
| **Distancia L2-PH4** | 119.733 | 119.782 | 119.763 | 119.706 | 119.758 | 119.91 | 119.658 | 119.799 | 119.848 | 119.736 | 119.769 | 120 |
| **Distancia L2-PH5** | 119.759 | 119.85 | 119.773 | 119.697 | 119.789 | 119.883 | 119.666 | 119.832 | 119.835 | 119.774 | 119.786 | 120 |
| **Linealidad PH** | 0.003 | 0.022 | 0.026 | 0.028 | 0.061 | 0.074 | 0.018 | 0.025 | 0.02 | 0.058 | 0.033 | |
| **Diámetro C1** | 6.12 | 6.102 | 6.132 | 6.137 | 6.114 | 6.176 | 6.115 | 6.156 | 6.151 | 6.15 | 6.135 | 6 |
| **Circularidad C1** | 0.047 | 0.049 | 0.035 | 0.034 | **0.106** | 0.031 | 0.043 | 0.068 | 0.056 | 0.042 | 0.051 | |
| **Diámetro C2** | 6.091 | 6.084 | 6.016 | 6.155 | 6.165 | 6.018 | 6.152 | 6.18 | 6.075 | 6.092 | 6.103 | 6 |
| **Circularidad C2** | 0.036 | 0.028 | 0.019 | 0.046 | 0.032 | **0.097** | 0.071 | 0.039 | 0.025 | 0.036 | 0.043 | |
| **Diámetro C3** | 6.084 | 6.162 | 6.1 | 6.156 | 6.134 | 6.14 | 6.157 | 6.169 | 6.133 | 6.103 | 6.134 | 6 |
| **Circularidad C3** | 0.001 | 0.015 | 0.015 | 0.021 | 0.027 | 0.002 | 0.02 | 0.028 | 0.018 | 0.02 | 0.017 | |
| **Distancia C2-C3** | 0.242 | 0.243 | **0.283** | 0.198 | 0.211 | 0.262 | 0.177 | 0.173 | 0.202 | 0.213 | 0.22 | 0.2 |
| **Distancia C1-PMC** | 47.016 | 47.012 | 47.026 | 47.028 | 47.056 | 46.995 | 46.984 | 46.994 | 47.02 | 47.035 | 47.017 | 47 |
| **Distancia L1-C1** | 21.426 | 21.282 | **21.232** | 21.351 | 21.374 | 21.24 | 21.317 | 21.279 | 21.326 | 21.316 | 21.314 | 21.5 |
| **Distancia L2-C1** | 109.815 | 109.856 | 109.755 | 109.771 | 109.906 | 109.851 | 109.773 | 109.811 | 109.811 | 109.839 | 109.819 | 110 |
| | | | | | | | | | | | | |
| **RMS Distancia L1-PVX** | 0.032 | 0.014 | 0.028 | 0.017 | 0.017 | 0.059 | 0.025 | 0.029 | 0.012 | 0.028 | | |
| **RMS Distancia L2-PHX** | 0.014 | 0.034 | 0.029 | 0.014 | 0.045 | 0.022 | 0.015 | 0.022 | 0.007 | 0.03 | | |

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## HP: high precision results

| | HP1 | HP2 | HP3 | HP4 | HP5 | HP6 | HP7 | HP8 | HP9 | HP10 | $\bar{X}$ | Valor nominal |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Linealidad L1** | **0.103** | 0.04 | 0.053 | 0.055 | 0.049 | 0.046 | 0.038 | 0.026 | 0.049 | 0.061 | 0.052 | |
| **Linealidad L2** | 0.022 | 0.056 | 0.02 | 0.053 | 0.005 | 0.013 | 0.002 | 0.013 | 0.019 | 0.047 | 0.025 | |
| **Distancia L1-PV1** | 89.652 | 89.958 | 89.875 | 89.935 | 89.877 | 89.783 | 89.793 | 89.765 | 89.686 | 89.812 | 89.814 | 90 |
| **Distancia L1-PV2** | 89.663 | 89.936 | 89.904 | 89.933 | 89.871 | 89.811 | 89.8 | 89.779 | 89.726 | 89.812 | 89.823 | 90 |
| **Distancia L1-PV3** | 89.709 | 89.94 | 89.859 | 89.933 | 89.889 | 89.803 | 89.783 | 89.764 | 89.753 | 89.813 | 89.825 | 90 |
| **Distancia L1-PV4** | 89.728 | 89.917 | 89.832 | 89.898 | 89.855 | 89.789 | 89.776 | 89.824 | 89.774 | 89.794 | 89.819 | 90 |
| **Distancia L1-PV5** | 89.752 | 89.941 | 89.821 | 89.906 | 89.848 | 89.754 | 89.775 | 89.798 | 89.771 | 89.804 | 89.817 | 90 |
| **Distancia L1-PV6** | 89.761 | 89.958 | 89.841 | 89.885 | 89.837 | 89.774 | 89.759 | 89.793 | 89.774 | 89.799 | 89.818 | 90 |
| **Distancia L1-PV7** | 89.806 | 89.955 | 89.863 | 89.898 | 89.865 | 89.778 | 89.79 | 89.782 | 89.741 | 89.821 | 89.83 | 90 |
| **Distancia L1-PV8** | 89.786 | 89.96 | 89.891 | 89.892 | 89.86 | 89.82 | 89.776 | 89.788 | 89.731 | 89.831 | 89.834 | 90 |
| **Linealidad PV** | 0.042 | 0.045 | 0.078 | 0.027 | 0.04 | 0.068 | 0.033 | 0.059 | 0.072 | 0.029 | 0.049 | |
| **Distancia L2-PH1** | 119.767 | 119.81 | 119.778 | 119.775 | 119.825 | 119.823 | 119.799 | 119.771 | 119.889 | 119.862 | 119.81 | 120 |
| **Distancia L2-PH2** | 119.756 | 119.796 | 119.752 | 119.76 | 119.816 | 119.822 | 119.77 | 119.76 | 119.867 | 119.849 | 119.795 | 120 |
| **Distancia L2-PH3** | 119.75 | 119.775 | 119.734 | 119.781 | 119.792 | 119.804 | 119.8 | 119.806 | 119.883 | 119.86 | 119.799 | 120 |
| **Distancia L2-PH4** | 119.776 | 119.801 | 119.742 | 119.809 | 119.792 | 119.794 | 119.806 | 119.873 | 119.853 | 119.884 | 119.813 | 120 |
| **Distancia L2-PH5** | 119.812 | 119.84 | 119.764 | 119.853 | 119.819 | 119.824 | 119.832 | 119.913 | 119.967 | 119.913 | 119.854 | 120 |
| **Linealidad PH** | 0.022 | 0.056 | 0.02 | 0.053 | 0.005 | 0.013 | 0.002 | 0.013 | 0.019 | 0.047 | 0.025 | |
| **Diámetro C1** | 6.072 | 6.067 | 6.064 | 6.07 | 6.052 | 6.034 | 6.047 | 6.061 | 6.058 | 6.053 | 6.058 | 6 |
| **Circularidad C1** | 0.064 | 0.075 | 0.032 | 0.063 | 0.037 | 0.037 | 0.013 | 0.018 | 0.029 | 0.035 | 0.04 | |
| **Diámetro C2** | 6.03 | 5.95 | 6.058 | 5.982 | 6.014 | 6.073 | 6.01 | 6.06 | 5.963 | 6.001 | 6.014 | 6 |
| **Circularidad C2** | 0.013 | 0.054 | 0.041 | 0.055 | 0.045 | 0.079 | 0.046 | 0.048 | 0.02 | 0.076 | 0.048 | |
| **Diámetro C3** | 6.03 | 6.044 | 6.04 | 6.038 | 5.991 | 6.02 | 5.993 | 6.004 | 6.022 | 6.088 | 6.027 | 6 |
| **Circularidad C3** | 0.069 | 0.043 | 0.029 | 0.049 | 0.038 | 0.026 | 0.025 | 0.023 | 0.04 | **0.156** | 0.05 | |
| **Distancia C2-C3** | 0.075 | 0.187 | 0.138 | 0.096 | 0.14 | 0.107 | 0.122 | 0.111 | 0.125 | **0.03** | 0.113 | 0.2 |
| **Distancia C1-PMC** | 46.948 | 47.066 | 47.001 | 47.019 | 46.946 | 46.991 | 46.97 | 46.96 | 46.94 | 47.033 | 46.987 | 47 |
| **Distancia L1-C1** | 21.313 | 21.368 | 21.376 | 21.334 | 21.45 | 21.285 | 21.283 | 21.351 | 21.376 | 21.333 | 21.347 | 21.5 |
| **Distancia L2-C1** | 109.697 | 109.843 | 109.812 | 109.86 | 109.822 | 109.865 | 109.858 | 109.745 | 109.908 | 109.872 | 109.828 | 110 |

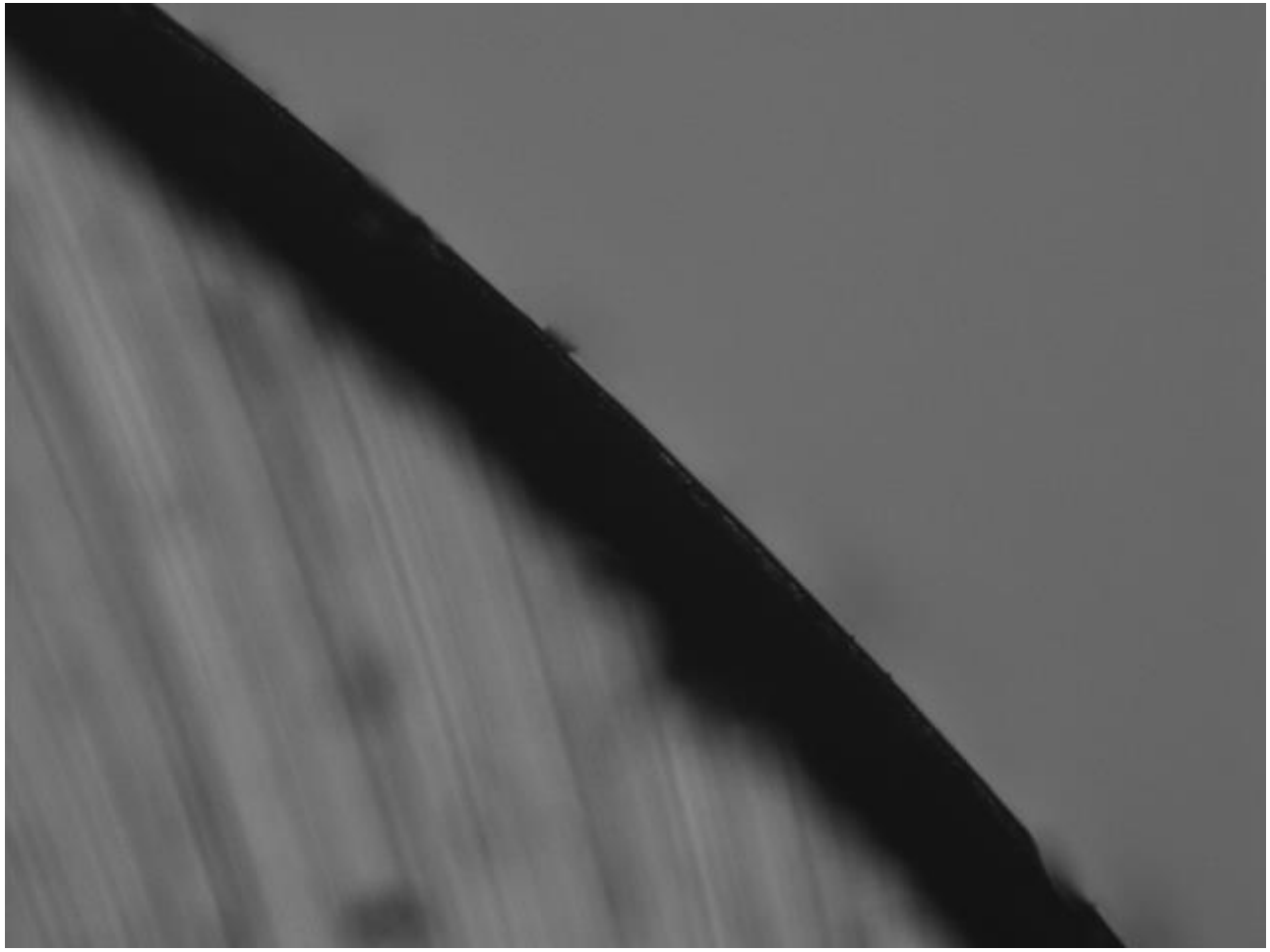
| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **RMS Distancia L1-PVX** | 0.055 | 0.015 | 0.029 | 0.02 | 0.016 | 0.022 | 0.013 | 0.02 | 0.03 | 0.012 |
| **RMS Distancia L2-PHX** | 0.024 | 0.023 | 0.017 | 0.037 | 0.016 | 0.014 | 0.022 | 0.066 | 0.044 | 0.025 |

Conclusions:

- I have to apologize. I haven't been able to analyze the results in detail.
- The precision and quality of the carbon fibers is poor or very poor.
- I really do not know what manufacturing procedures has followed our provider to manufacture the low and high precision samples because all of them are out of spec in many dimensions (length, diameter, position of centers…)
- Next steps:
  - Approach our CF provider with a report to:
    - Try to make sense of the metrologies. Understand what manufacturing procedures did they use and if it makes any sense with our metrology. For example, even though the low precision holes have sharper and nicer edges, their circularity is bad.
    - Depending of the reaction of the provider to our complain, we will decide to make more samples (for free of course).
    - Nonetheless, I do not know if it makes sense to continue working with this provider.

# End

Thank you for your time.



- T-frame: Ø6g6 (5,988 - 5,996)
- Carbon Fiber:  Ø6H7 (6,000 – 6,012)