LASER INTERFEROMETER GRAVITATIONAL WAVE OBSERVATORY

LIGO Laboratory / LIGO Scientific Collaboration

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Cross weld tests

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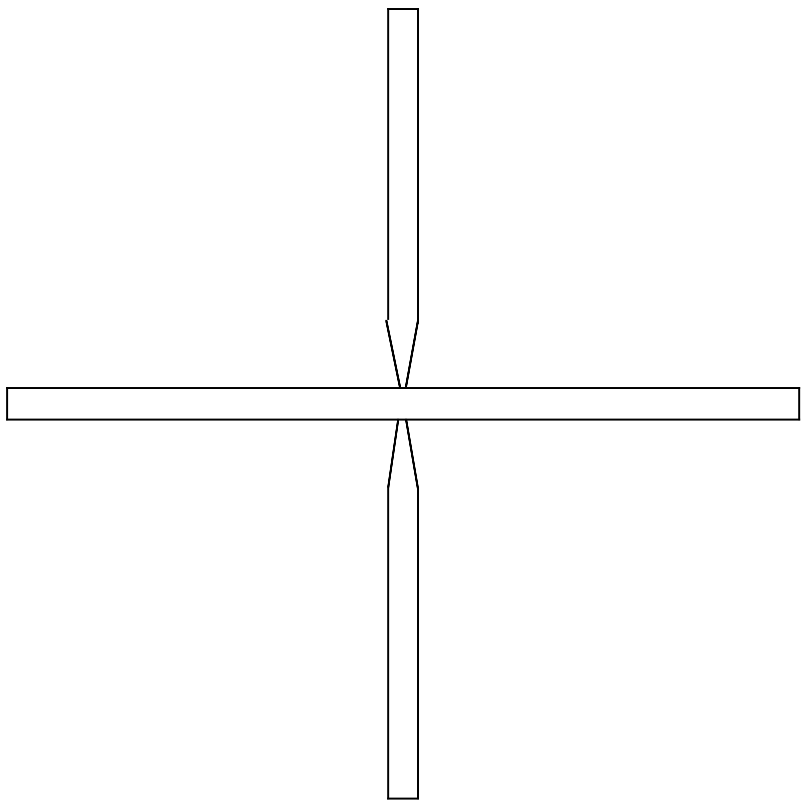
We made several egg-crate cross weld tests with the configuration shown below.

The cut part has been tapered to allow better welding.

Welding was performed on both sides of each arm with the geometry sketched below.



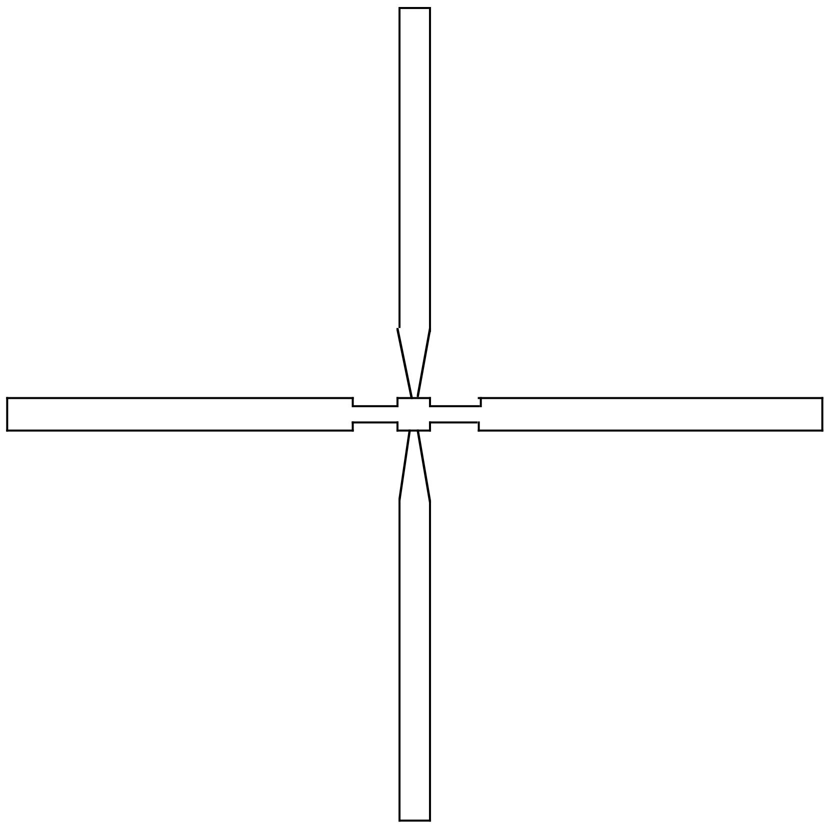
The first set of tests was apparently successful, with some blemishes, due to loss of Ar-He feed at the end of the sample, but otherwise smooth welds.

Cut and polish tests also showed rather good, compact welds.

A second set of tests, though, presented an unacceptable number of cavities and we were not able to replicate the success level of the first test.

Several follow-up tests convinced us that at least part of the problem was excessive heath loss towards the other three arms of the cross.

We therefore decided to apply the already successfully tested tapered-bar-and-trench technique illustrated below.



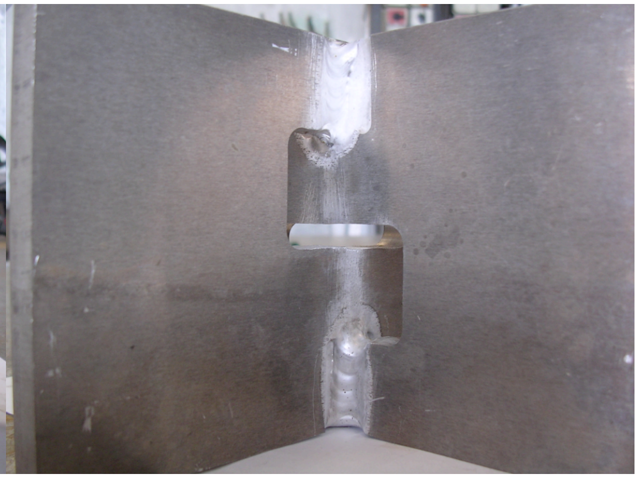
The tests again were relatively positive, but small cavities were observed below the weld.

These results are illustrated in the following photos

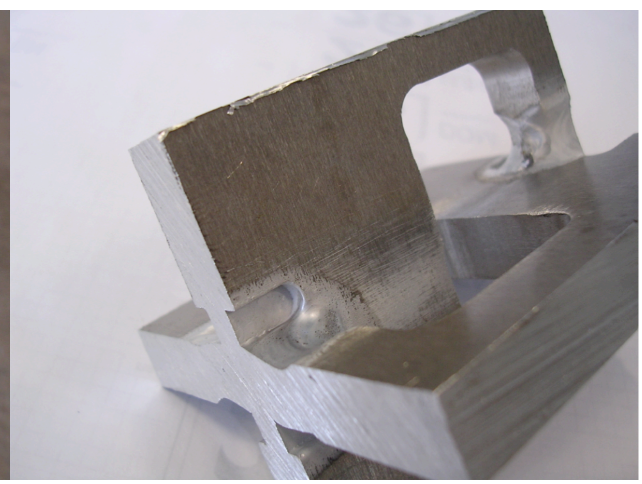
The first four show the four sides of the cross welds.

The fifth is a zoom in what, in the photo, appears as a crack. It is the remnant of the machined trench wall, molten and dragged by surface tension on the two sides. At close inspection it does not present the risk of a virtual leak, but better design of trenching will be done to avoid even this visual problem.

The sixth photo shows an inclined view of the cross and the turn around point between two weld tracts.

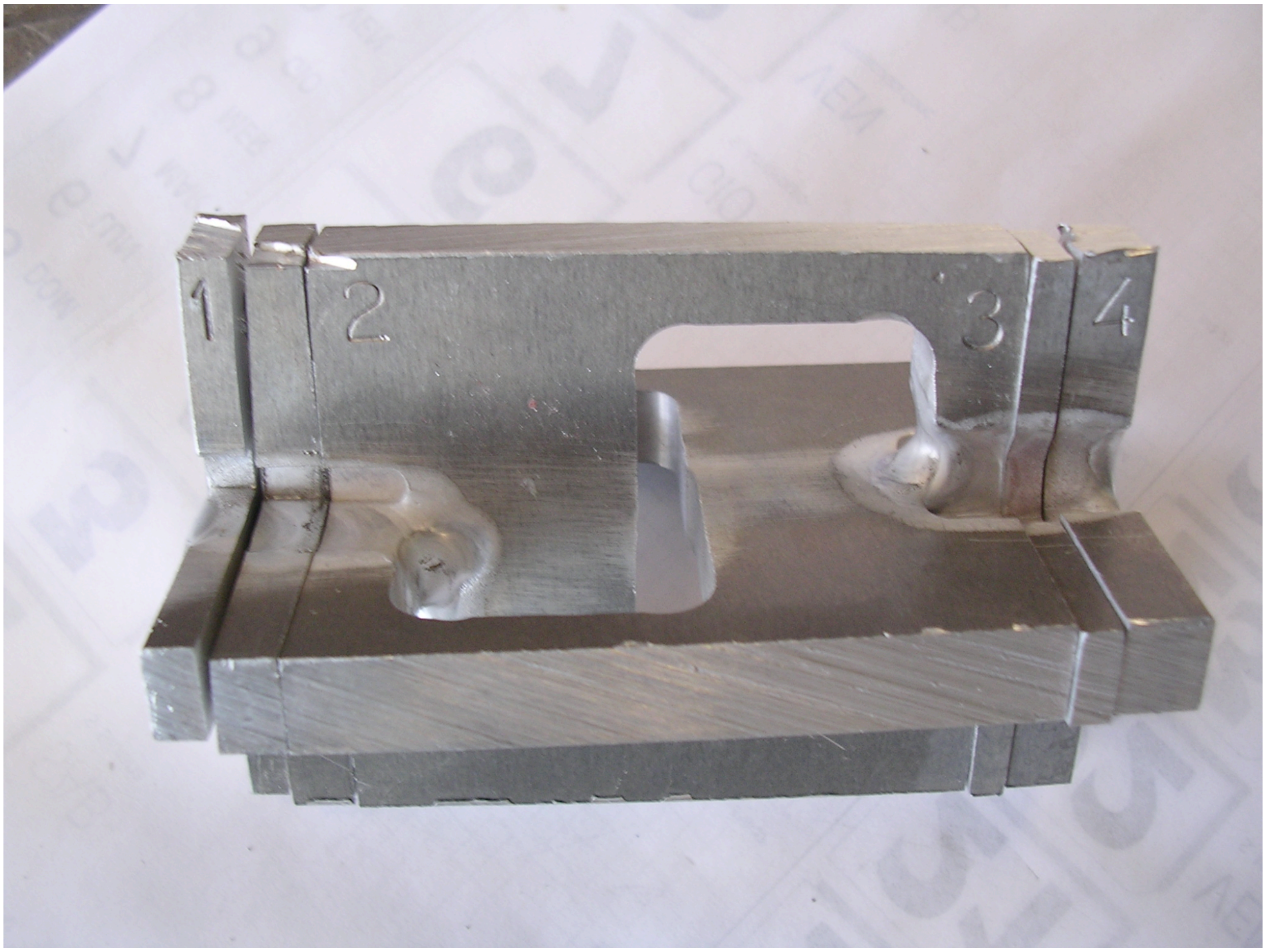




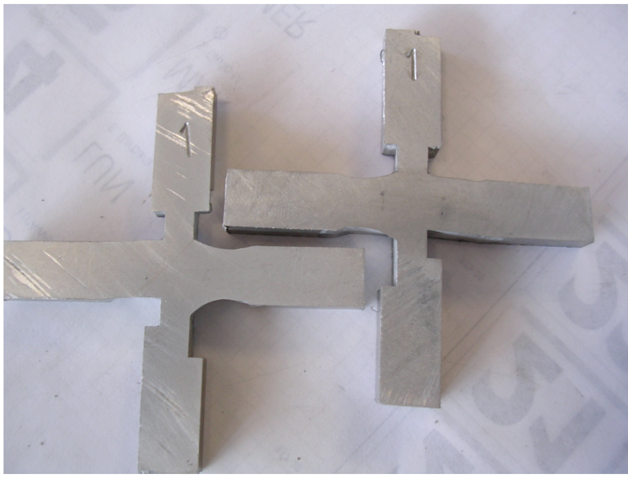
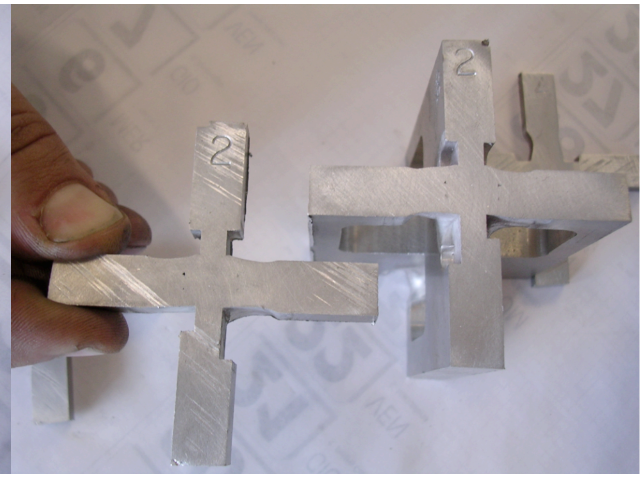
Although not perfect, it was a visually satisfactory weld test.

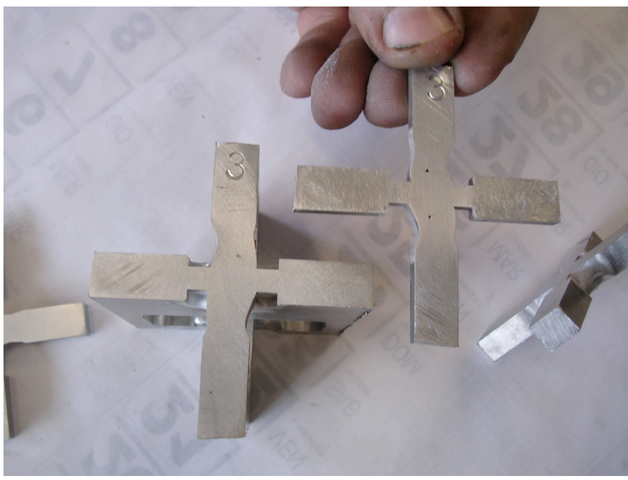
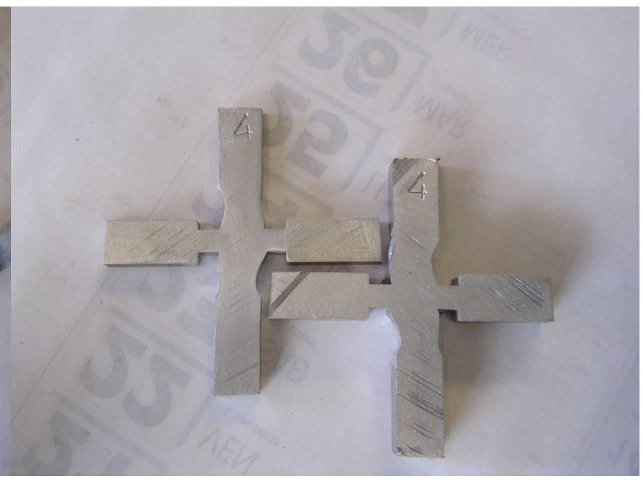
Then we proceeded to slit the welds and inspect the compactness of the welds.

The next photo shows the four cuts performed on this section of eggcrate and the labeling of the cuts. The numbers refer to the closest cut.



the following four photos show the eight sides of the four polished cuts.

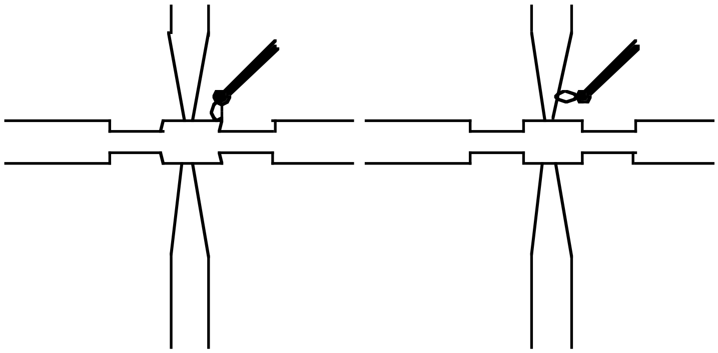



These welds present small cavities, that appear to be short (do not extend for the full or most of the length of the weld as in some of the previous tests) and while a large fraction of the landings between the tapered plates and the cross plate are molten, not everywhere the gap is closed.

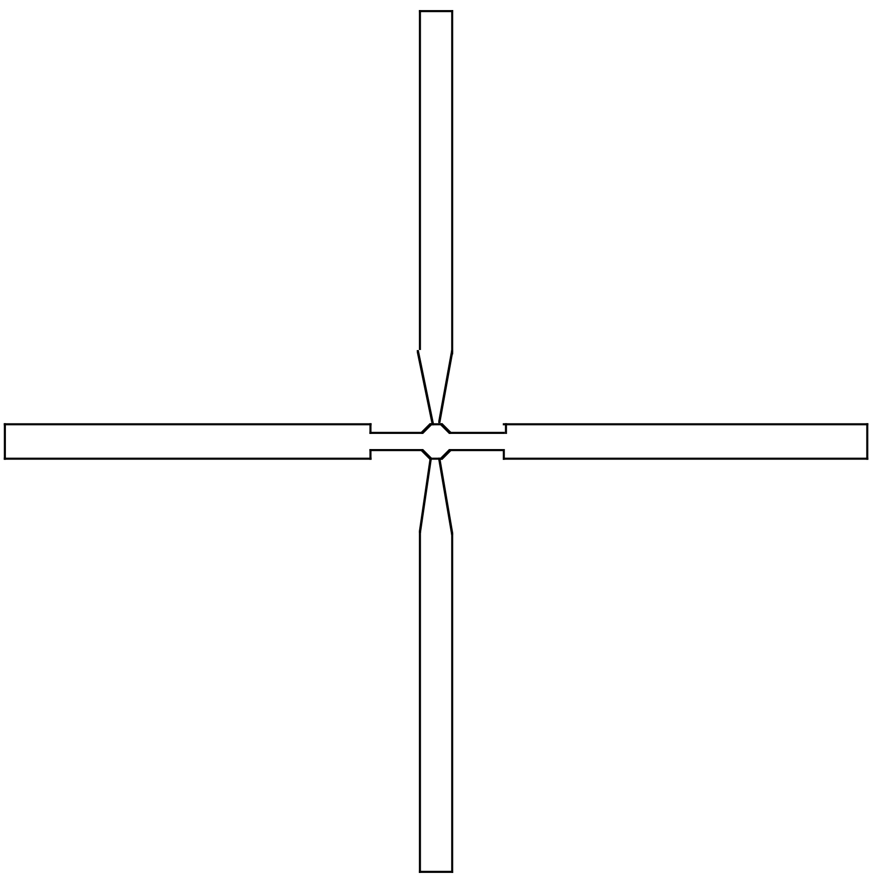
The electron lance did not act in the ideal direction did not generate welding in the desired direction (the landing and the corner between the plates. Two steps to be taken were identified. The shoulder meeting the tapered plate need to be redesigned to better accept the electron lance (discussed later) and the trenches must be made few mm wider to better accept and orient the welding gun nozzle. We expect that these two steps will allow reducing the gaps in the weld to really negligible amount, if not eliminate them altogether.

What we think is at the root of the problem is that when the angular opening between the surfaces through which the electron gun must be directed is less than 90^{o} the electron lance is electrostatically directed away from the junction to be welded, and avoids depositing heat at the bottom of the canyon where it is most needed, as illustrated in the following sketch.

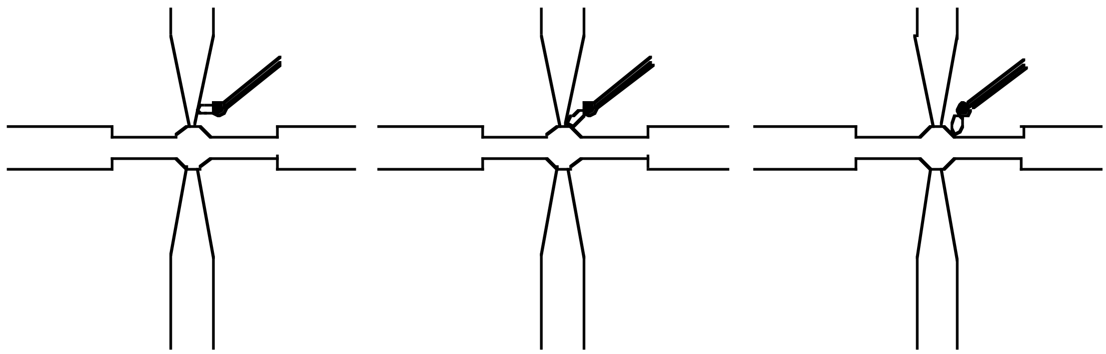


This problem is exacerbated by the fact that the gun power had to be kept low in order not to punch through destructively. As a result low heating and insufficient fluidity is obtained in the contact area, with reduced contact area welding and little shrinkage and expulsion of the air gaps by surface tension of the weld surface.

The way we try to solve the problem is to change the geometry of the region to weld according to the sketch below. In this geometry the angular opening of the target region is increased from 80^o to 135^o and is expected to be much more accessible to the electron lance.

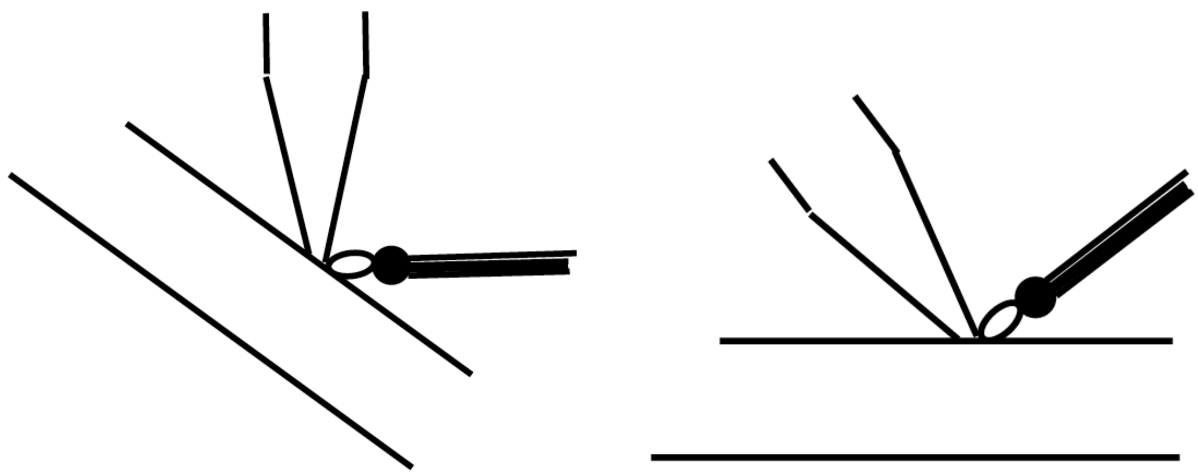


We expect that with this geometry the small wavings of the operator arm, will become effective in sweeping and heating the region to be welded, without "jumping" it.



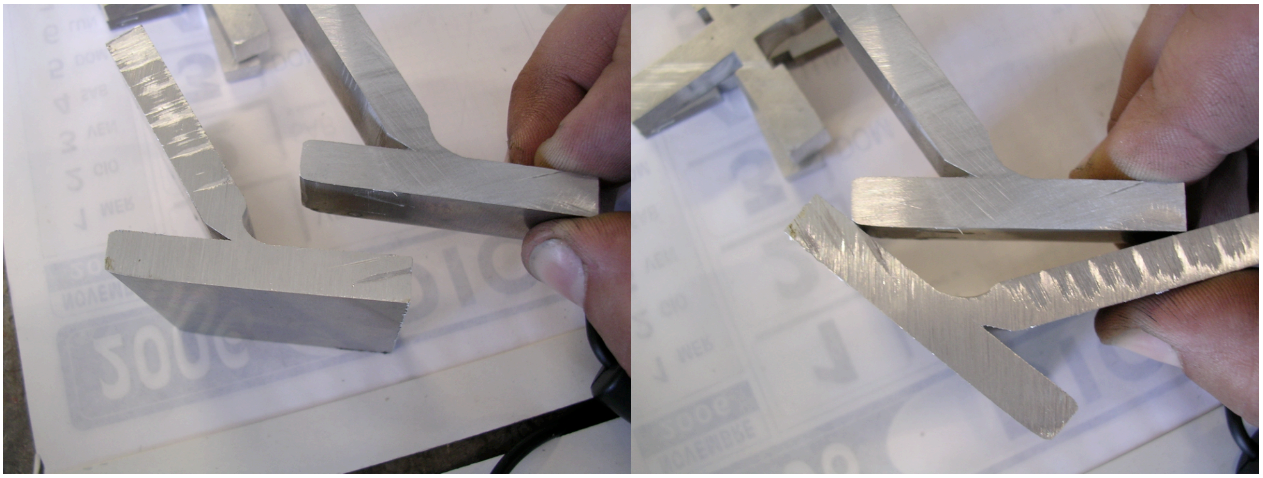
Implementation of this technique requires further machining of the test parts. Before committing to that we made a quick test of the effectiveness in depositing heat in the desired area with the more open geometry.

We did this using a tapered end bar, with a 45° slanted landing, welding it at 45° on a flat bar and welding from a single side (in this test geometry it is impossible to reach the other side of the weld.



The results of this test are shown in the pictures below.

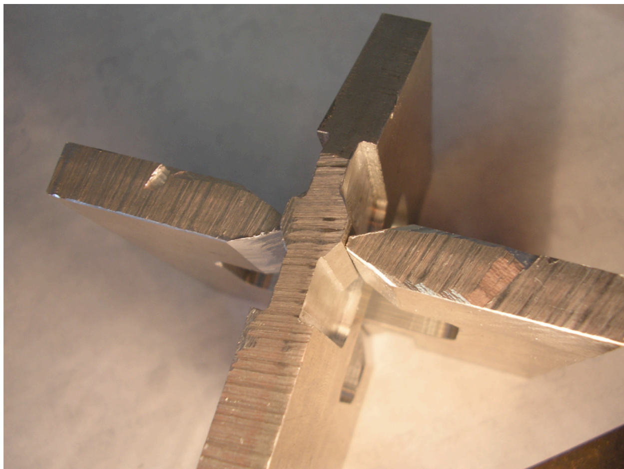
Despite the fact that there was no trenching in the bottom bar the welds was substantially easier to perform and came out welded at full penetration and perfectly compact.

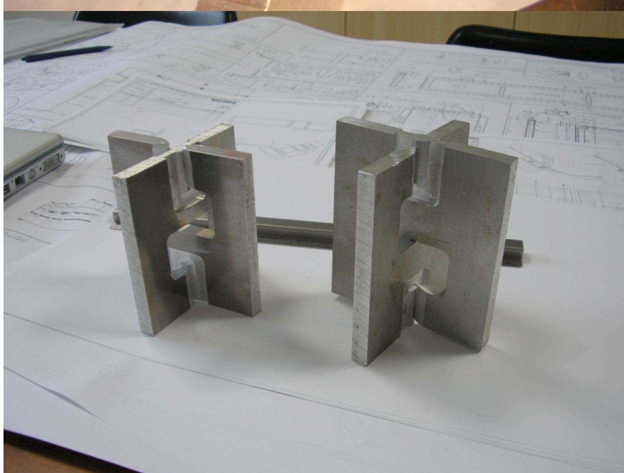


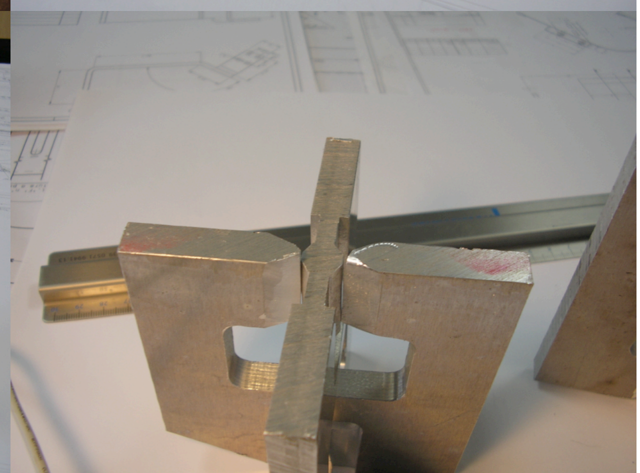
This successful test gives us good confidence that the proposed geometry will be more effective in obtaining full penetration welding and expulsion of gaps from the weld volume.

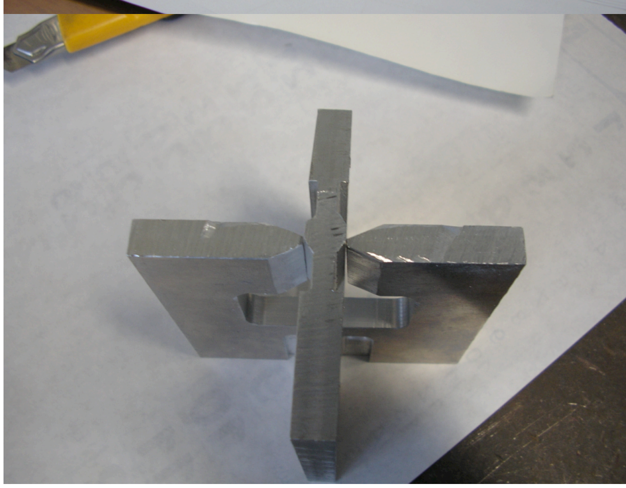
We are now proceeding with tests of cross welding with the new geometry.

The following images show the preparation of the parts before welding





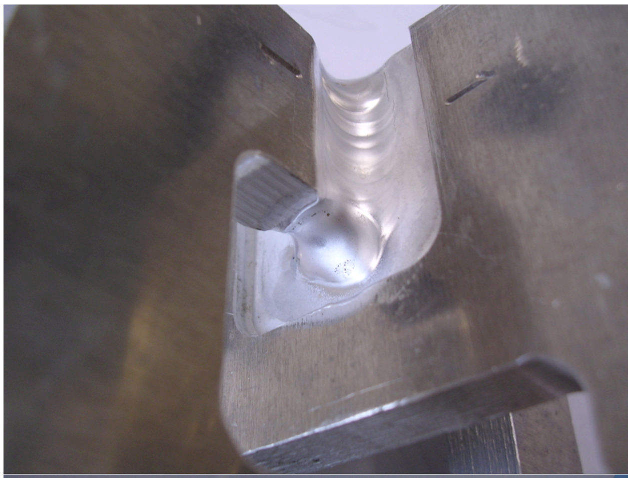
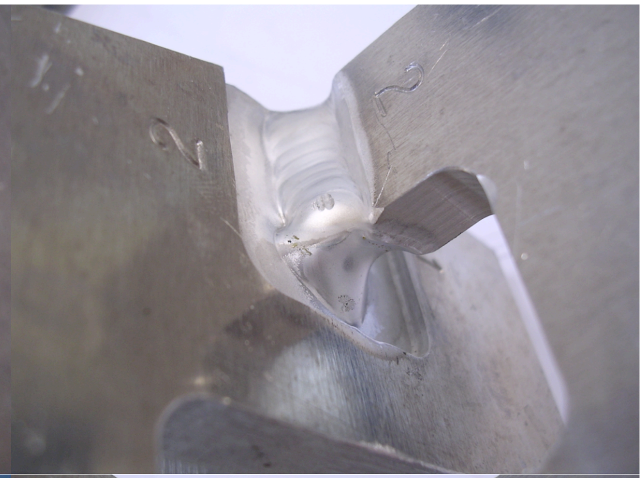
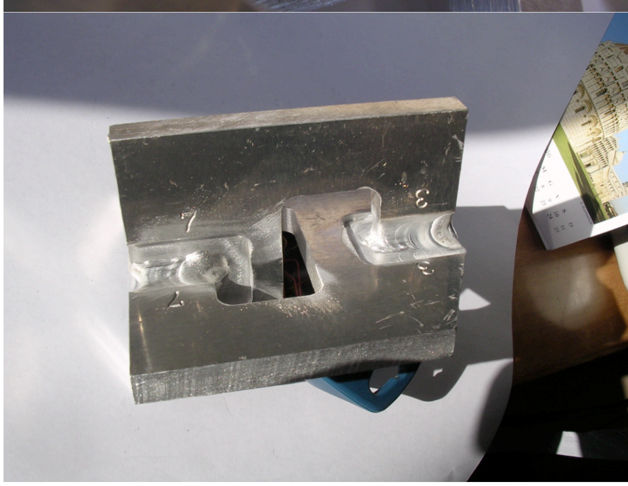


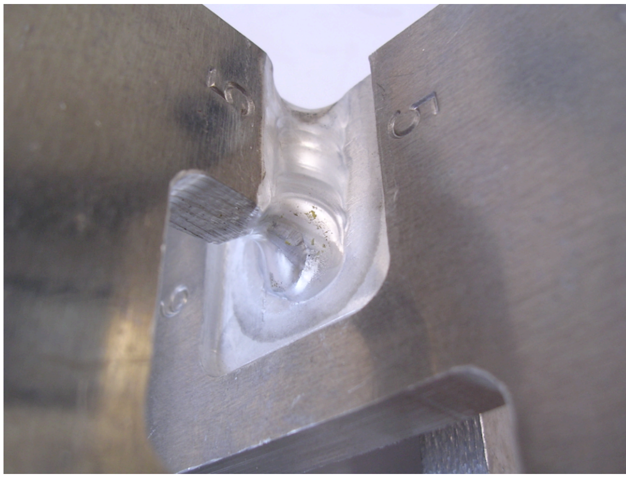
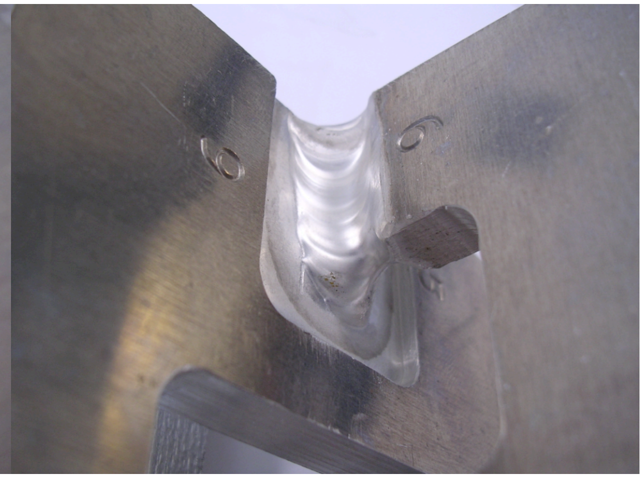


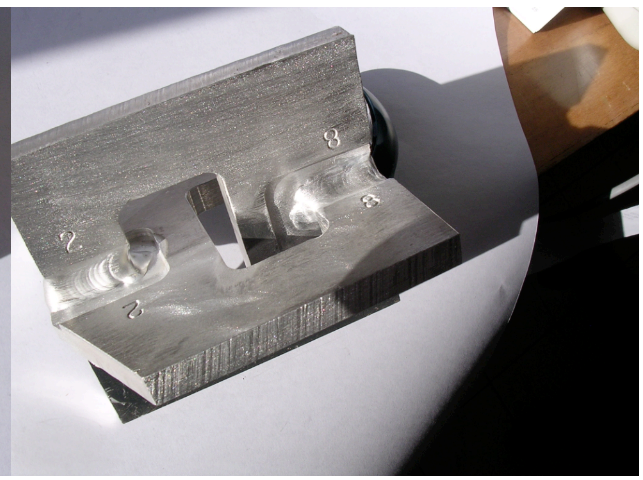
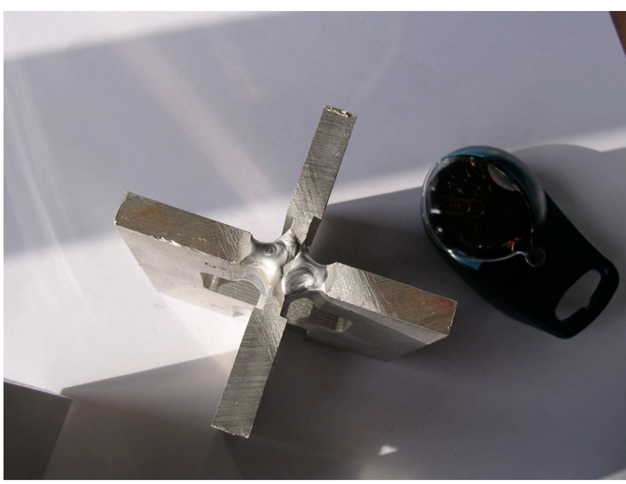
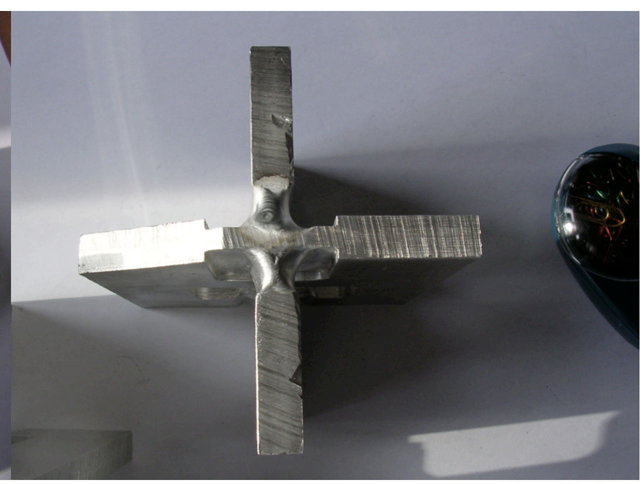
View from the inside point of view of the 8 welds of the **first** test sample and edge view of the two sides of the crosses.

Most welds have the geometry shown in the first 8 images (view from inside) on both sides, while the welds at the outer edges of the honeycomb structure have the edge view geometry.

Most of attention was dedicated to the welds shown in the first 8 images, but even the edge welds (last two images) came out satisfactorily.

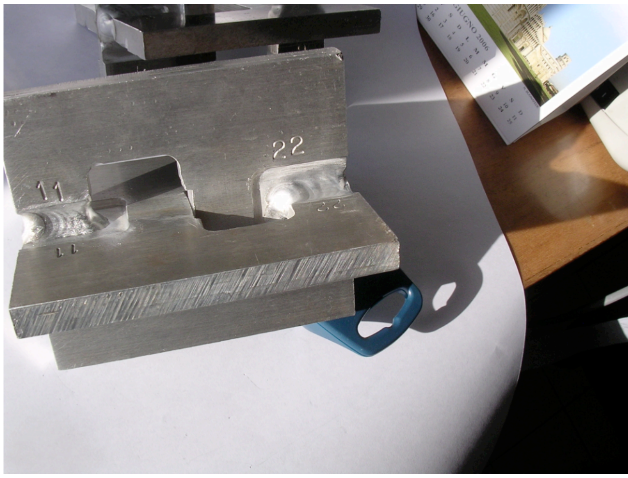




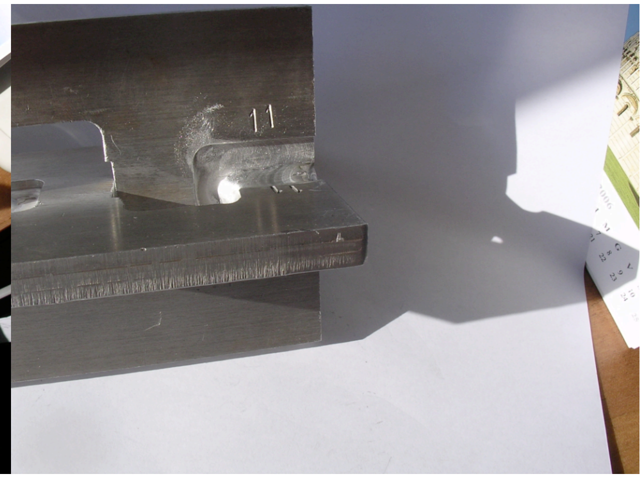




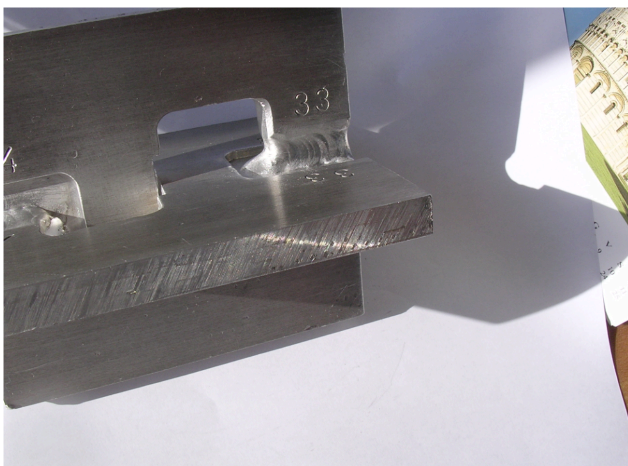




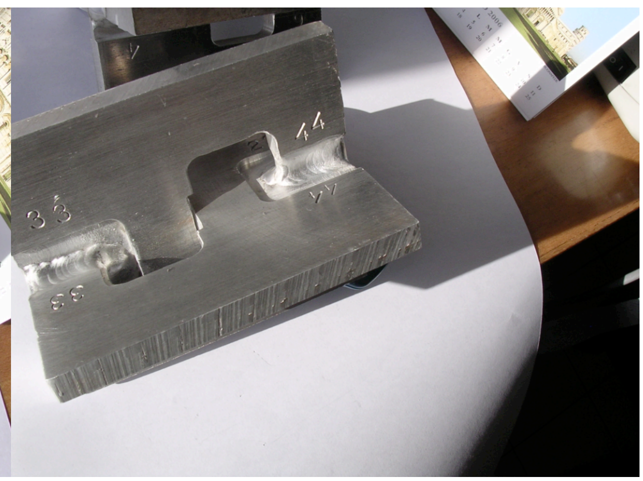
View from the inside point of view of the 8 welds of the **second** test sample and edge view of the two sides of the crosses.

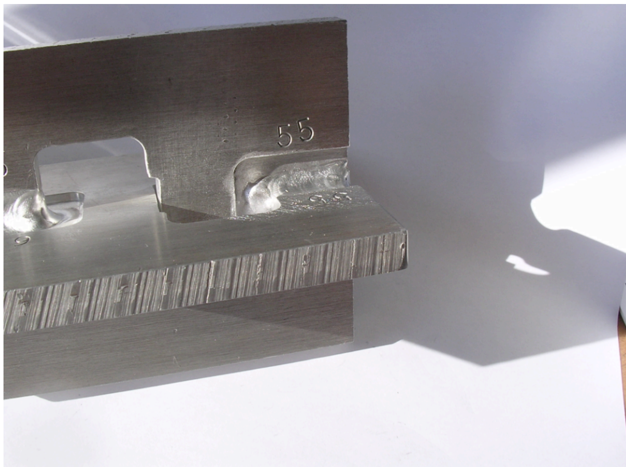
The results are the same as in the first test. Although the image seems to







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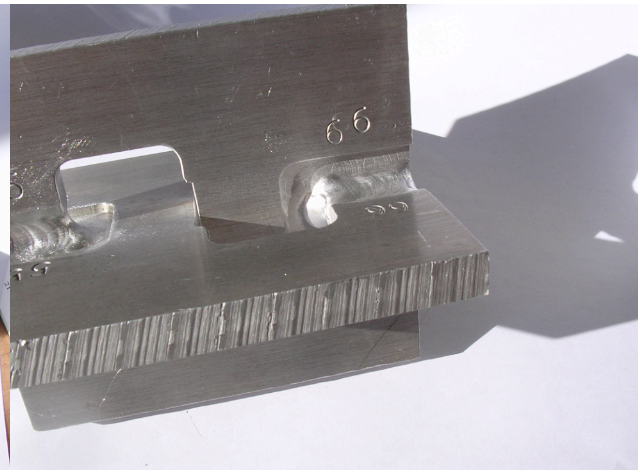
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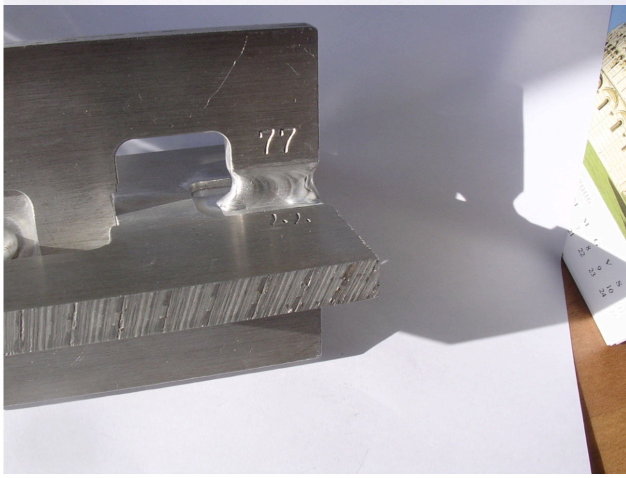
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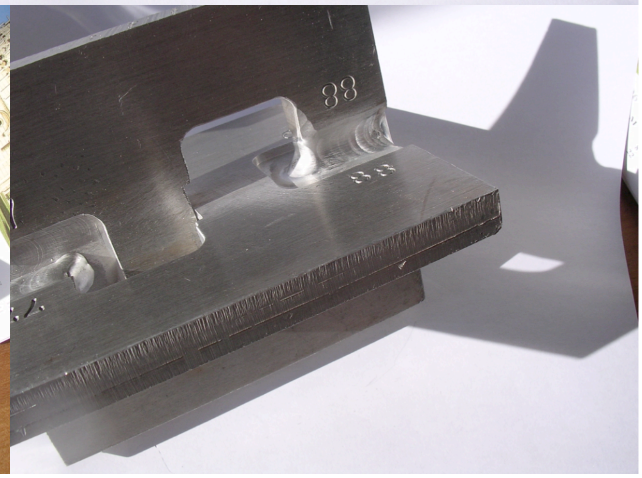
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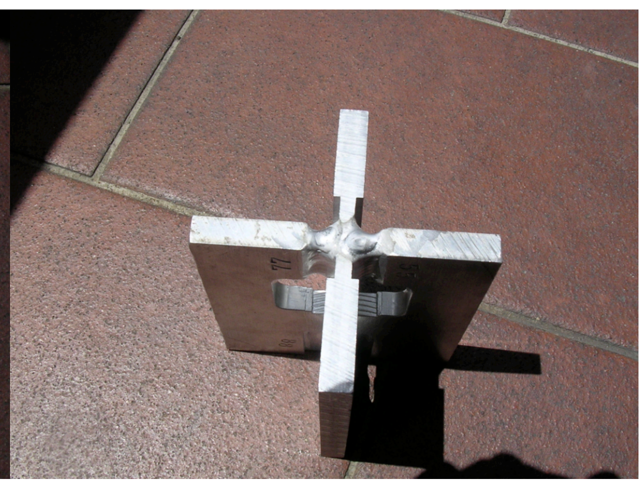
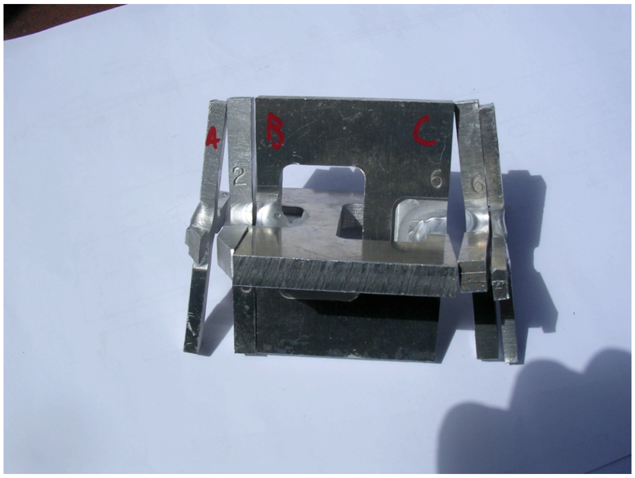
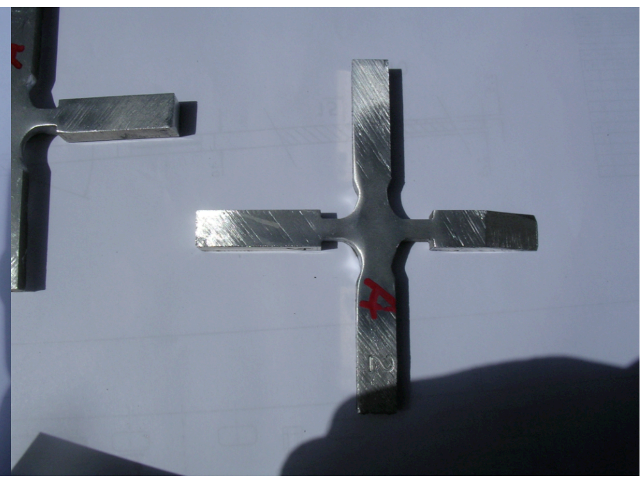


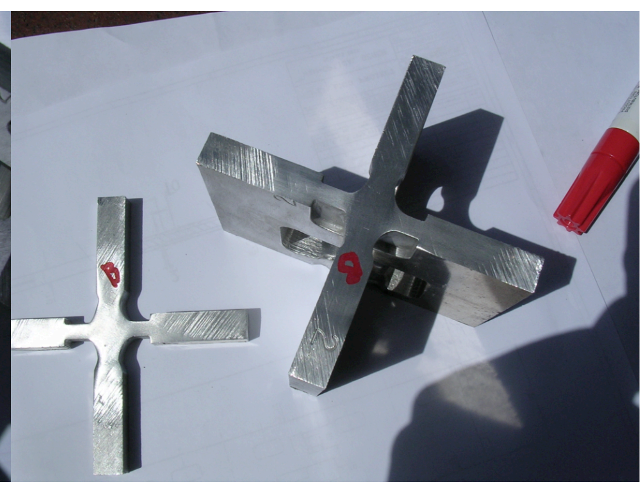
The following images show the cuts of the first sample

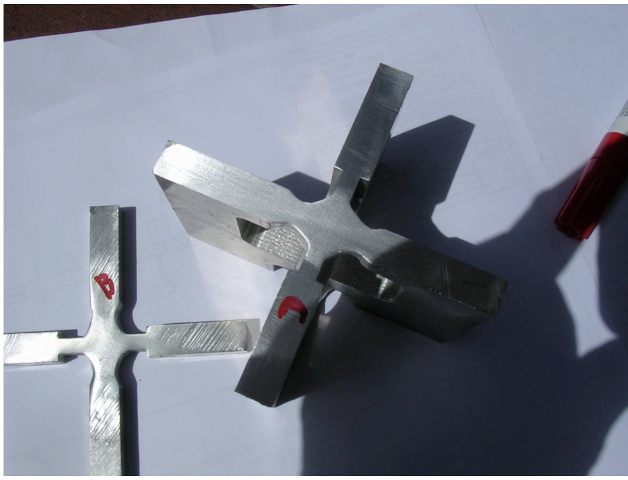
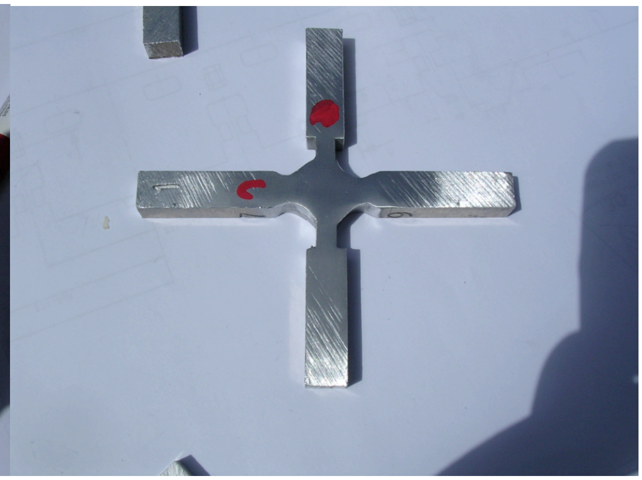
Only small localized cavities are visible in some of the cuts.

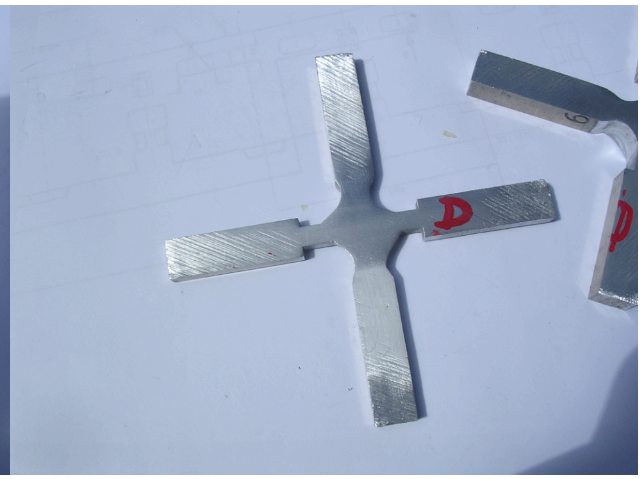
Some cavities do not even extend through the thickness of the cut.





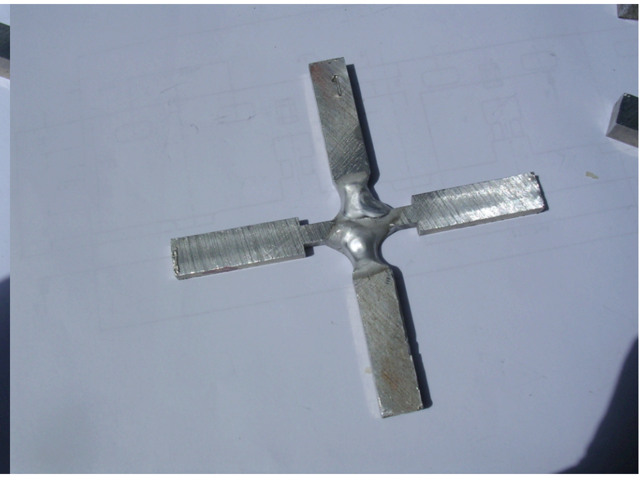




View of the edge of the cross weld.

It is clearly visible that even these welds, that were given less attention assuming that they were not used in the weldments, are acceptable.



We conclude that with the machined geometry, the cross welds satisfy the LIGO requirements.

Welds with an opening larger than 90^{o} are satisfactory and produce the desiredfull penetration welds.