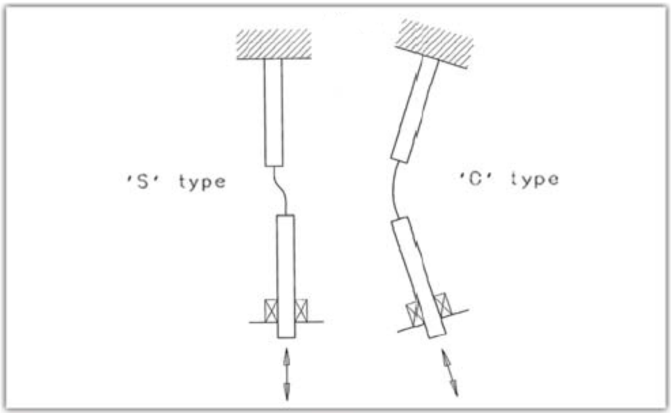
Effect of Frame Alignment on Tensile Strength of Unidirectional Carbon Fiber Laminates

What is Frame Alignments?

There are two types of misalignment:

1. Concentric misalignment
2. Angular misalignment

Concentric misalignment (or S-bending) is caused when the centerline of the upper grip is offset from the centerline of the lower grip. **Angular misalignment** (or C-bending) is caused when the centerline of the grips are at an angle to each other.



Why Should I Care About Alignment?

Alignment is important because it will have an effect on your test data. The misalignment in your load string causes rigid test specimens to bend which induces extra stress. Because the specimen is under more stress it will fail at lower tensile loads than expected.

This effect is well known to many customers but others may be unaware until they begin testing on a test frame with different alignment conditions. In one particular instance a customer added an Instron testing frame to a lab with a competitor's frame. After using the machine for several weeks the customer contacted us because he thought the test frame was producing values for tensile strength that were higher than the other frames in the lab. An Instron Service team member went in to look at the problem and after many diagnostic tests found that instead of a problem with the Instron there were alignment problems on their old non-Instron frames. To fix the problem, the customer decided to replace their old frame with an Instron as well.

How Much Can Alignment Affect Results?

To quantify the effect of alignment on tensile strength we recently performed a test to compare the test results obtained with a well aligned load string and a poorly aligned load string. We found that a well aligned load string produces tensile strength data for unidirectional carbon fiber laminates that is 6% higher and more consistent than a poorly aligned load string.

How Much Does 6% Cost Your Company?

A 6% difference may sound insignificant, but that may very well mean the difference between shipping a product and rejecting it. How much less material would you have to reject if your results were 6% higher? How much could that save you in material and personnel costs?

How much business are you losing because your results are 6% lower than they should be? Have you lost business to a competitor because they had slightly better specs, and if so were their specs better by less than 6%?

Appendix A: Experimental Setup

An Instron 5985 system was setup with a 250 kN load cell, a 25 0kN AlignPRO fixture, 100kN hydraulic grips with serrated faces for flat specimens, and an AutoX750 extensometer. Tensile tests were performed on 2 batches of unidirectional carbon fiber laminates under well aligned and poorly aligned conditions.

The poorly aligned grips induced 5.0%, 13.7%, and 26.7% bending at the bottom, middle, and top of the specimen respectively. Testing was performed to failure according to ASTM D3039 with a crosshead speed of 2 mm/min. The grips were then properly aligned so that there was 1.4%, 2.3%, and 4.0% at the bottom, middle, and top of the specimen respectively. Testing was then performed to failure according to ASTM D3039 with a crosshead speed of 2 mm/min.

After all of the tests were conducted, the data was analyzed by using a Student's t-test to verify if the results had a statistically significant difference.

After analysis, there was a statistically significant effect on both the maximum load and maximum tensile stress. Both the load and the maximum stress increased on better aligned frames and were much more consistent.

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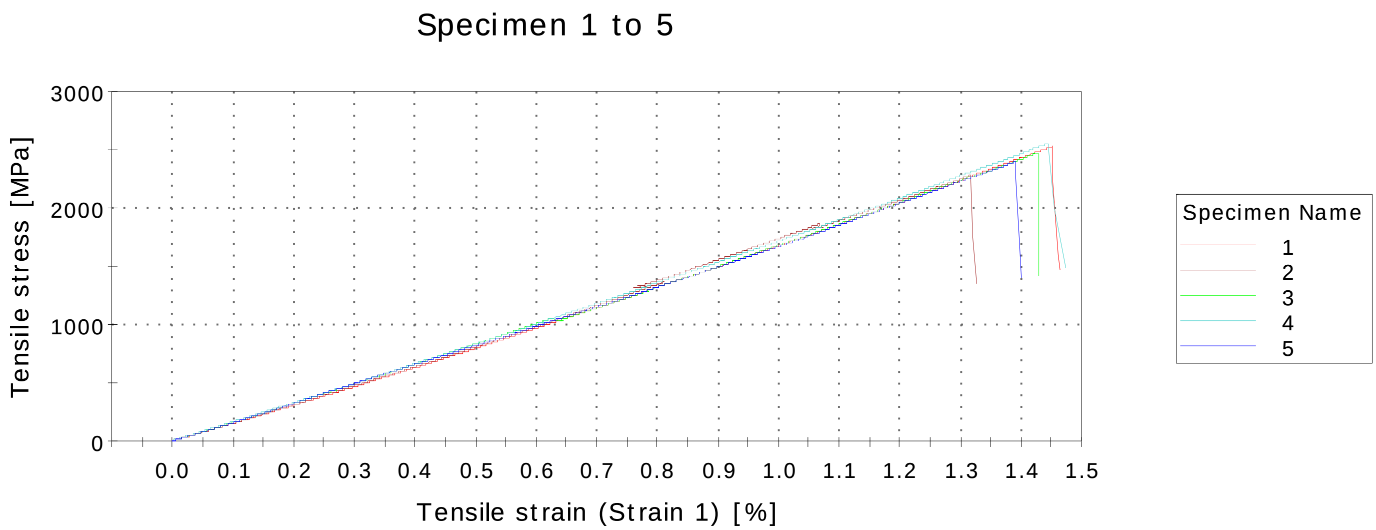
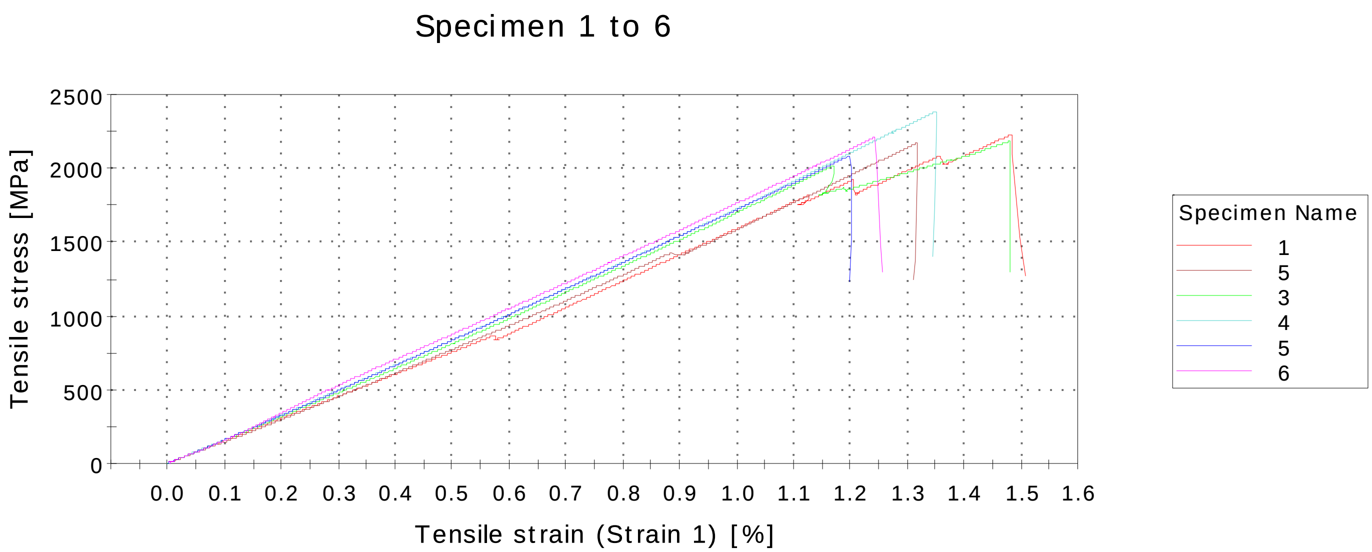
Appendix B: Test Results

Batch 1: Poor Alignment Results



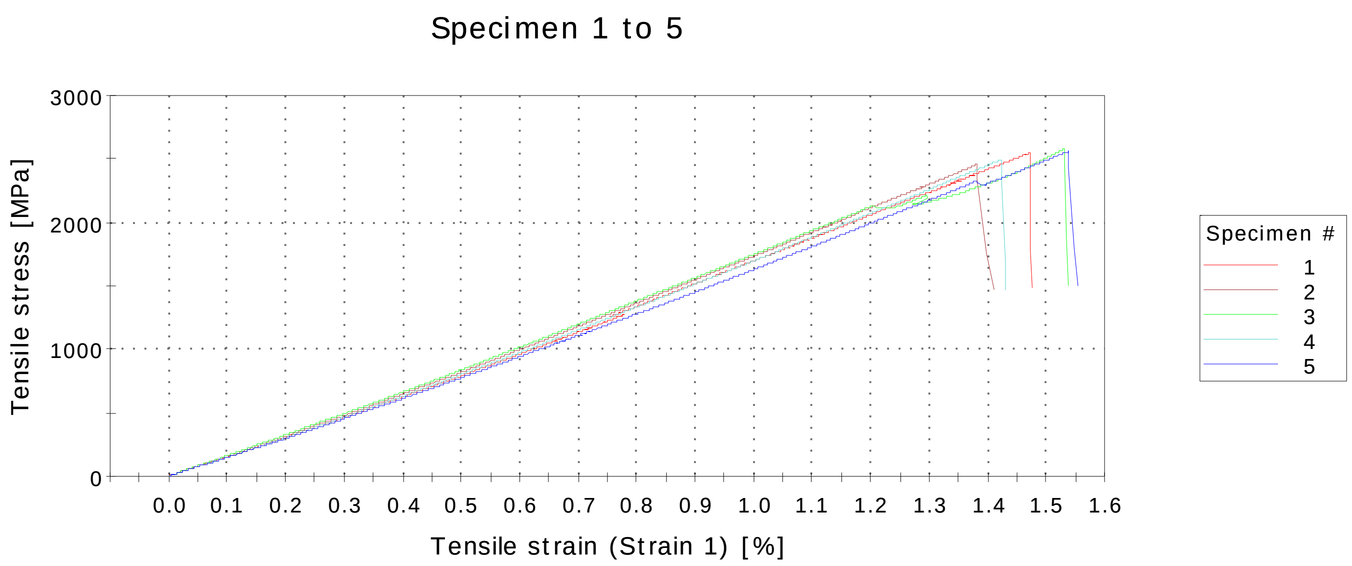
	Strain 1 at Maximum Load [%]	Maximum Load [N]	Tensile stress at Maximum Load [MPa]
1	1.452	35515	2526.5
2	1.317	32974	2277.5
3	1.429	36659	2474.6
4	1.446	38146	2555.4
5	1.391	35474	2396.1
Mean	1.407	35753	2446.0
Median	1.429	35515	2474.6
Coefficient of Variation	3.951	5.3080	4.5774

Batch 2: Poor Alignment Results



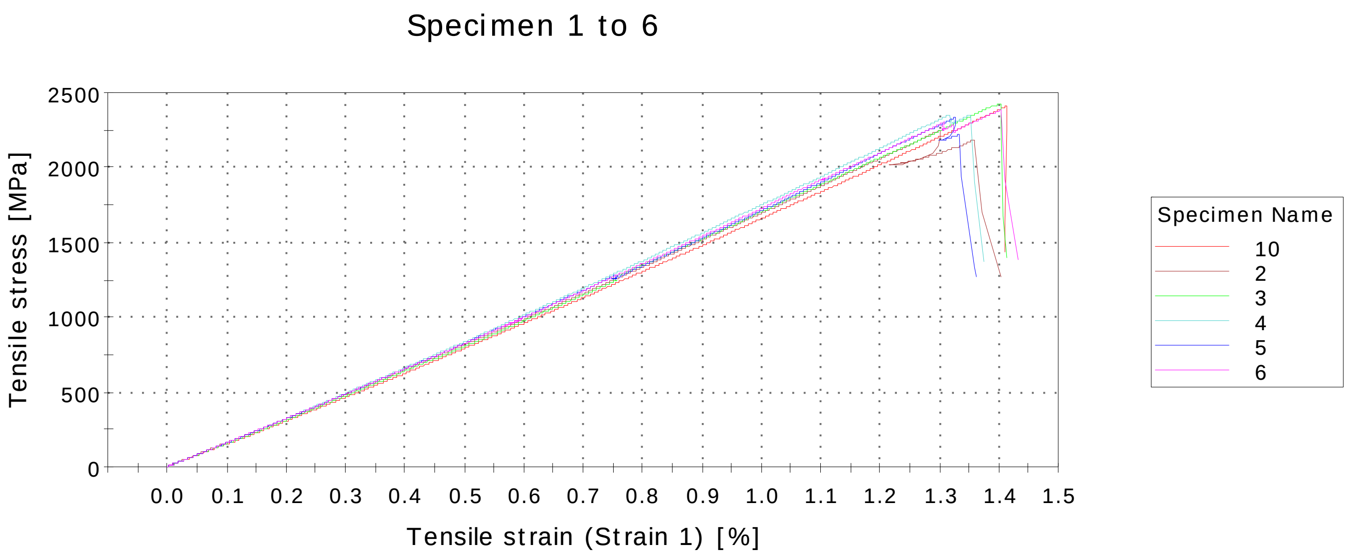
	Strain 1 at Maximum Load [%]	Maximum Load [N]	Tensile Stress at Max Load [MPa]
1	1.484	29610	2231.5
2	1.318	32635	2173.2
3	1.481	32866	2186.5
4	1.351	35638	2385.2
5	1.200	31436	2087.1
6	1.244	32927	2214.8
Mean	1.346	32518	2213.0
Median	1.334	32750	2200.6
Coefficient of Variation	8.764	6.0987	4.4342

Batch 3: Good Alignment Results



	Strain 1 at Maximum Load [%]	Maximum Load [N]	Tensile stress at Maximum Load [MPa]
1	1.474	38159	2552.2
2	1.381	36639	2455.2
3	1.531	37965	2583.7
4	1.425	37220	2496.1
5	1.538	38279	2560.4
Mean	1.470	37652	2529.5
Median	1.474	37965	2552.2
Coefficient of Variation	4.609	1.8596	2.0776

Batch 4: Good Alignment Results



	Strain 1 at Maximum Load [%]	Maximum Load [N]	Tensile Stress at Maximum Load [MPa]
1	1.413	35896	2410.5
2	1.302	33449	2249.6
3	1.403	36000	2425.5
4	1.353	34873	2353.3
5	1.327	34088	2336.4
6	1.405	33741	2387.6
Mean	1.367	34675	2360.5
Median	1.378	34480	2370.5
Coefficient of Variation	3.406	3.1613	2.7053