Tensile Testing of Tube Materials

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The tensile properties of the Al 3003 alloy used in the 30 mm diameter drift tubes for the Atlas MDT chambers were determined using an Instron servo-hydraulic tensile testing machine. Six specimens were prepared and tested:

1. Metalba tubing –axial direction (MET A)
2. Metalba tubing – circumferential direction (MET C)
3. Pennsylvania tubing – axial direction (PENN A)
4. Pennsylvania tubing – circumferential direction (PENN C)
5. Menzigen tubing –axial direction (MEN A)
6. Menzigen tubing – circumferential direction (MEN C)

Each specimen was 6 mm wide and, of course, 0.4 mm thick. They were cut to a length of 90 mm. The axial specimens were cut from the tube wall along the length of the tube and were, thus, already straight but not quite flat. The circumferential specimens were prepared by cutting of a 6 mm length of tubing, slitting this in one place axially and then carefully straightening the specimen. Care was taken to minimize the cold working done to the metal as this stage.

The specimens were left as straight strips with no attempt made to make a narrow test section. Each specimen was clamped in the grips of the Instron with the specimen aligned in the test direction and with 25 mm held in the grips at each end. The test load was measured accurately by the Instron load cell and the overall specimen extension was measured by recording the crosshead movement as load was applied. This was not an accurate measurement as the actual clamping point in the grips was not well determined and some axial motion of the specimen occurred within the grips. However, as we were only interested in getting strength data, this error was not important. The force vs. extension data was logged by a PC connected to the Instron and was saved in a spreadsheet.

Five of the specimens broke in the grips. This introduces some error in the breaking strength due to the stress concentration present at the grip points. The sixth specimen broke at its mid point.

The results for the Metalba, Pennsylvania and Menzigen tubing are presented in the six accompanying graphs. The load values were converted to stress using a cross section area of 6*0.4 = 2.4 mm^2. The peak value on each graph was taken as the ultimate tensile strength (UTS). An approximate estimate was made of the 0.2% yield strength by drawing a line starting at an estimated strain of 0.2% and parallel to the linear, elastic part of each curve. The intersection of this line with the curve gives the yield strength (S_y). This was a quite approximate process as some curves were somewhat non-linear in the elastic part of the curve. This was particularly true for the circumferential specimens. These also had a slightly higher elastic modulus.

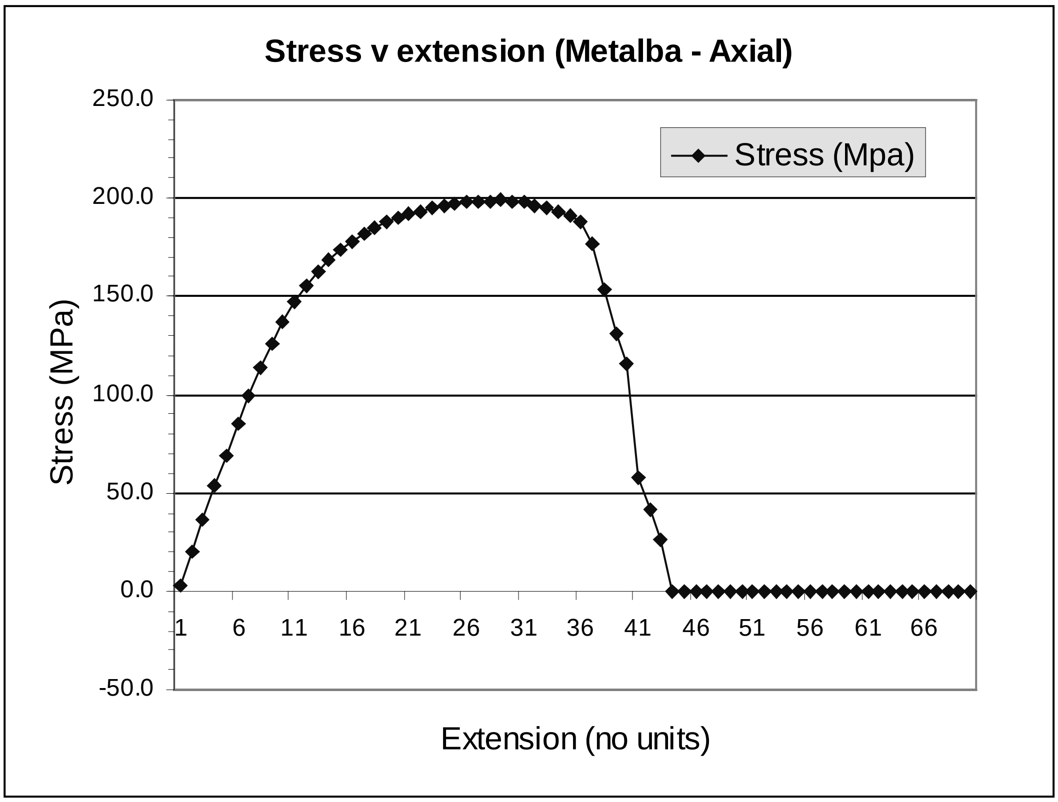
Summary of results:

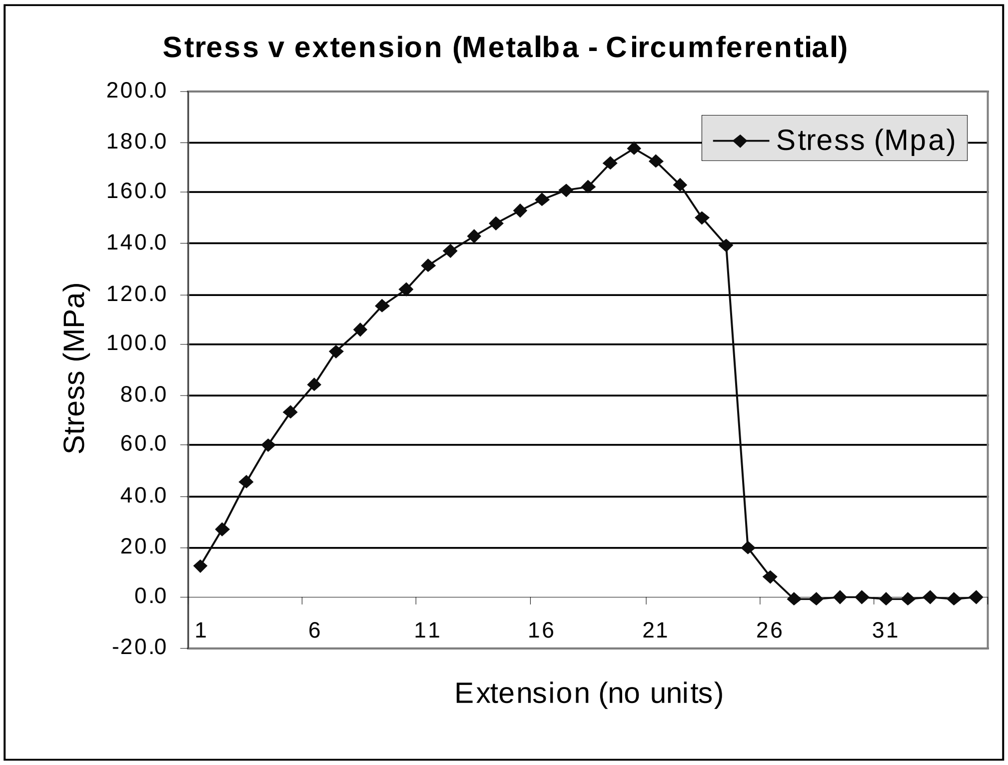
	Metalba		Pennsylvania		Menzigen	
Strength	Axial	Circumferential	Axial	Circumferential	Axial	Circumferential
UTS (Mpa)	198	178	162	149	228	206
Yield (Mpa)	120	110	105	73	163	133

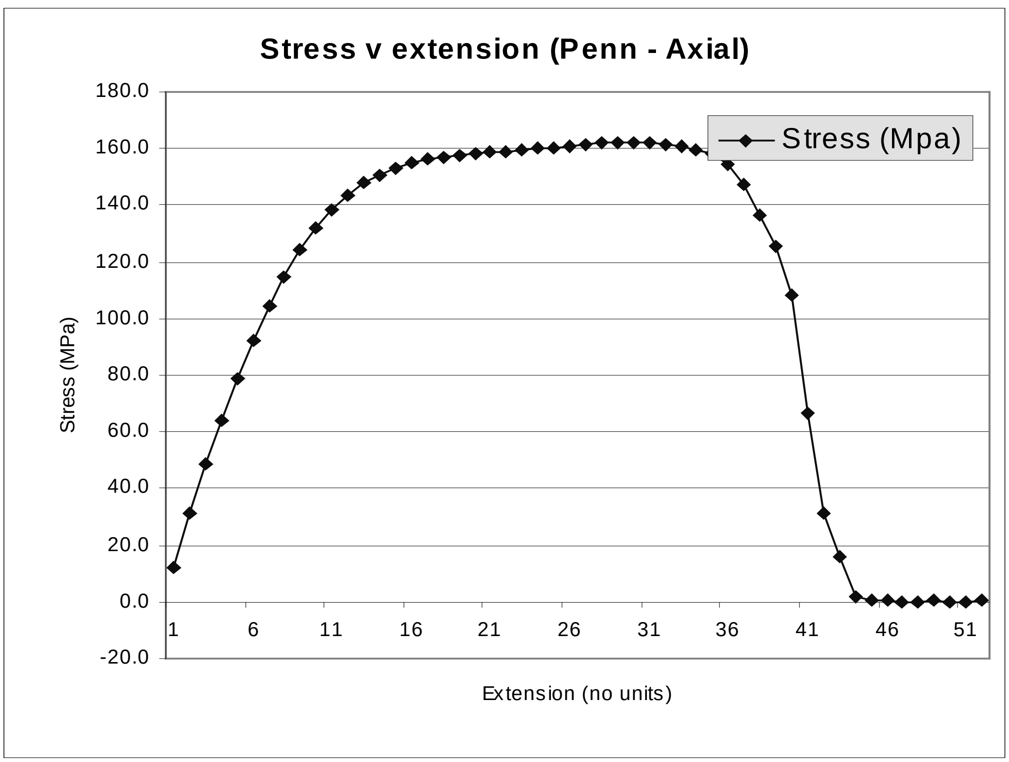
While the absolute values will have some errors, especially for the yield strengths, they are all well inside the range of values given for 3003 alloy and a variety of heat treatments. The relative values of the strengths do reveal some clear trends. In all cases, the axial specimens are significantly stronger than the circumferential ones. This is to be expected, given the very large amount of axial cold working involved in drawing these tubes. The metal grains are highly elongated in the axial direction and a large amount of strain hardening will occur in this direction. This is accompanied by a reduction in strength in the circumferential direction. With Al alloys, the Young's modulus also decreases slightly along with this axial plastic strain. The circumferential Young's modulus is expected to increase slightly. This effect is seen in the data. All of these results are expected.

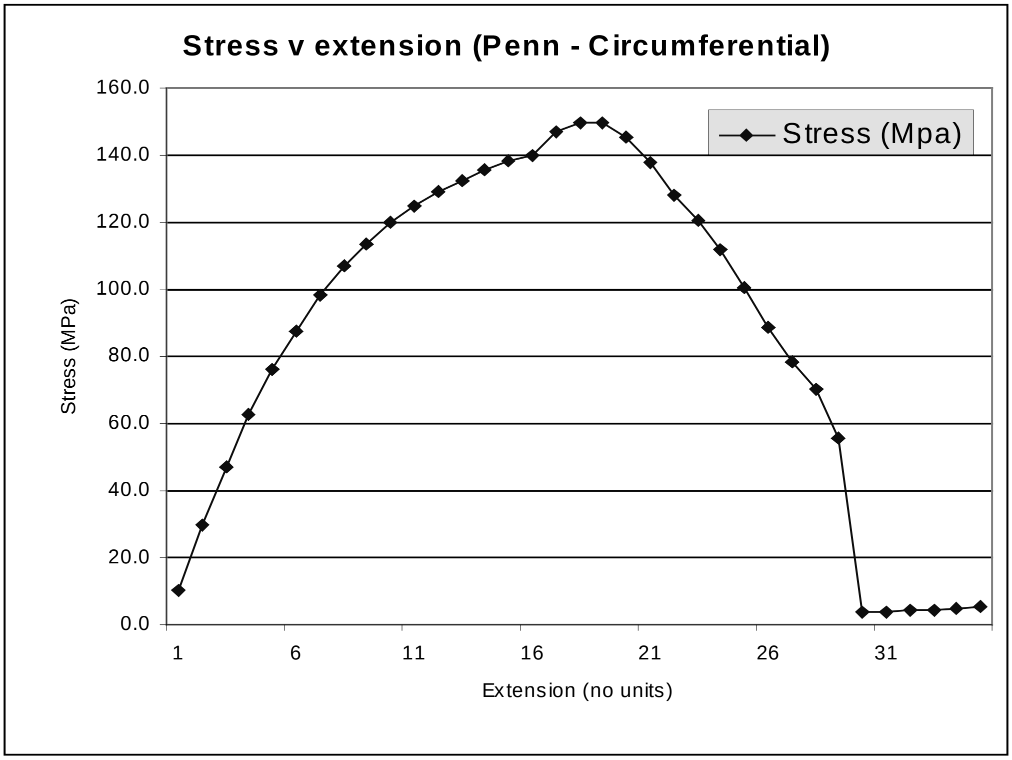
The other major trend is that the Metalba tubes are significantly stronger than the Pennsylvania tubes across the board. Chemical analysis of both manufacturer's tubing shows that both meet the specification for 3003 alloy. The reason for the difference is not obvious. If anything, one would expect the opposite as Metalba claim that they do some intermediate heat treatment during the drawing process, presumably an annealing step. One would thus expect a reduction in strength. The Menzigen tubes are somewhat stronger than the Metalba tubes, especially the yield strength. The alloy used is not known and no chemical analysis was done for these tubes. No details of the drawing process and/or any heat treatment were available for the Menzigen tubing.

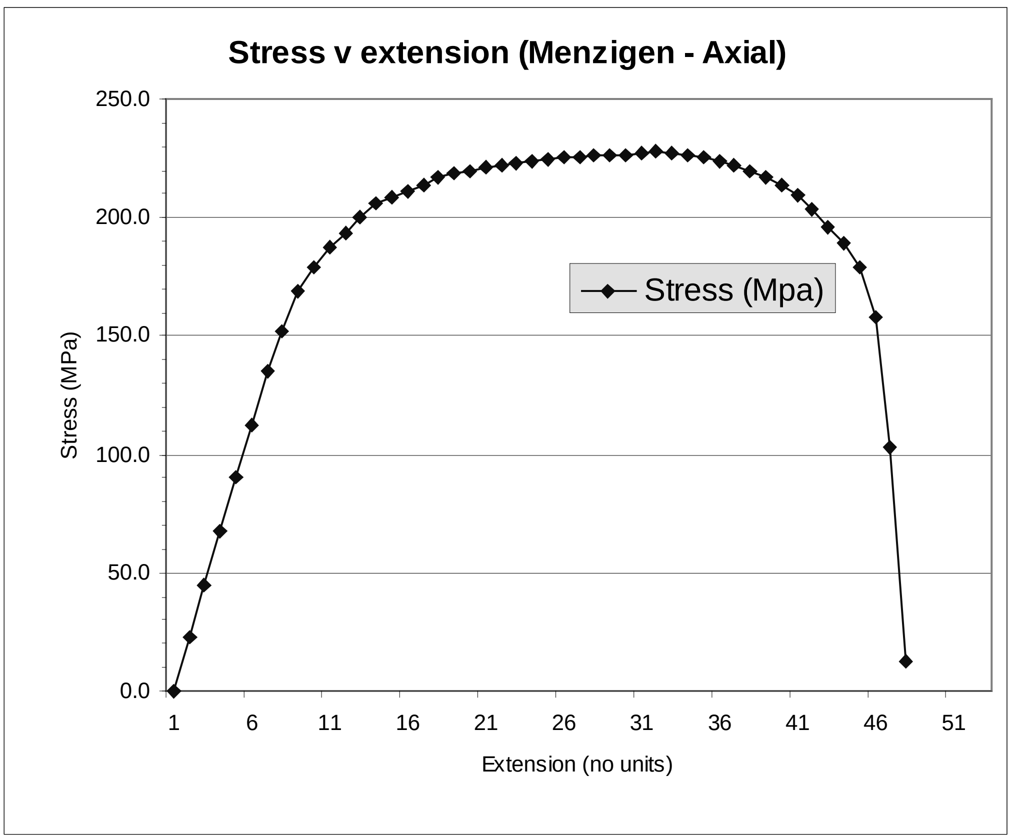
Further conclusions cannot be reached without more knowledge of the processing to which each manufacturer's tubes are exposed.

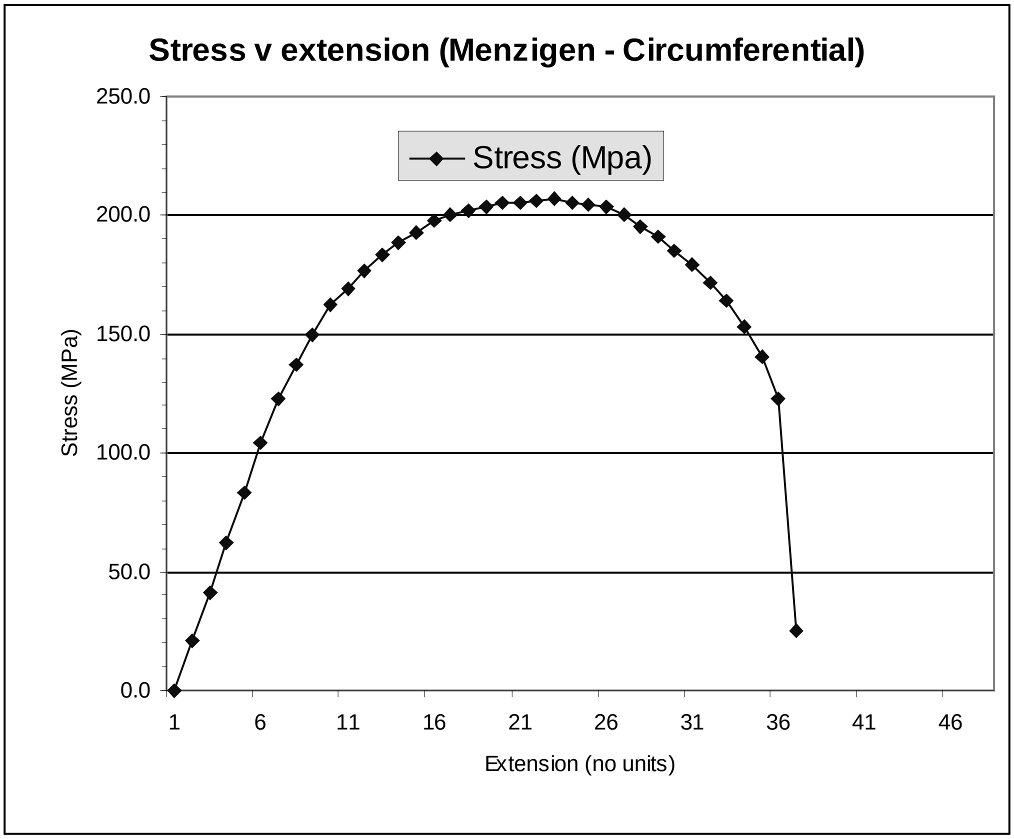



Stress v extension (Metalba - Circumferential)
Stress (Mpa)
Stress (MPa)
200.0
180.0
160.0
140.0
120.0
100.0
80.0
60.0
40.0
20.0
0.0
-20.0
1
6
11
16
21
26
31
Extension (no units)


Stress v extension (Penn - Axial)
Stress (Mpa)
Stress (MPa)
180.0
160.0
140.0
120.0
100.0
80.0
60.0
40.0
20.0
0.0
-20.0
1
6
11
16
21
26
31
36
41
46
51
Extension (no units)


Stress v extension (Penn - Circumferential)
Stress (Mpa)
Stress (MPa)
Extension (no units)
160.0
140.0
120.0
100.0
80.0
60.0
40.0
20.0
0.0
1
6
11
16
21
26
31


Stress v extension (Menzigen - Axial)
Stress (Mpa)
Stress (MPa)
Extension (no units)
250.0
200.0
150.0
100.0
50.0
0.0
1
6
11
16
21
26
31
36
41
46
51


Stress v extension (Menzigen - Circumferential)
Stress (Mpa)
250.0
200.0
150.0
100.0
50.0
0.0
Stress (MPa)
1
6
11
16
21
26
31
36
41
46
Extension (no units)