Electromagnetic pulse crimping of axial form fit joints

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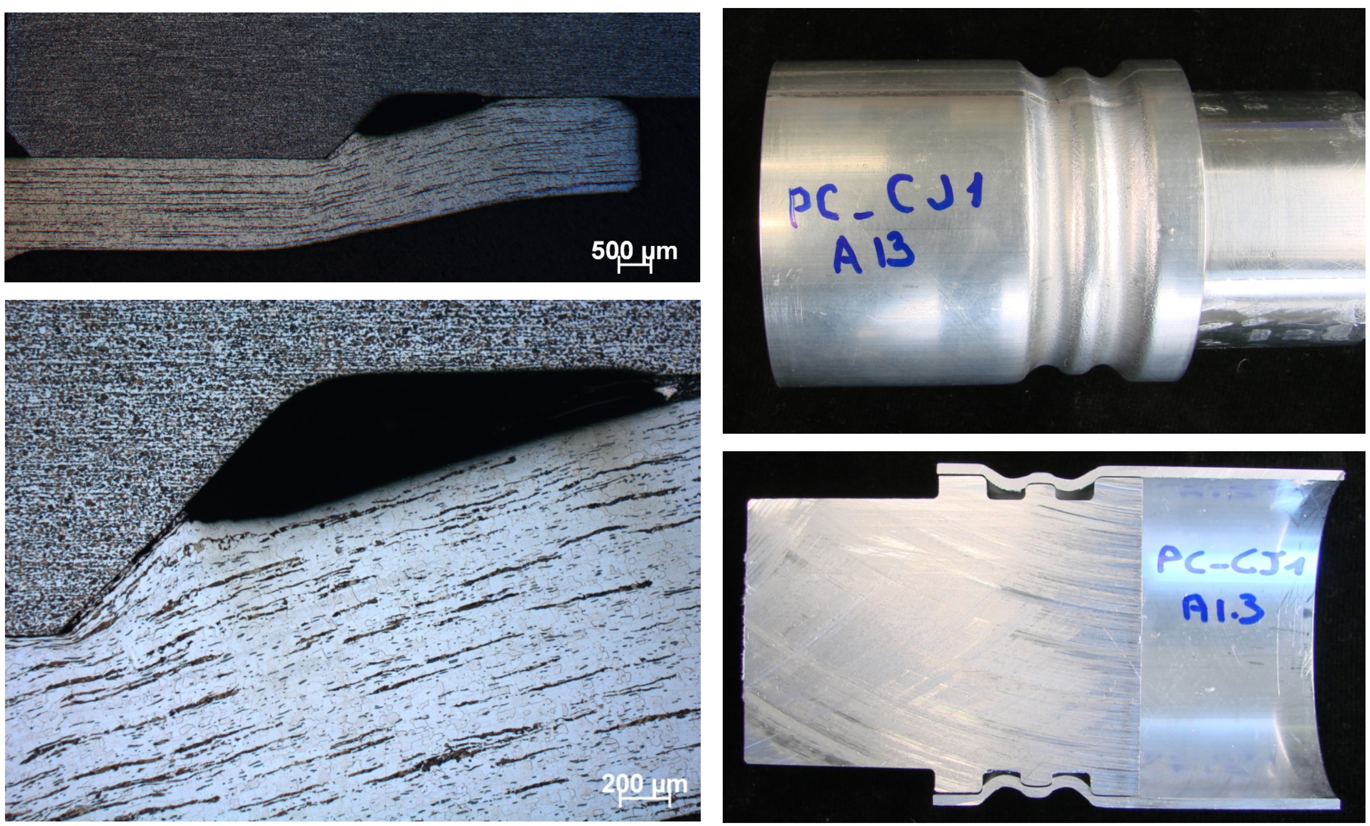
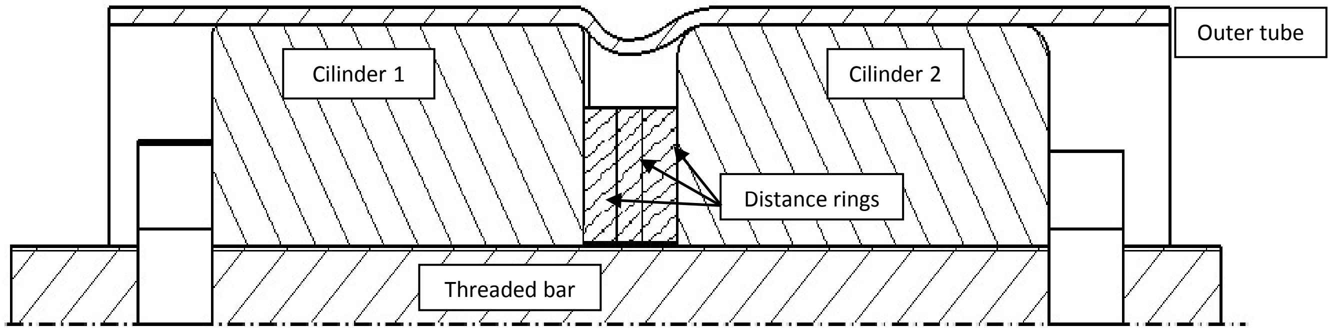
Axial crimp joints

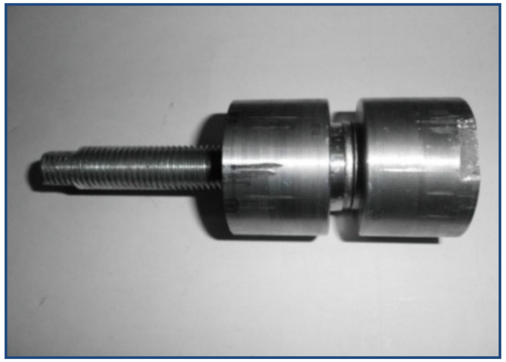
- Determination of the influencing parameters on the strength for a double groove design
- Optimisation of the internal workpiece of a crimp joint to create a strong connection
- Materials : Tubes D50 × 1,5 mm – aluminium (6060 T6)

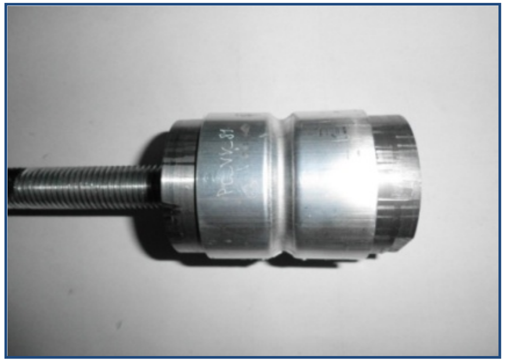


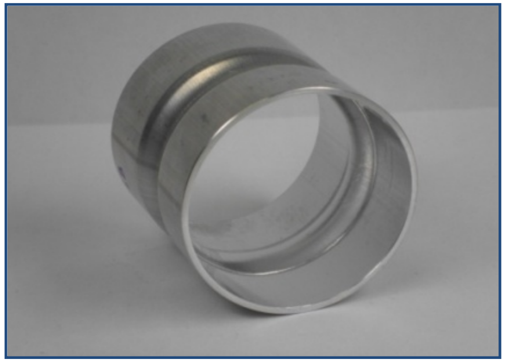
Free deformation experiments

- Test set-up







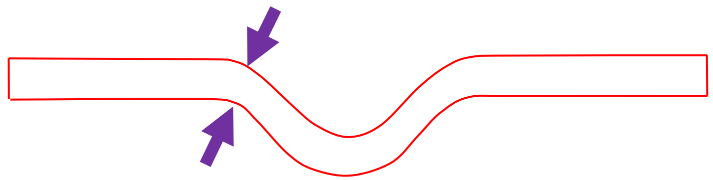


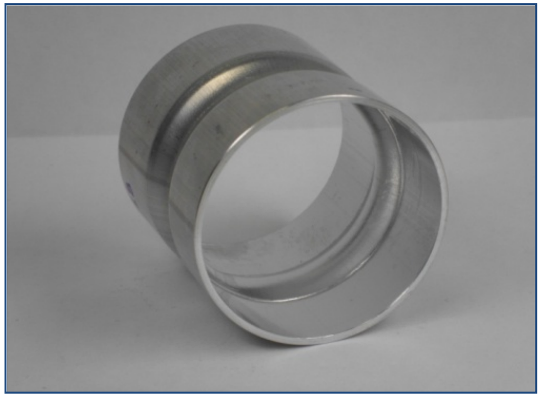
- Parameters :
  - Groove edge radius : 0,5 - 1,0 - 1,5 mm
  - Groove width : 6 - 14 mm
  - Charging voltage : 5 - 13 kV

Free deformation experiments

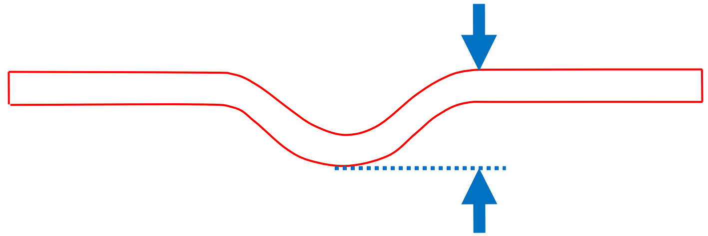
Measurements :

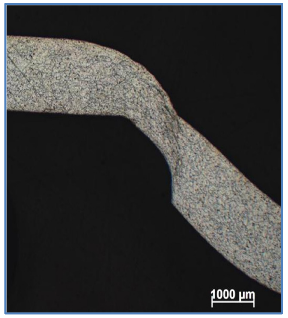
- Tube wall thickness reduction

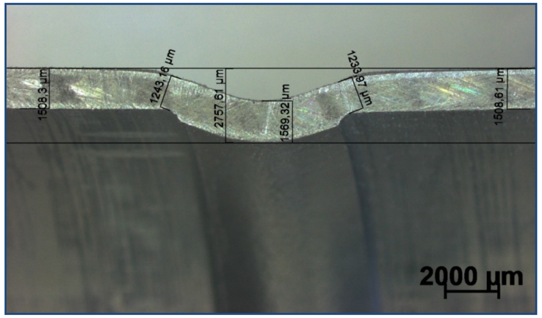




- Radial inward displacement

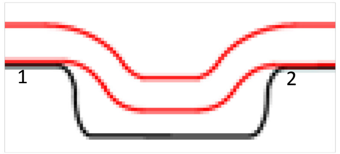




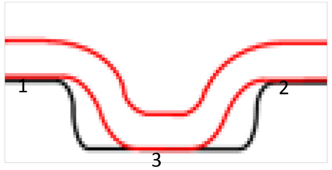


Leaktightness

2 areas of contact:

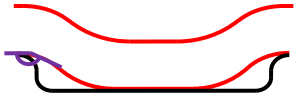


3 areas of contact:

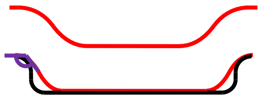


Strength

Minimal voltage

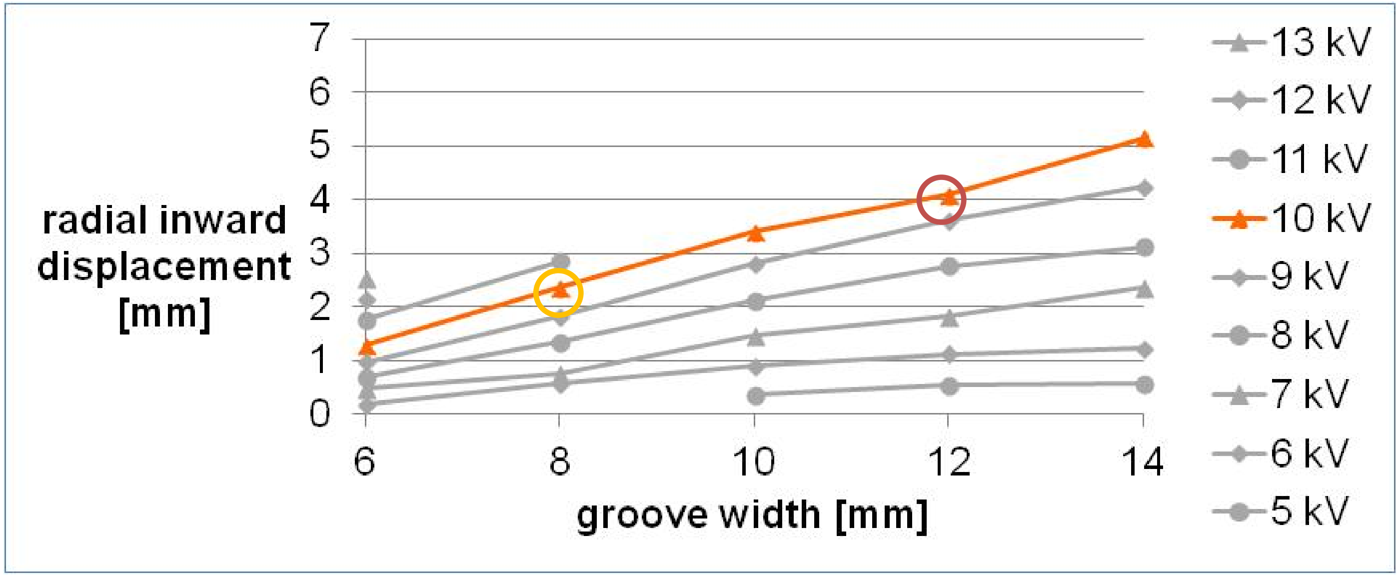


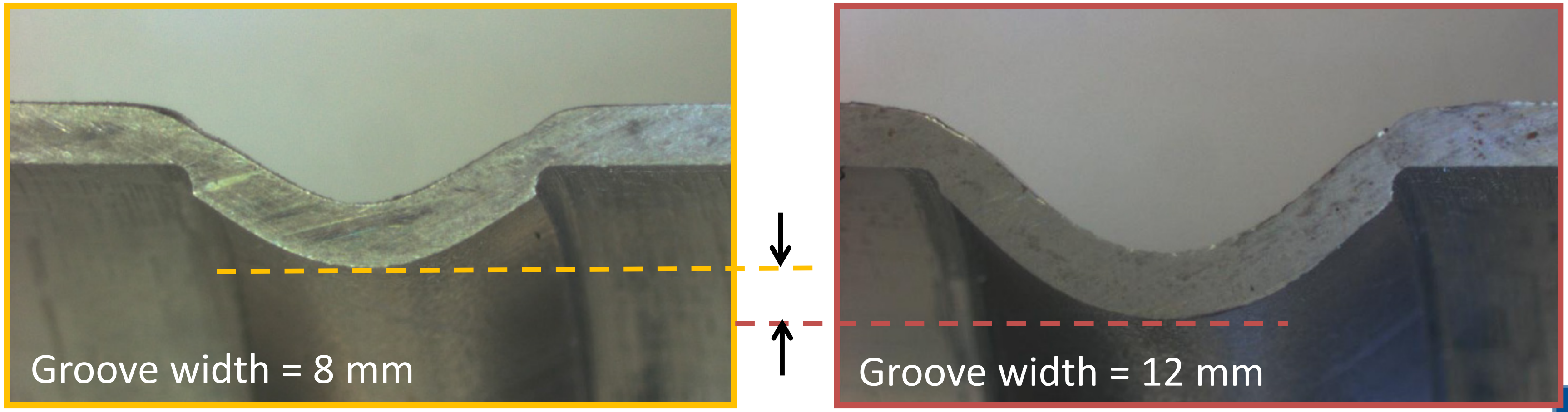
A voltage larger than the minimal required voltage



Free deformation experiments

- Radial inward displacement (R_{edge} = 0,5 mm)

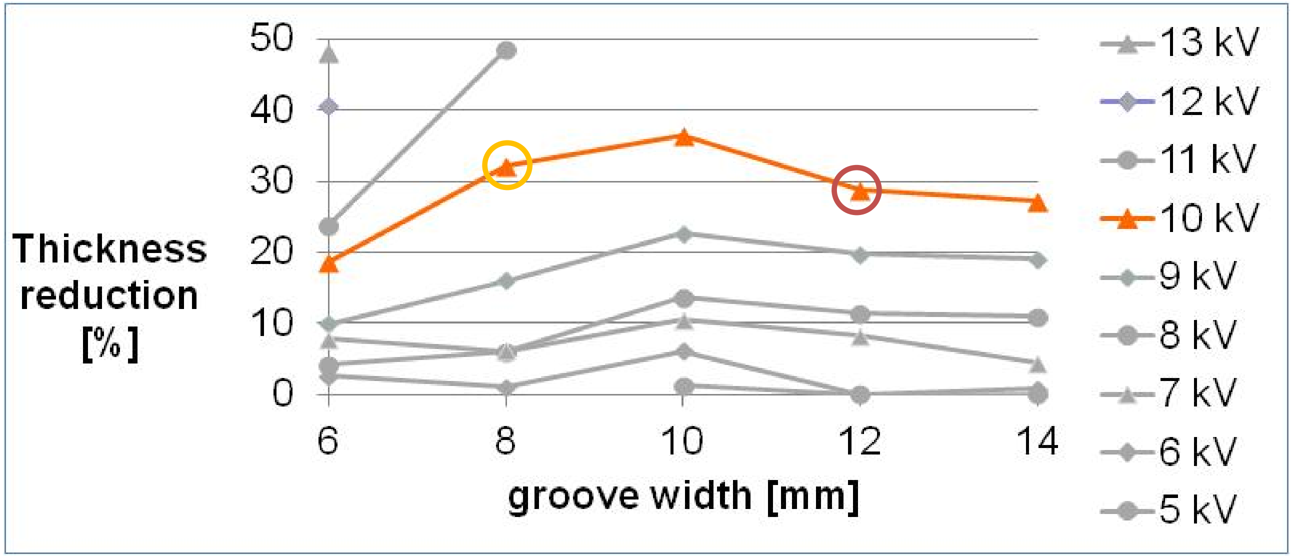


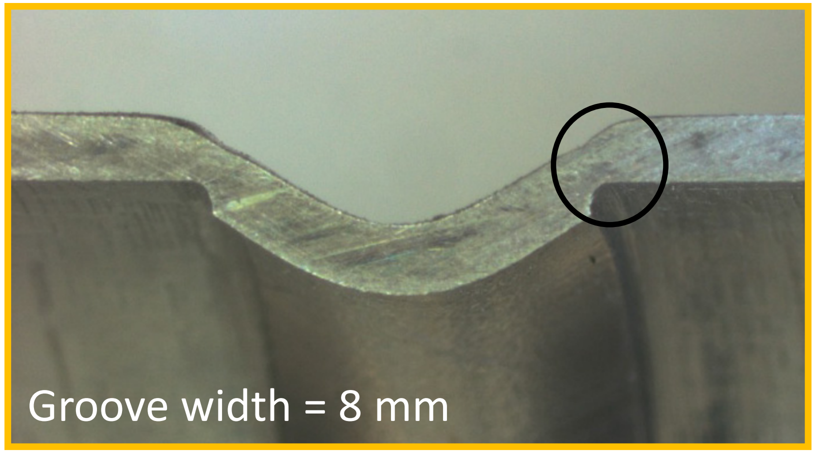


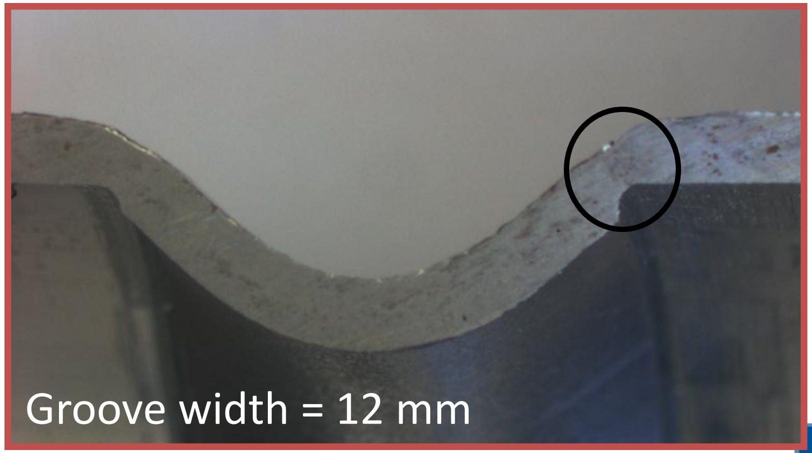
Larger radial inward displacement (approx. 40% more)

Free deformation experiments

- Tube wall thickness reduction (R_{edge} = 0,5 mm)



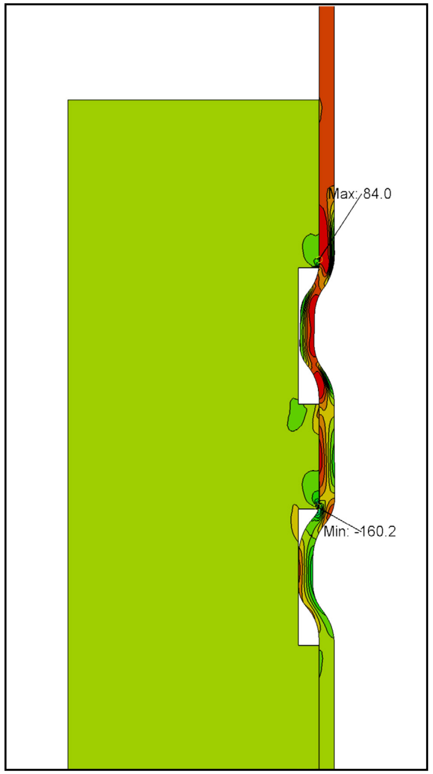


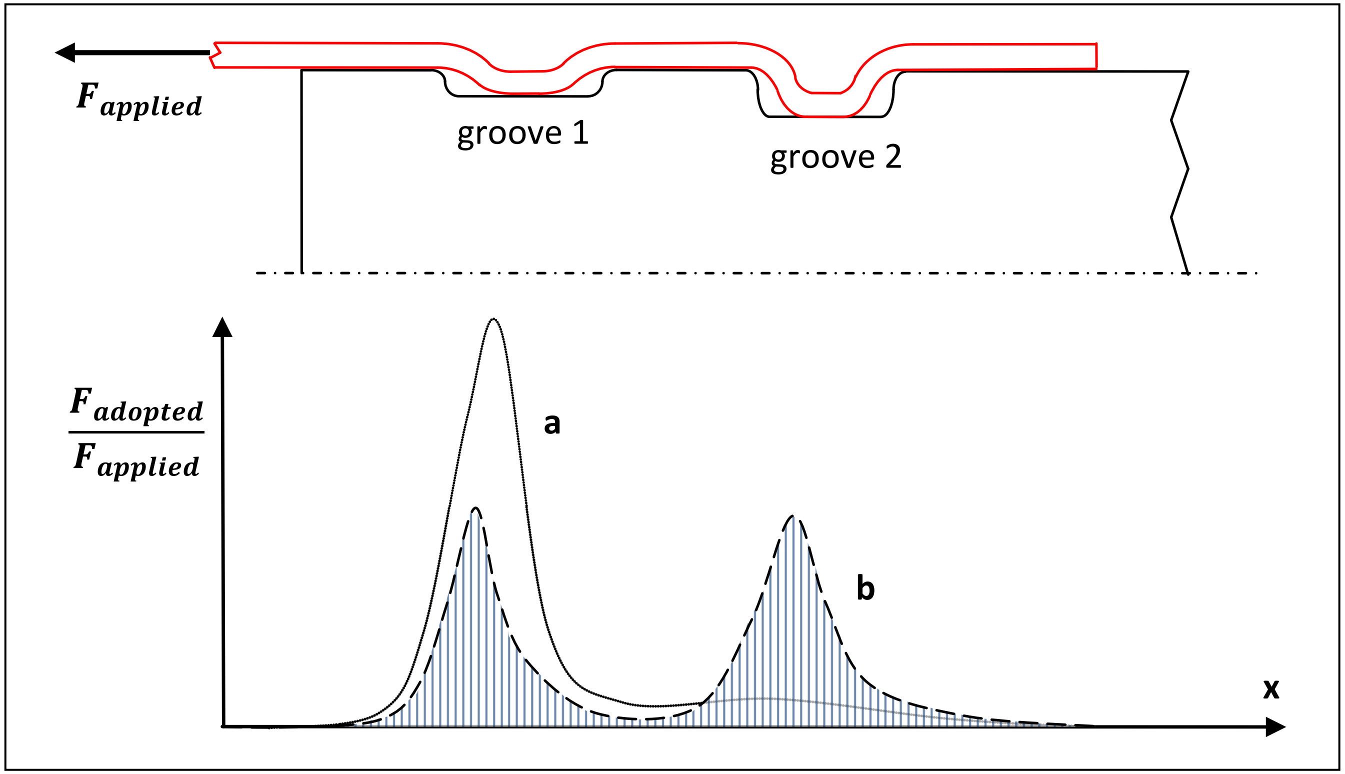


Same thickness reduction (approx.30%)

Optimisation of axial crimp joints

- Joints with a double groove design of the internal workpiece
- Optimisation :
  - Decreasing the load taken up by the first groove
  - Homogenisation of the distribution of the load
  - Minimisation of the tube wall thickness reduction at the first groove

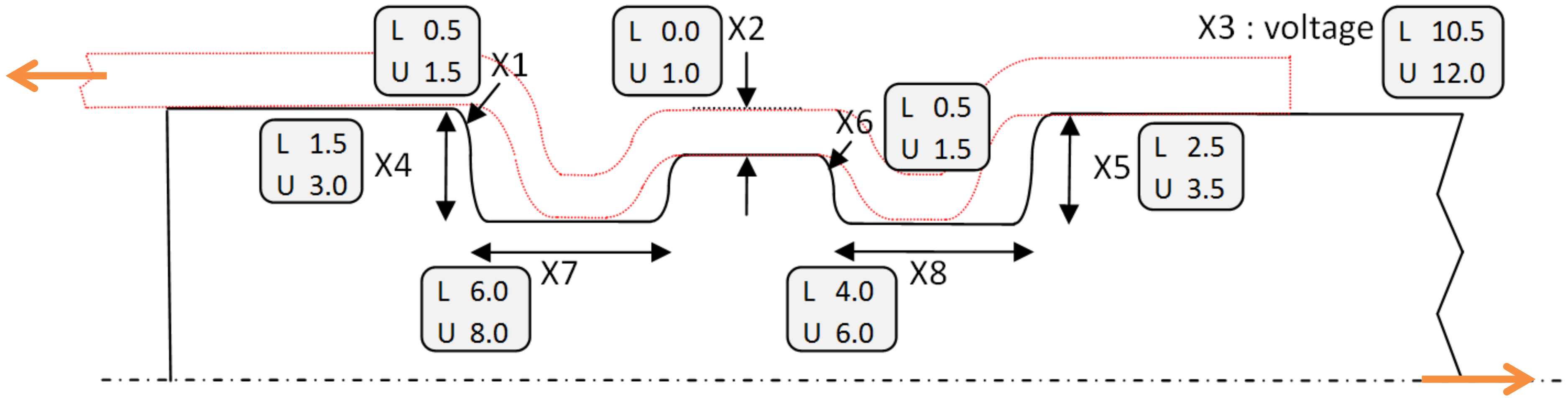




Optimisation of axial crimp joints

<u>Aluminium tubes D50 × 1,5 mm; aluminium internal workpieces</u>

- Design of Experiments : Statistical technique for analysing optimal designs
- 8 parameters ➡ Upper and lower value
- Two runs ➡ Reduce scatter
- Output value = relative tensile strength



Optimisation of axial crimp joints

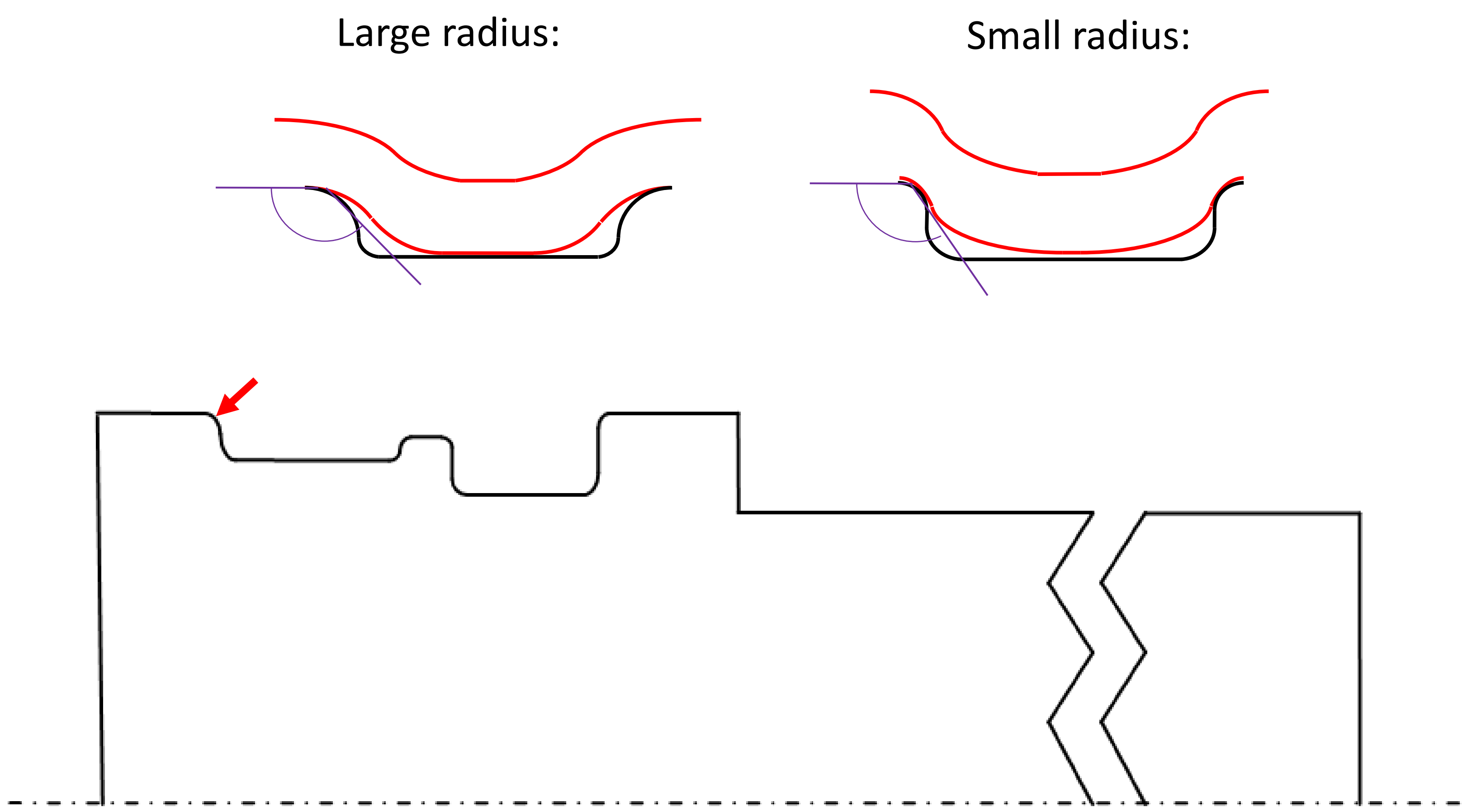
design number		relative tensile strength 1st series [%]	relative tensile strength 2nd series [%]	average tensile strength [%]	design number		relative tensile strength 1 [%]	relative tensile strength 2 [%]	average tensile strength [%]
1		79.0	84.4	81.7	33		86.7	86.5	86.6
2		75.9	76.6	76.3	34		62.2	61.5	61.9
3		81.3	78.6	80.0	35		73.4	72.5	73.0
4		75.9	82.0	79.0	36		71.0	71.0	71.0
5		81.7	79.6	80.6	37		67.3	68.0	67.6
6		70.3		70.3	38		72.1		72.1
7		71.1	72.7	71.9	39		73.7	78.2	76.0
8		69.4	72.3	70.9	40		64.7	63.1	63.9
9		74.7	76.9	75.8	41		77.0	76.2	76.6
10		75.9	85.1	80.5	42		73.3	79.1	76.2
11		89.1	87.4	88.3	43		74.5	83.0	78.8
12		77.8	75.4	76.6	44		64.0	72.2	68.1
13		76.9	78.9	77.9	45		59.0	64.6	61.8
14		68.1	72.3	70.2	46		57.1	55.6	56.4
15		74.9	78.2	76.6	47		58.7	60.7	59.7
16		64.7	71.2	68.0	48		68.3	75.6	72.0
17		**100.3**	92.4	96.4	49		84.3	80.4	82.4
18		74.1	73.6	73.9	50		64.8	62.7	63.8
19		73.7	75.1	74.4	51		64.3	62.6	63.4
20		79.5	85.1	82.3	52		80.4		80.4
21		72.0	75.9	73.9	53		65.7	64.3	65.0
22		81.3	87.9	84.6	54		77.4	81.3	79.4
23		83.4	88.0	85.7	55		76.3	79.7	78.0
24		71.3	77.4	74.3	56		63.9	64.8	64.3
25		99.8	83.3	91.5	57		78.4	76.5	77.5
26		87.1	92.1	89.6	58		84.7	91.5	88.1
27		98.7	90.8	94.7	59		86.4	93.1	89.8
28		80.2	81.4	80.8	60		75.6	75.5	75.6
29		82.0	87.2	84.6	61		81.9	78.2	80.0
30		77.4	74.8	76.1	62		76.0	78.0	77.0
31		74.9	75.1	75.0	63		78.0	77.7	77.8
32		78.5	85.8	82.2	64		76.7	78.3	77.5

Aluminium tubes D50 × 1,5 mm; aluminium internal workpieces

- Design of Experiments test matrix

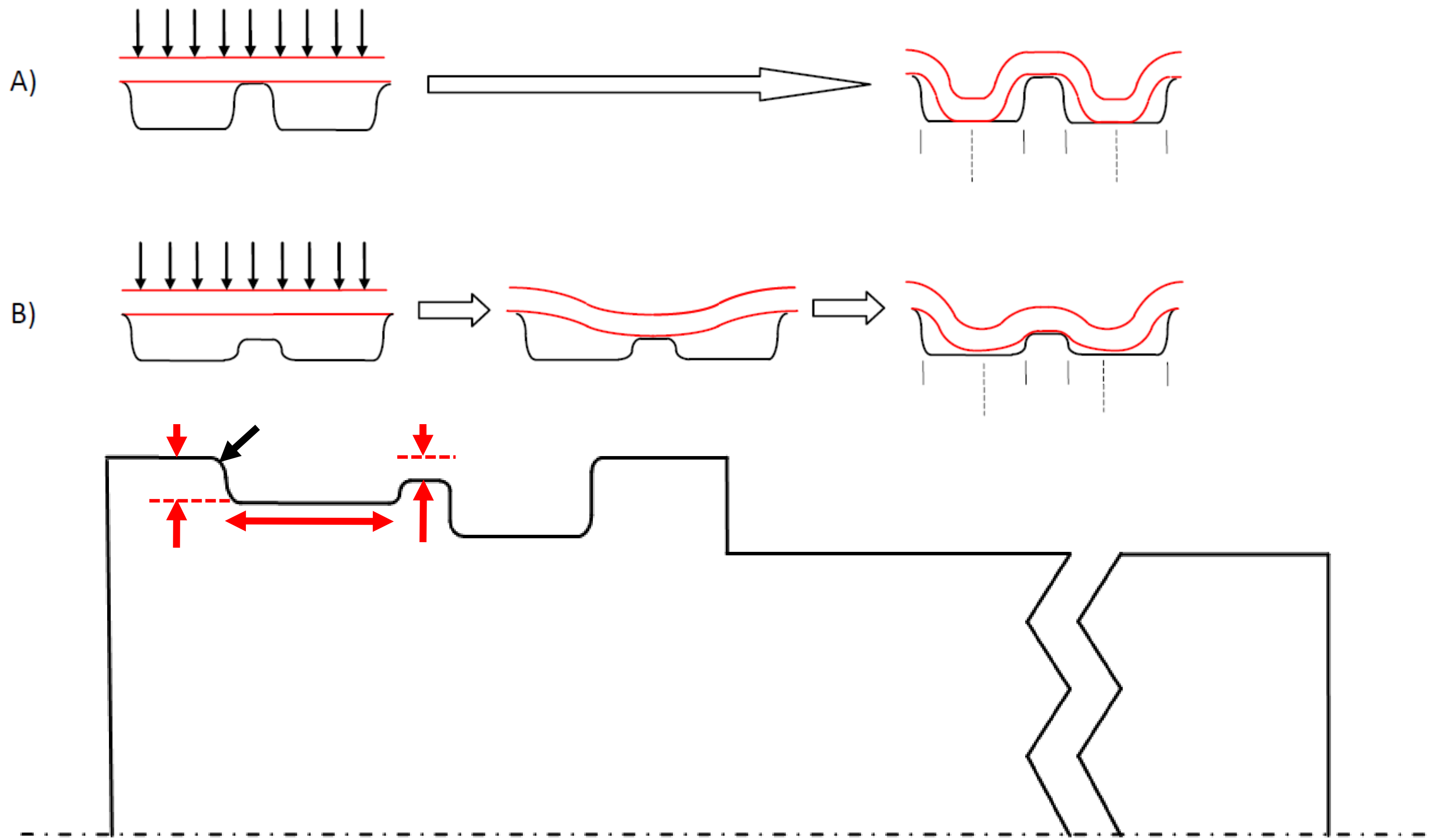
Optimisation of axial crimp joints

- Small first groove edge radius ➡ mechanical interlock



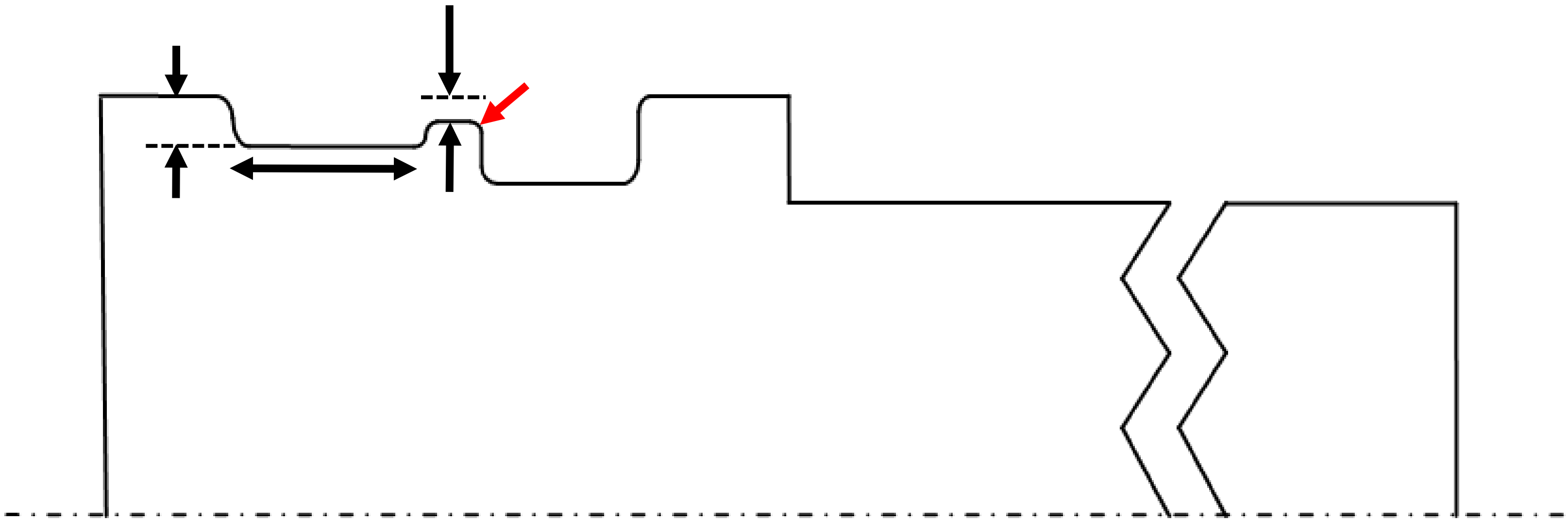
Optimisation of axial crimp joints

- Limit shearing ➡ adjust first groove dimensions



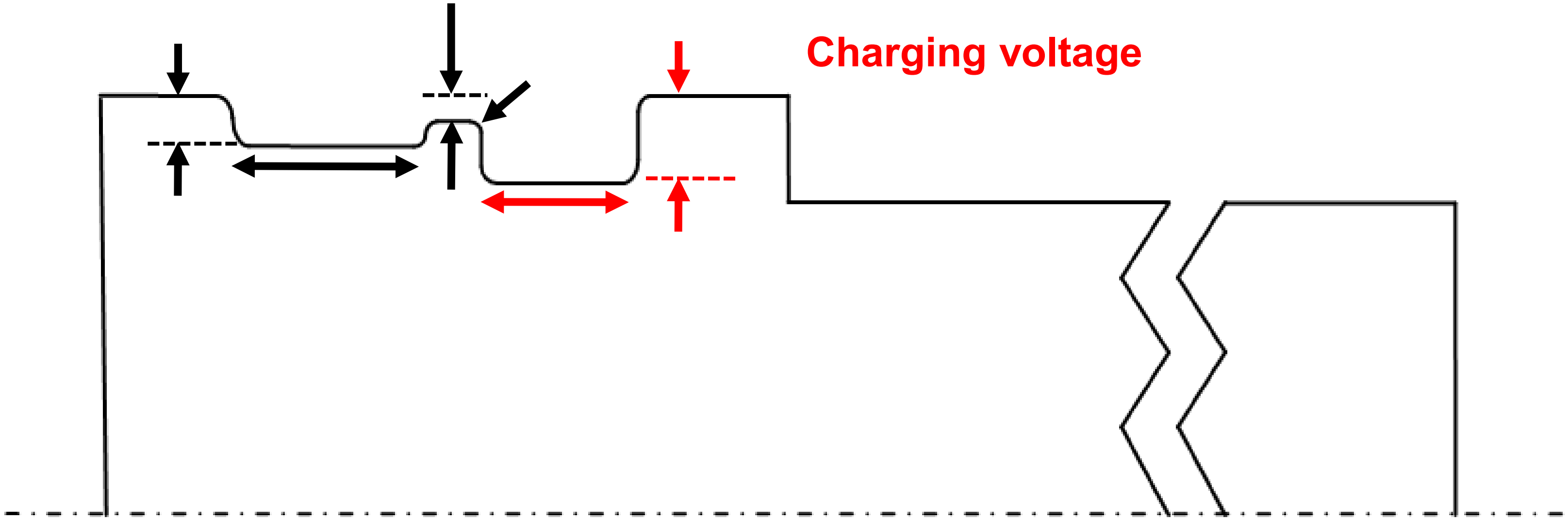
Optimisation of axial crimp joints

- Small second groove edge radius ➡ mechanical interlock



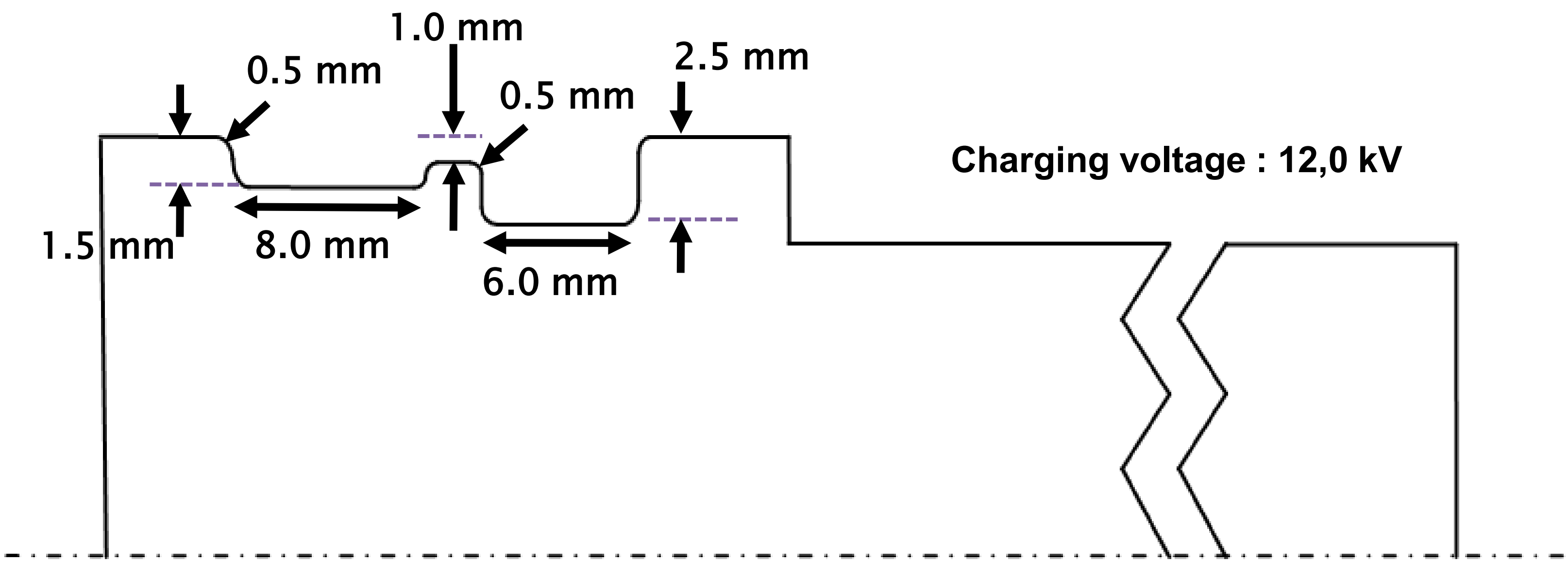
Optimisation of axial crimp joints

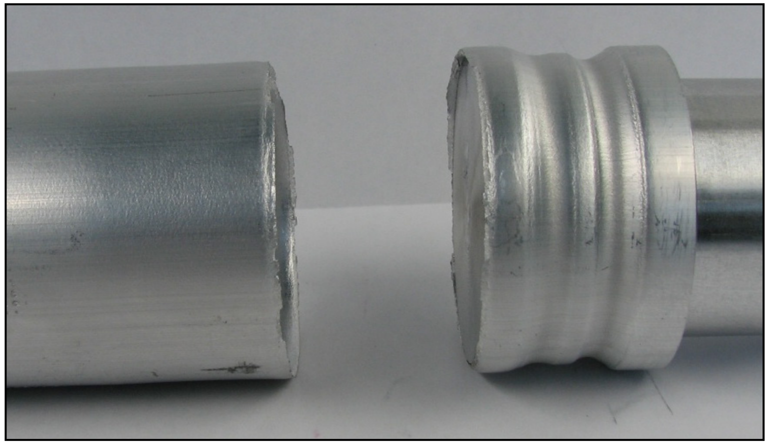
- Allow sufficient deformation in second groove

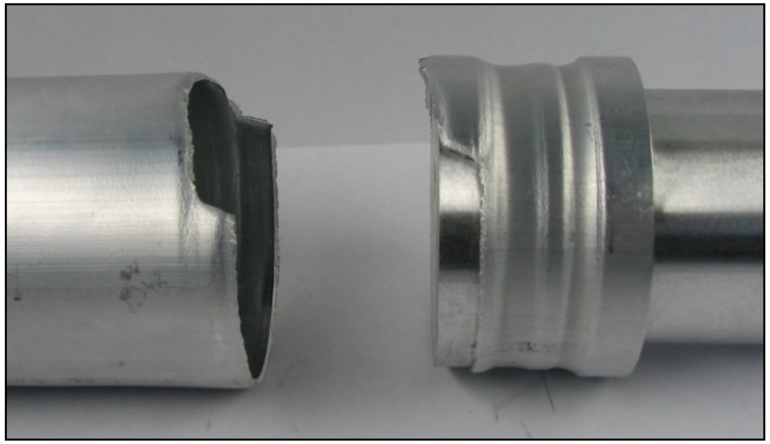


Optimisation of axial crimp joints

OPTIMAL DESIGN

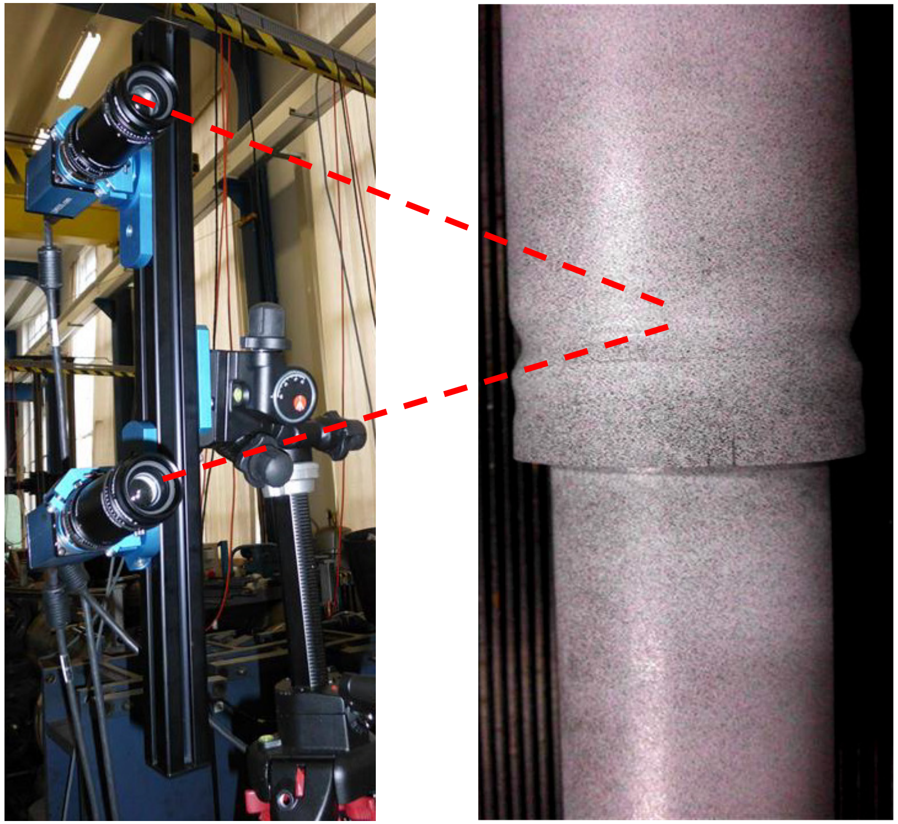


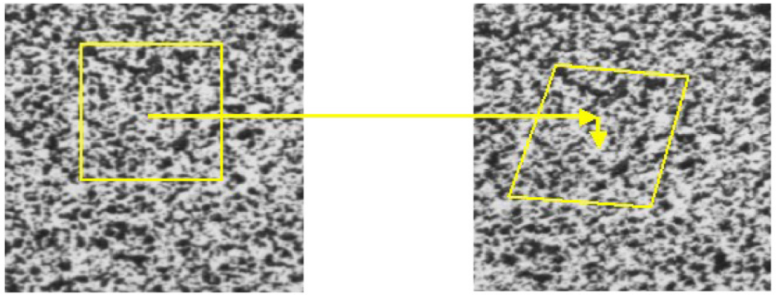




Failure modes

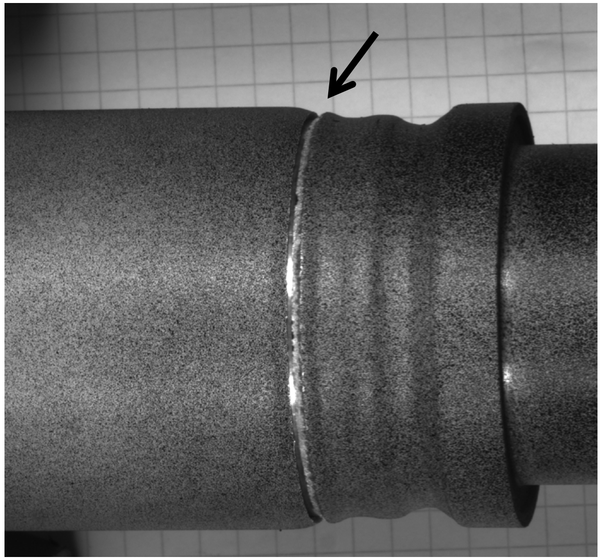
- Digital Image Correlation (DIC)

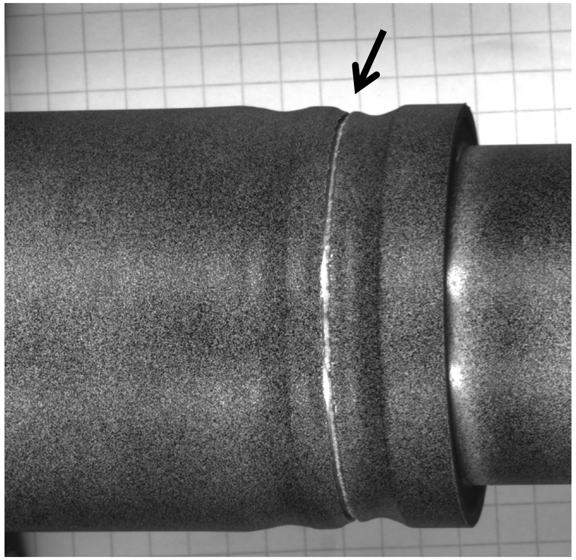


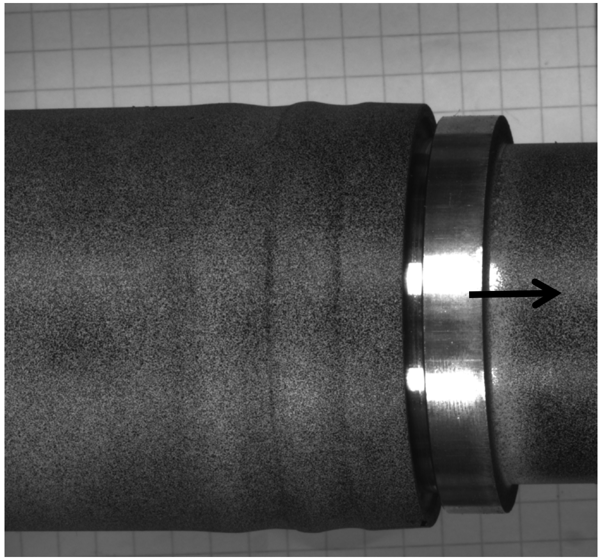


Failure modes

- Failure mode 1: The tube tears at edge 1_1 at the complete circumference
- Failure mode 2: The tube tears at edge 2_1 at the complete circumference
- Failure mode 3: The tube gets pulled off the internal workpiece, no tearing occurs



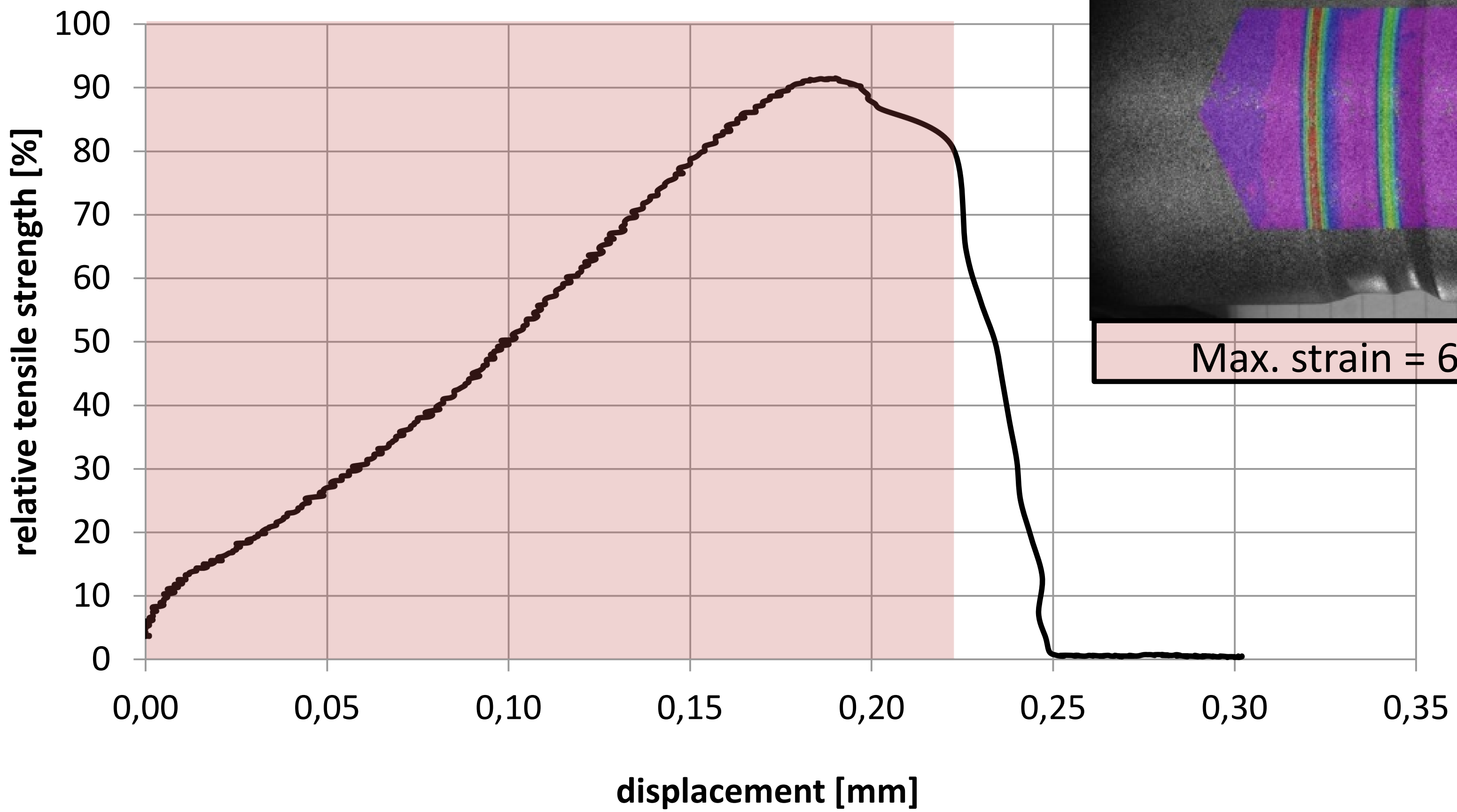


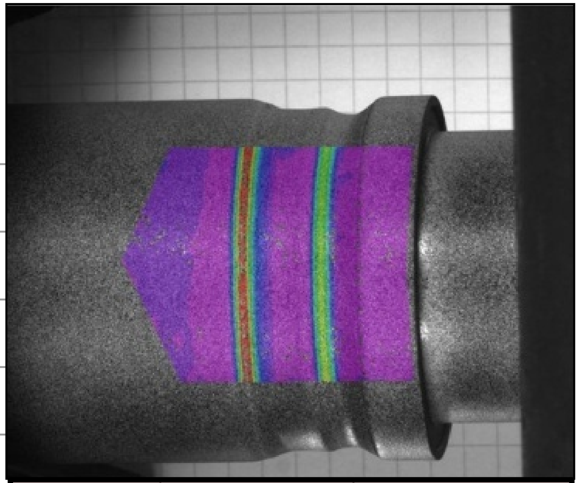


research

Failure modes

- **Failure mode 1 :** The tube tears at edge 1_1 at the complete circumference





Max. strain = 6.9%

Failure modes

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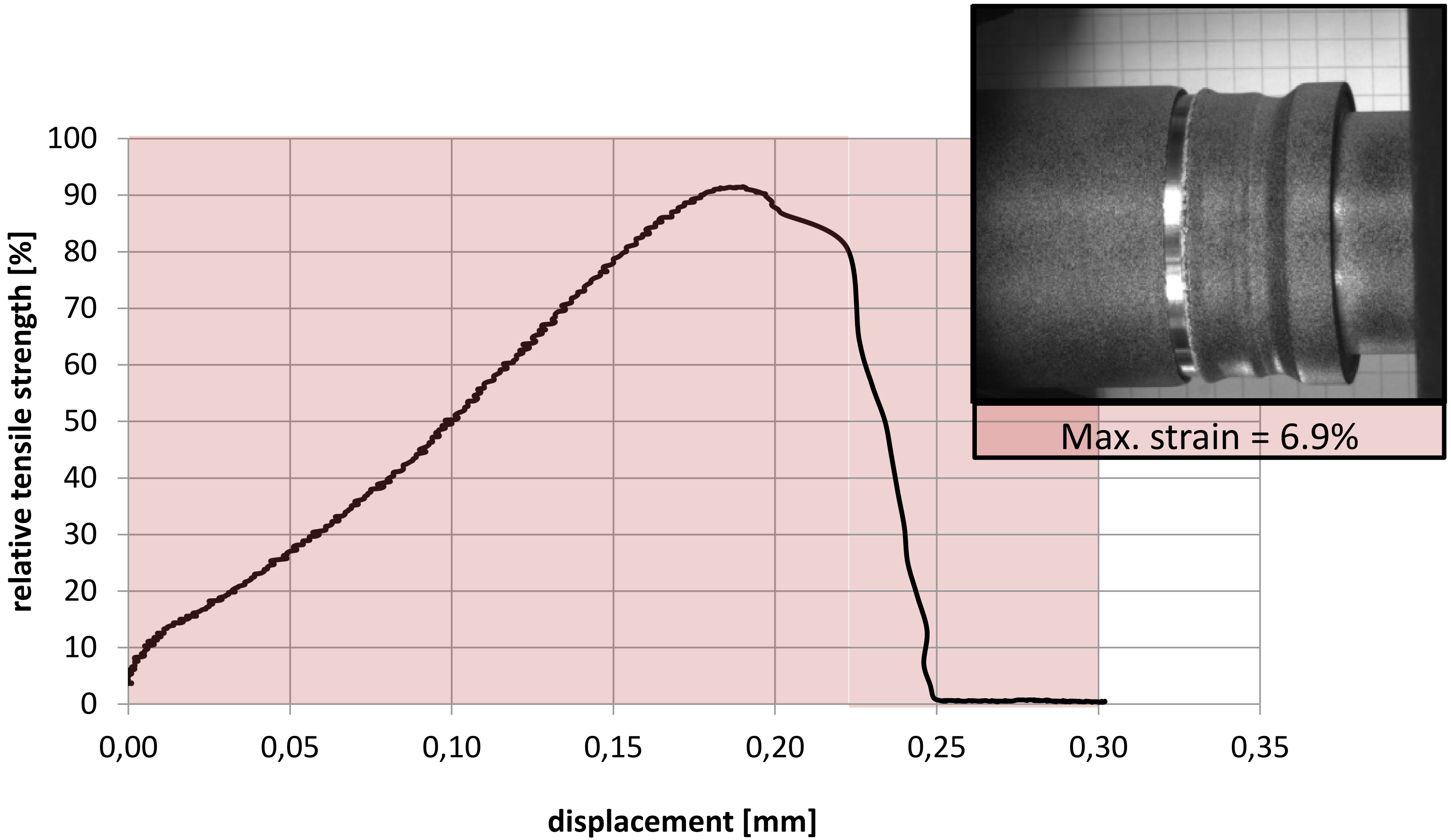
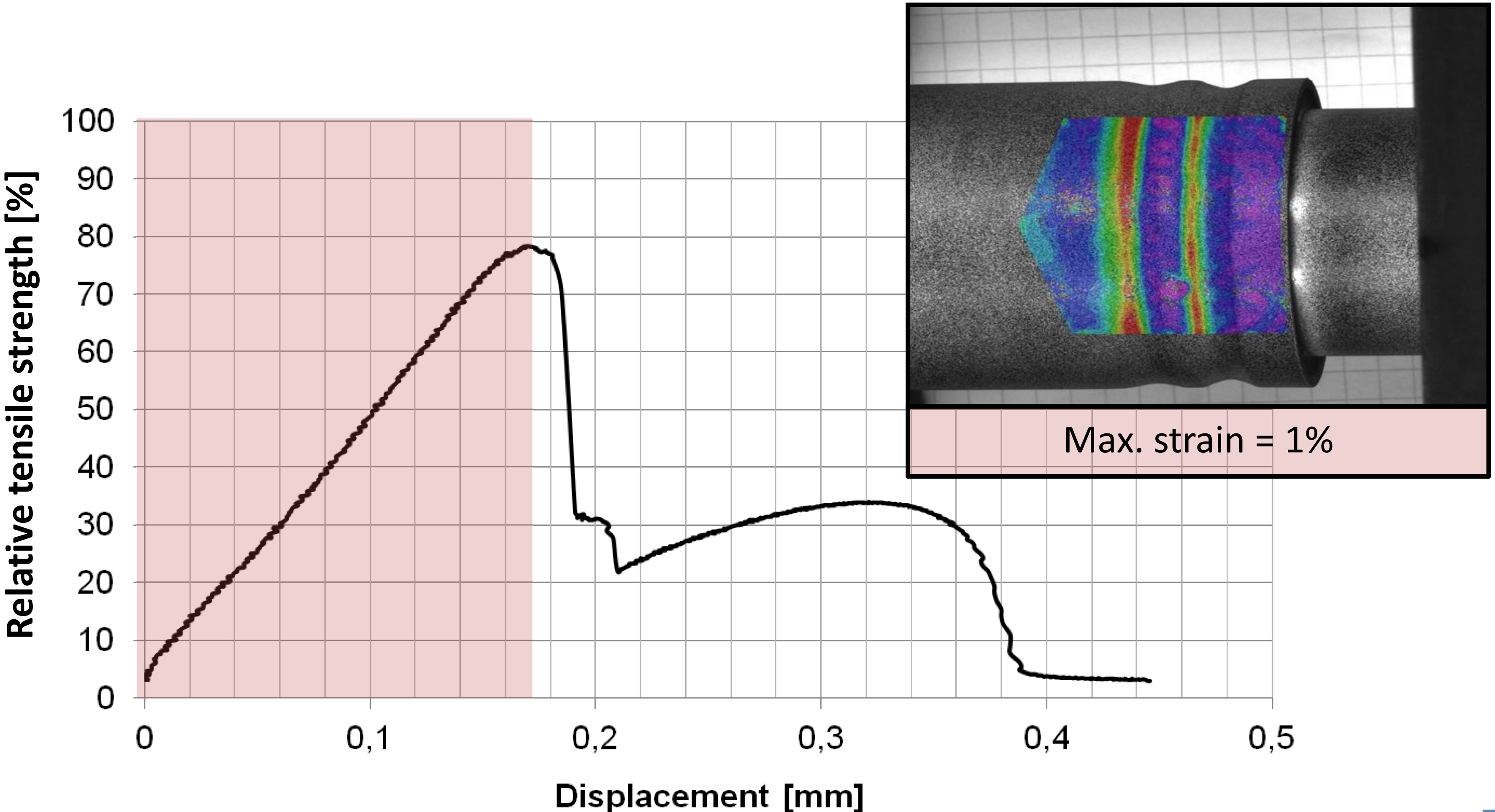


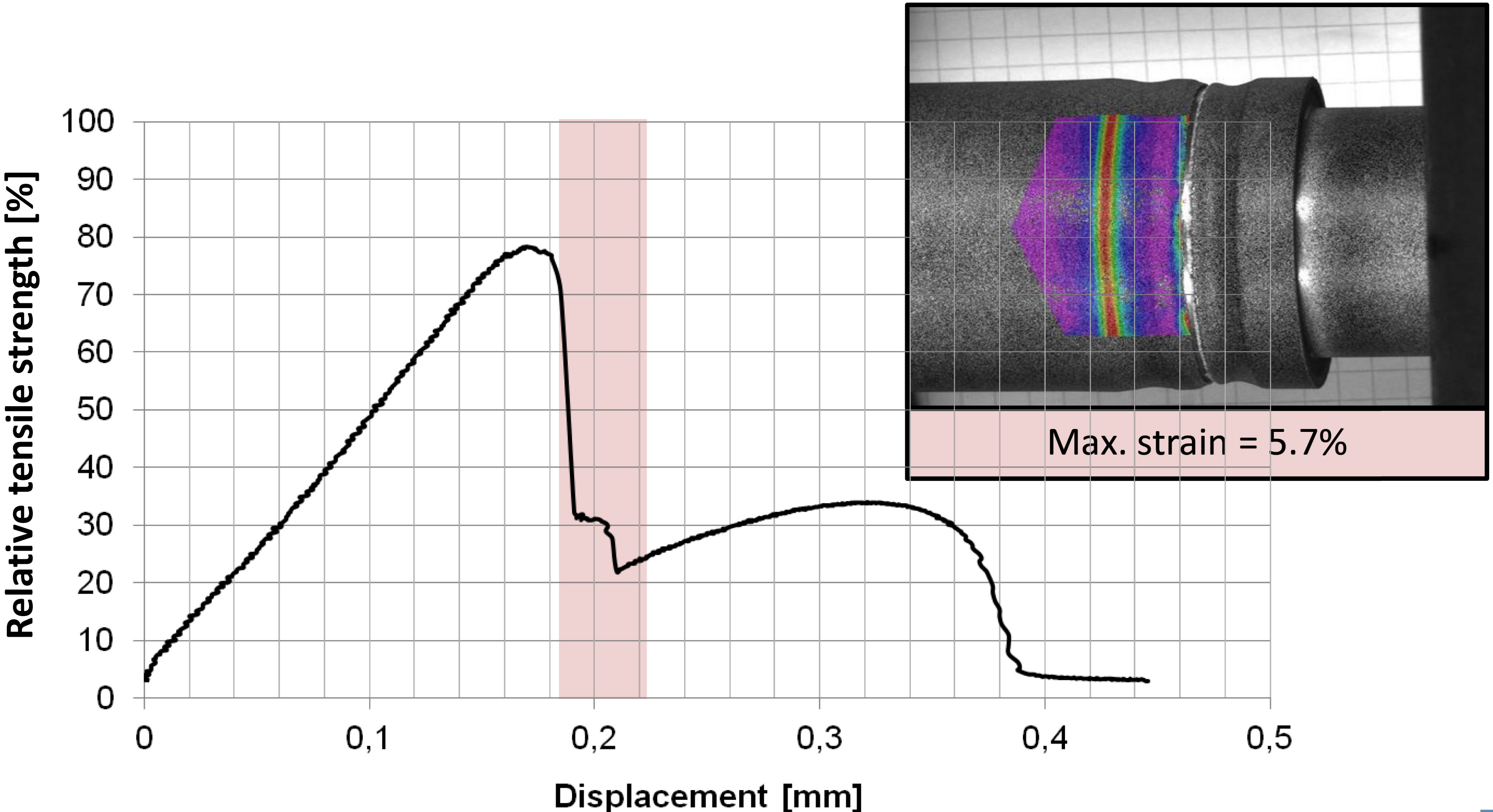
Failure modes

- **Failure mode 2 :** The tube tears at edge 2_1 at the complete circumference



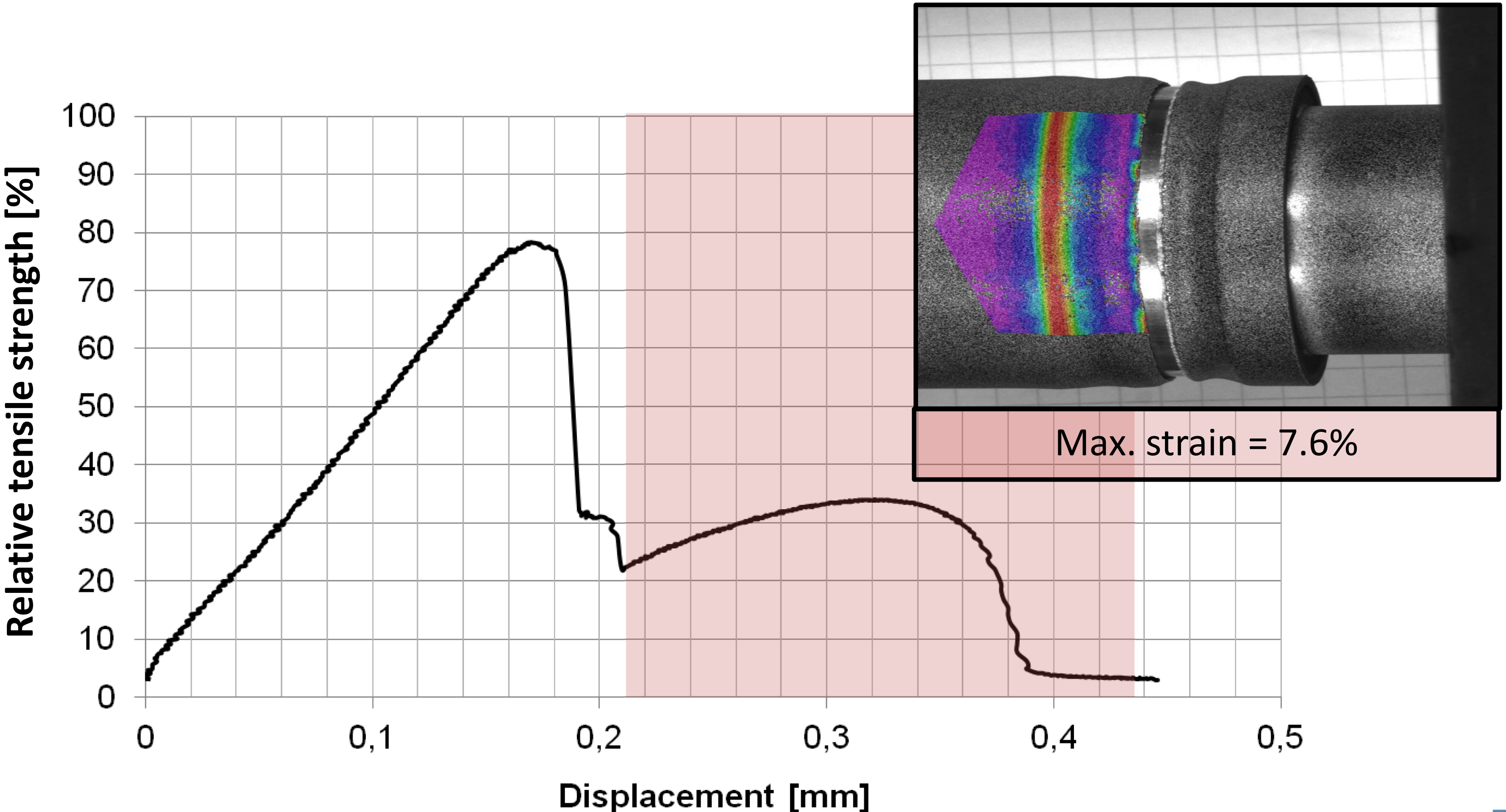
Failure modes

- **Failure mode 2 :** The tube tears at edge 2_1 at the complete circumference



Failure modes

- **Failure mode 2 :** The tube tears at edge 2_1 at the complete circumference



Failure modes

- Failure mode 1: The tube tears at edge 1_1 at the complete circumference
- Failure mode 2: The tube tears at edge 2_1 at the complete circumference
- Failure mode 3: The tube gets pulled off the internal workpiece, no tearing occurs

Failure behaviour	**Average relative tensile strength [%]**	**Percentage of occurrence [%]**
Failure mode 1	81.7	63.0
Subgroup 1	*74.0*	*16.8*
Subgroup 2	*80.0*	*29.4*
Subgroup 3	*91.0*	*16.8*
Failure mode 2	75.3	12.0
Failure mode 3	66.4	14.0

Conclusion

- Free deformation experiments :
  - Relation between the thickness reduction and radial deformation into a groove as function of the groove dimensions and energy level
- Optimisation of crimp joints with a double groove design :
  - DoE : optimal double groove design
  - Tensile strength of 96 - 100%
- DIC : 3 failure modes