Mirrors for the SST: How to make them?

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Outline of the talk…

- Brief review of the problem

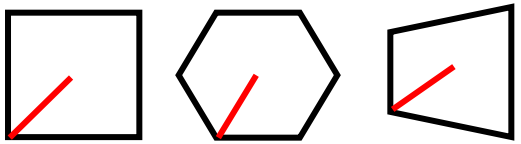
- Cold glass slumping technique

- Is the cold glass slumping usable for SST mirrors?

- Final considerations and (few) recommendations

Difficulties in making mirrors

SAGs [mm]	CTA-LST [D-C] spherical	MAGIC [D-C] spherical	CTA-MST [D-C] spherical
Primary	5.3	7	7



= ~700 mm

SAGs [mm]	CTA-SST D-C 7 m	CTA-SST S-C 4 m	CTA-SST S-C 7 m	CTA-SST 3MT 4 m		CTA-SST 3MT 7 m	
Primary	12	25	14	40		46	
Secondary		230	130	92		106	
Tertiary				160	80 80	184	92 92

Mild curvature, doable with cold glass slumping TBC

Mild curvature with aspherical profile, doable with cold glass slumping TBC

Strong and/or peculiar curvature, doable with a mixed cold+hot glass slumping TBC

Very strong and peculiar curvature, NOT doable with glass slumping, TBC

Difficulties in making mirrors

Is the cold glass slumping an usable technique to make the mirrors of the SSTs?

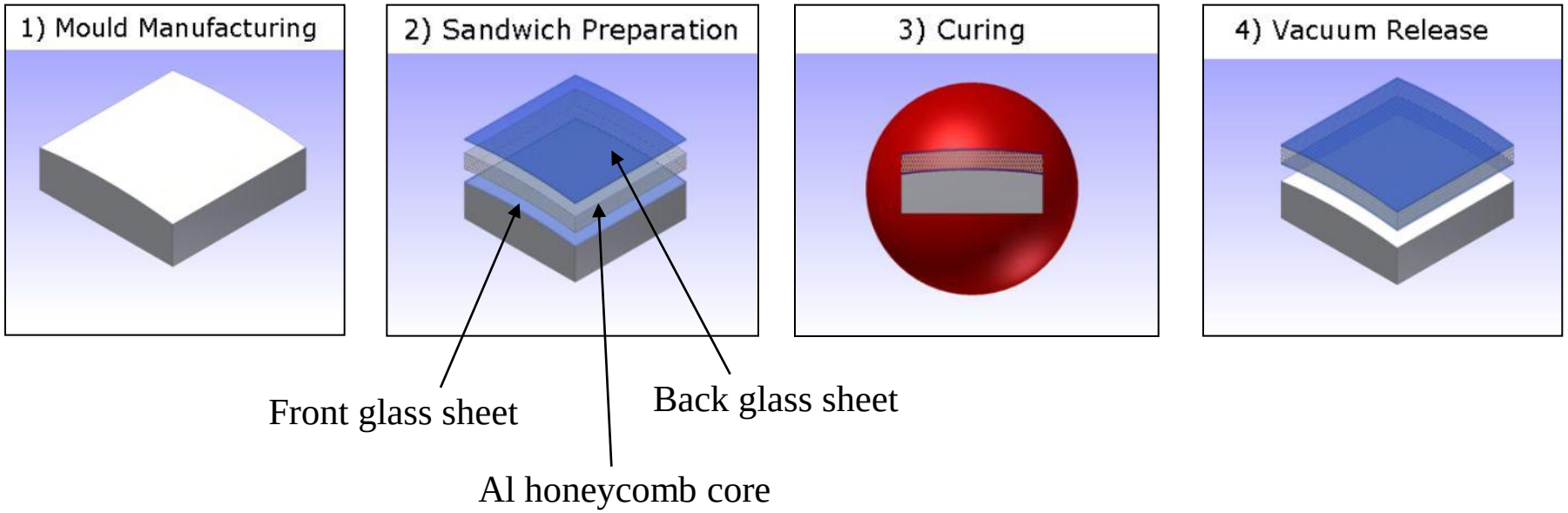
If YES:
- it is a proved technology;
- it is a very cheap technology;
- solid industrial partners available;
- we have a lot of experience!

If NOT:
- we have to find a new idea;
- we have to set an alternative industrial process;
- we have to invest a lot of money and time in development;

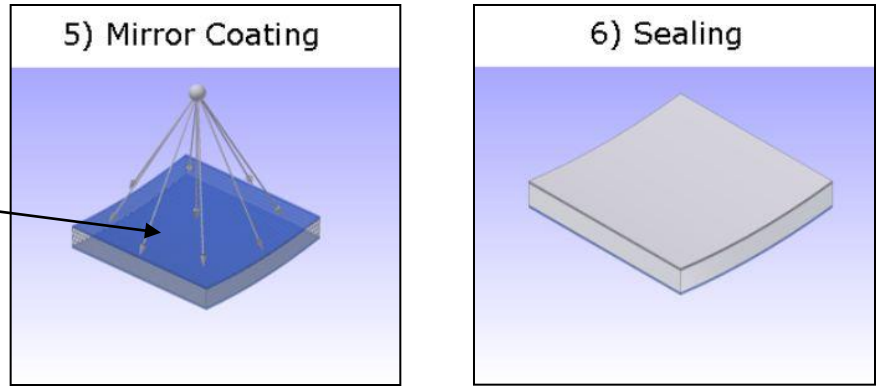
Remarks on the cold glass slumping technique

Today is already the best option for MST and LST

The cold glass slumping technique



PVD coating
Al + SiO_2



Is the cold glass slumping an usable technique to make the mirrors of the SST?

To try to answer to the Question we have started to investigate, through Finite Element Analyses, the theoretical limit of the cold glass slumping technology.

Using step-by-step analyses it is possible to follow the glass sheet during the whole process of the cold slumping.

Most critical is the vacuum suction, where the glass sheet is bended and forced to copy the shape of the master.
The bending is done taking advantage of the flexibility of the glass, and hence an elastic deformation occurs.
This inserts permanent stresses in the glass, than frozen by the bonding of the core.

Is the cold glass slumping an usable technique to make the mirrors of the SST?

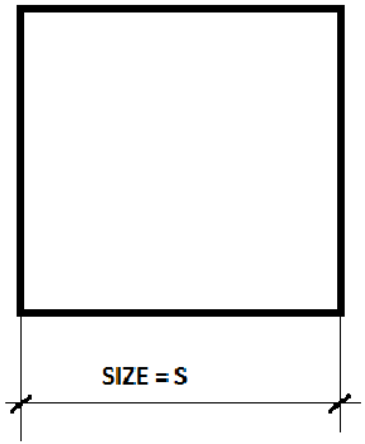
The question now becomes:

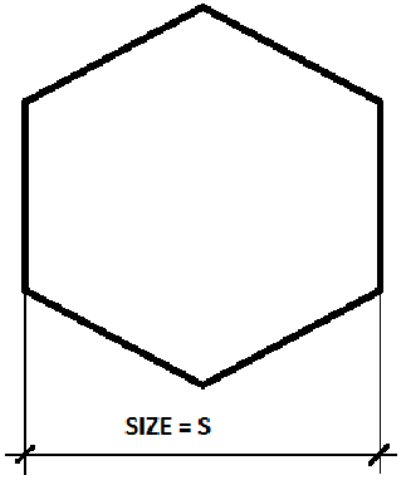
<u>Which is the stress level developed in the glass sheet?</u>

- is there any influence from the panel shape (petal, hexagon)?
- is there any influence from the panel size?
- is there any influence from the glass sheet thickness?

Can we make the radius of curvatures requested for the D-C or S-C?

Is the cold glass slumping an usable technique to make the mirrors of the SST?

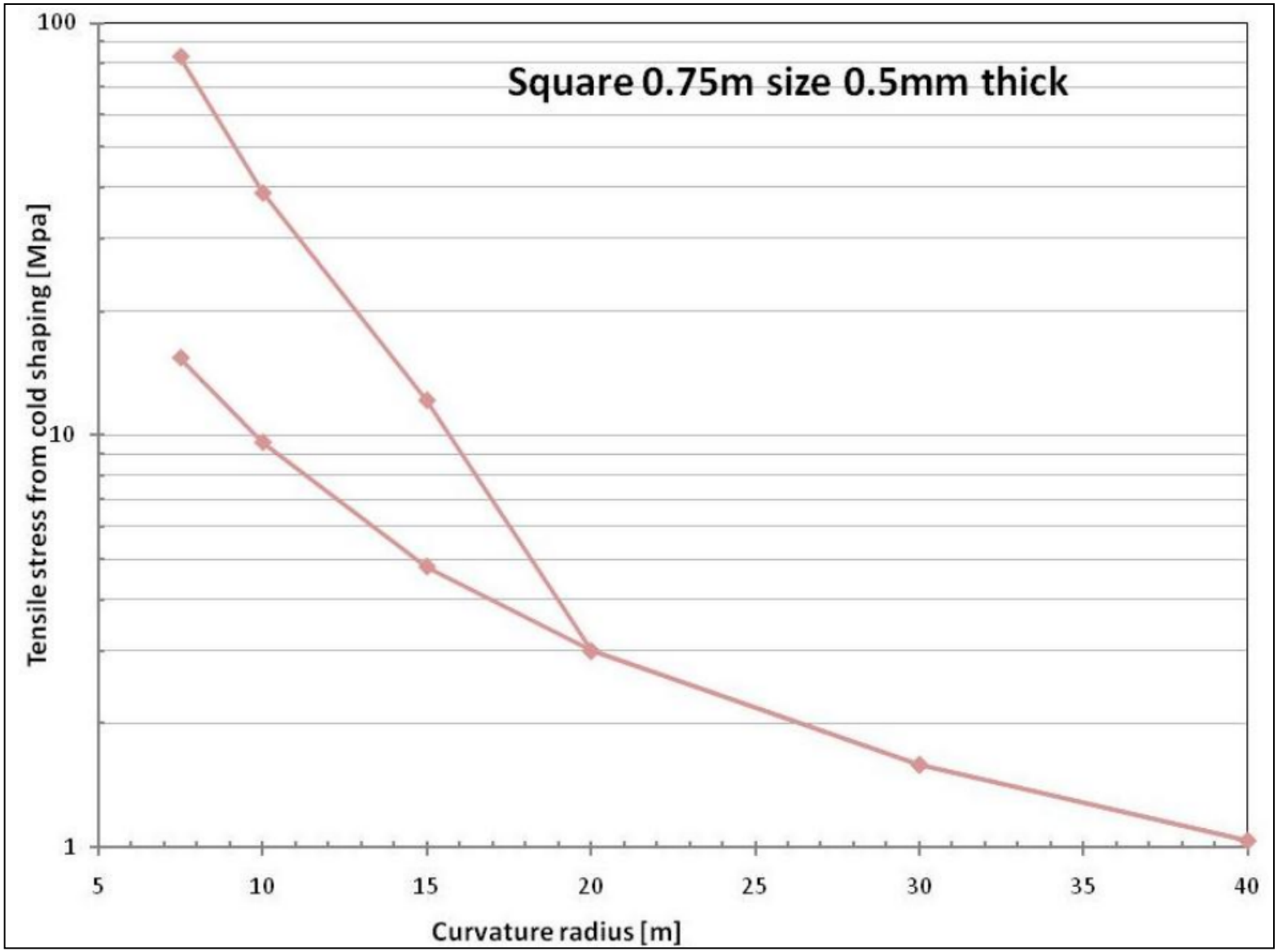




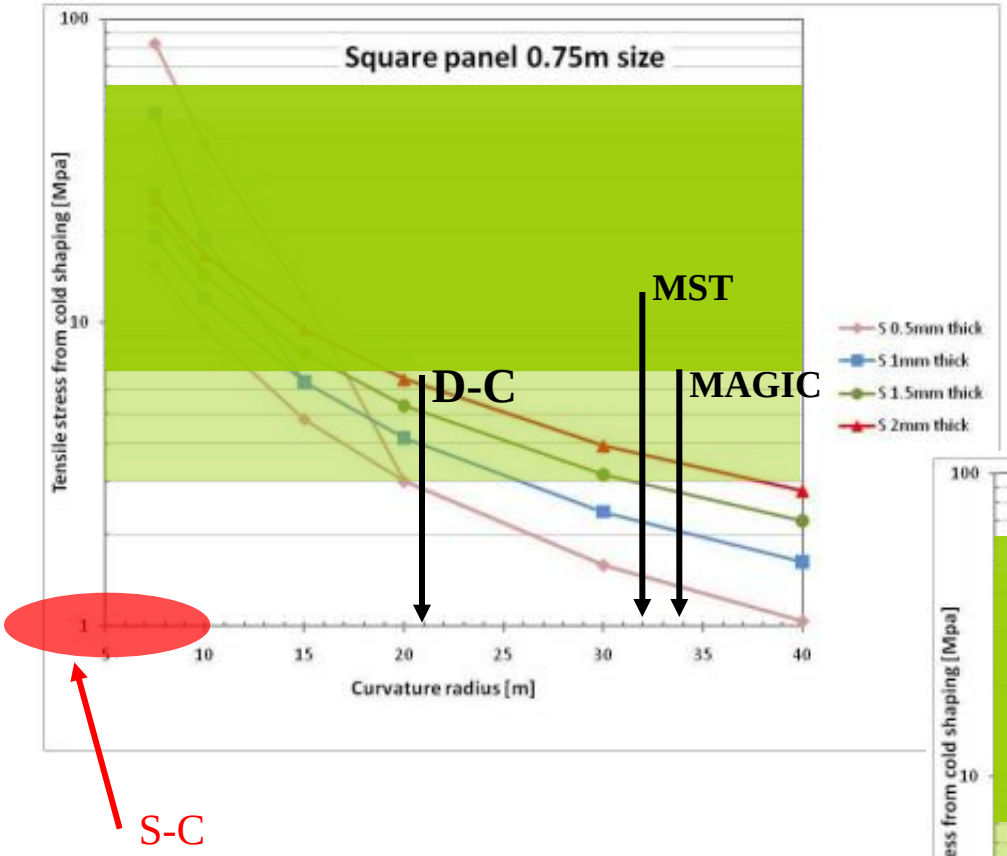
Standard float-glass properties	
Mass density	2.5 g/cm^3
Young's modulus	70 GPa
Poisson's ratio	0.2
CTE	$9 \cdot 10^{-6}$ K^{-1}
Tensile stress	6-~~7~~ MPa 3-4

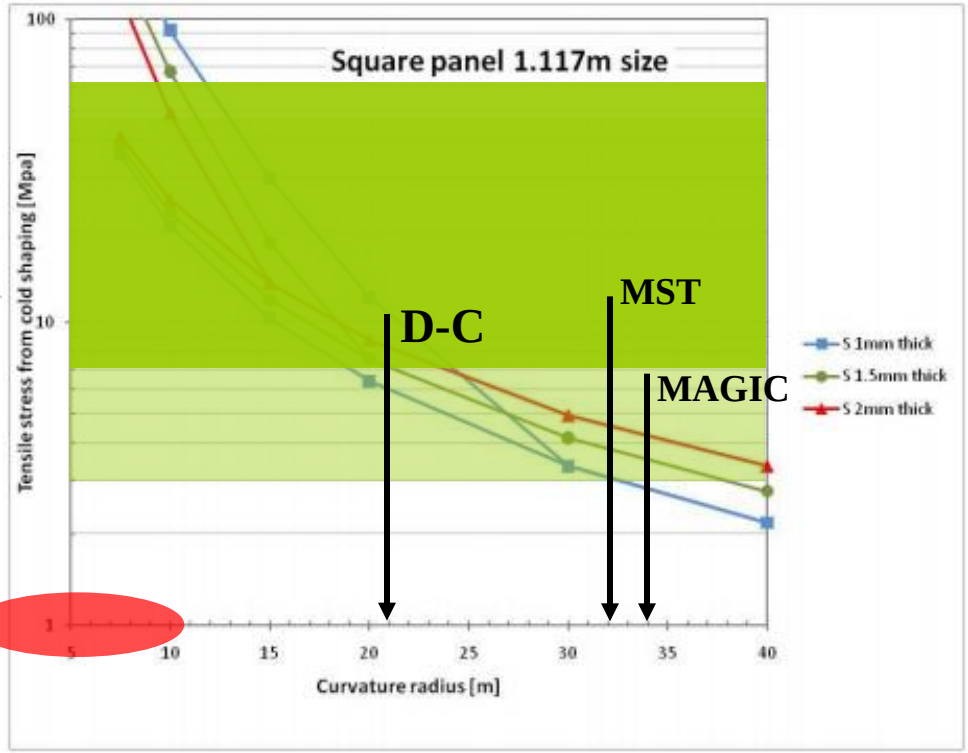
Square shape	Hexagonal shape	Panel area	Glass thickness
S = 0.75 m	S = 0.8 m	0.56 m^2	1.0; 1.5; 2.0 mm
S = 1.117 m	S = 1.2 m	1.247 m^2	0.5; 1.0; 1.5; 2.0 mm

Tensile stress [MPa] vs curvature radius [m] ~ example ~

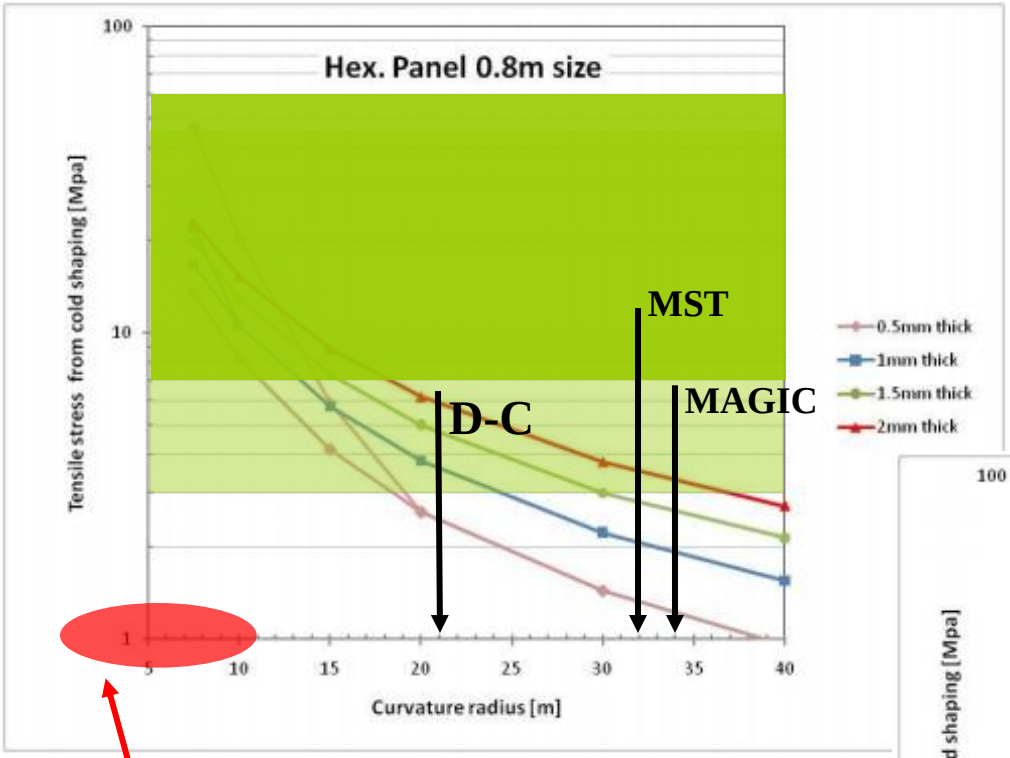


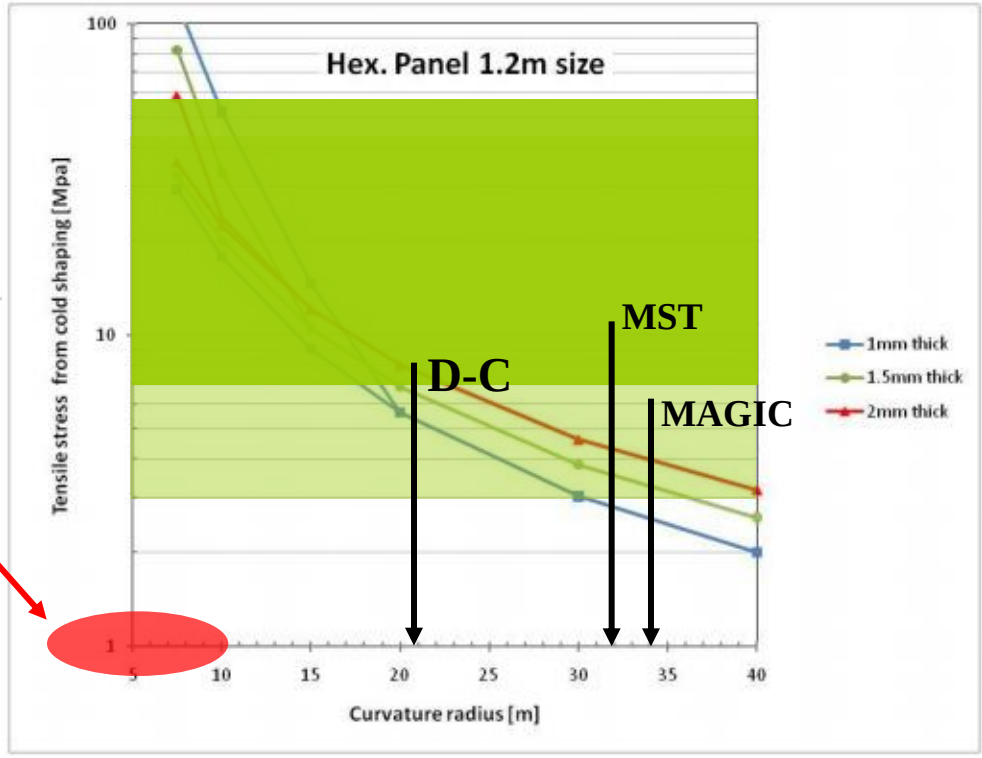
Tensile stress [MPa] vs curvature radius [m]
~ Square panels ~





Tensile stress [MPa] vs curvature radius [m]
~ Hexagonal panels ~





Final considerations

The work (and results) is still preliminary.

The indications are that the mirrors for the DC could be still doable with the cold slumping technology, but they are very close to the technology limits.

For the SC, there's no way to use the cold slumping "as it is".

Final considerations

For DC:

Recommendations are for smaller mirrors with the tile shape preferably as more symmetric as possible (i.e. hexagons are a bit better then petals).

But, small (and more) mirrors could mean higher costs (i.e. actuators, alignment system, dish structure).

To keep alive the large mirrors option, could be necessary to foresee some kind of glass surface treatments (edge cutting/finishing, chemical etching, chemical temper, etc.) to increase the glass strength.

We need to evaluate the cost increase in case of smaller mirrors vs surface treatments.

Final considerations

For SC:

Two options can be envisaged:

- use a different technology:
  - eForming? Taking advantage from the ALMA development
    - feasibility and cost should be investigated
  - direct figuring techniques (diamond milling, glass grinding, ect.) remain not competitive, at least from the production rate

- modify somehow the cold slumping:
  - use of a pre-shaped glass sheet with a “low-cost” thermal forming process
  - proceed with the usual steps foreseen in the cold slumping

Nickel eForming technology

Media Lario Reflector Technology

ALMA Telescope Basic Specifications

- Diameter: 12 m
- Reflectivity: Sunblind
- Total Surface: 128 m^2
- Nr. of Panels: 120

ALMA Panels Specifications

➢ Surface accuracy

• Surface accuracy including manufacturing and gravity (acceptance criterion, measured for each panel)

< 8.5 μm RMS

• Surface accuracy including environmental effects (analysis, supported by test)

< 11.0 μm RSS

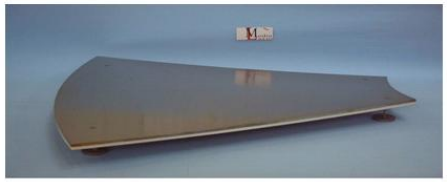
➢ Ability to observe the sun (solar radiation scattering surface)

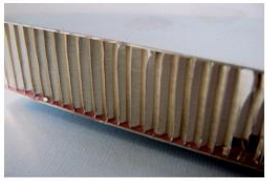
➢ Walkability (facilitate integration a alignment)

Media Lario Reflector Technology

Typical panel design

- Nickel alloy electroformed skins
- Aluminium honeycomb core
- Epoxy resin bonding material
- Silicon sealant material
- Special engraved surface finishing
- Rhodium coating of reflecting surface





Cold slumping 2.0

- Mixed approach → hot+cold glass slumping:
  - use of pre-curved glass sheets (i.e. from automotive industry, solar, architecture, etc.);
  - assembly of the panel following the cold approach.

Cost exercise: (based on a previous development)

- Hot step:
  - mould: 580x580 mm^2 with 5000 mm curvature: 8500 € (one-off)
  - glass: ~300 € per piece
- Cold step:
  - today costs about 2 k€/m^2

Being optimistic, foresaw total cost increase: about 20% more than today?

Final considerations

Anyway the cost per panel will be higher (today ~ 2 k€/panel).

How much higher? We need to evaluate it (and already started with industrial partner), but

<u>Please, keep this in mind when apply cost models in MC simulations!!</u>