

## Introduction:

- A flat glass gravity forming is the technology mainly used in automotive glass manufacturing.
- In this technology the glass is placed on the frame, is heated above the glass deformation temperature and is shaped due to its own weight.
- There are four main forming process parameters: viscosity of glass (which depends on glass composition and heating conditions), size of glass foil, frame shape and time of heat-treatment process.
- Profound understanding of the influence of parameters on the forming process enable the production of glass foils with high quality final geometry.
- Then this technology can be used for the production of optical mirrors.

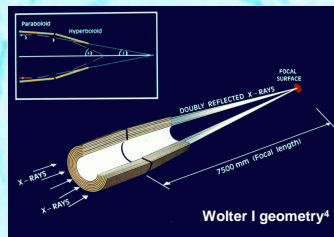
## Glass Gravity Forming – Technology for X-ray Space Telescopes:

- For future mission of x-ray telescopes the large collecting area is required. Glass could be a very promising material because of its low density.
- The mirror surface preserves its fine microroughness during forming because it is in no contact with any material.
- Wolter I geometry used for most of x-ray telescopes is a mirror assembly with several different radii, but gravity forming technology does not require preparation of precise mould for each radius of glass foil.
- The results from experiments were used for simulation to get parameters of forming process to prepare mirror with required radius of final geometry.

## Material specification:

- For experiment was used borosilicate glass,
- Desag D 263 produced by the Schott company,
- chemically resistant,
- with very fine surface micro roughness < 1 nm,
- produced by Corning technology with down directional pulling of glass,
- size of foil was 100 x 100 mm, 0,4 mm thick,
- density 2,51 g · cm<sup>-3</sup>.

## Possible future missions



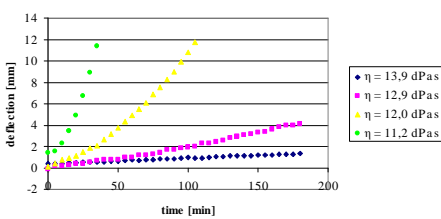
## Experiment specification:

- Glass foils were formed on a frame, by its own weight, without loading from the top.
- The frame consisted only from two opposite edges to simplify the experiment.
- The bending speed was examined at viscosity range log η from 11 to 14 dPas.
- Mirrors with required radii were prepared and measured by Taylor Hobson profilometer.
- Shape of prepared mirrors was compared with circle, parabola and polynomial functions.

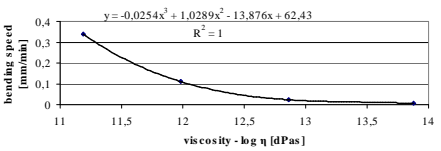
## Results of thermal forming:

- Dependence of deflection on the time of the heating process is unexpectedly non-linear.
- Average bending speed depends on viscosity of glass during forming.

Deflection for different heat-treatment processes



Average bending speed

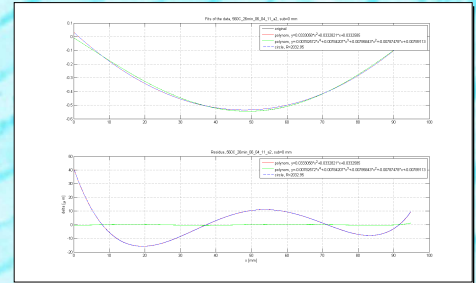
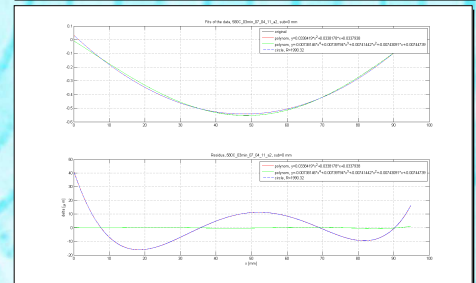


## Preparation of mirrors with required radius:

- From the diagram of deflection dependence on process conditions were obtained conditions for required radius.
- Deflection 1,3 and 0,6 mm is for radius 1 m and 2 m.

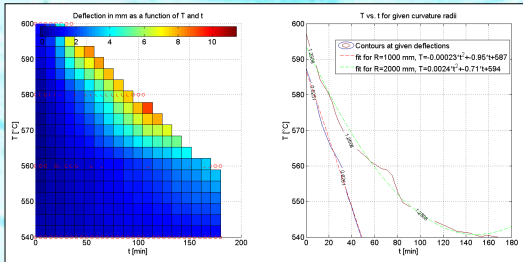
## Shape of mirrors with required radius 2 m:

- This two mirrors were prepared at different conditions and their shapes were compared.



## Conclusion:

- From the experiments was determined mathematical model of conditions of mirror forming process with required radius.
- This model can not be applied for times longer than 140 min and need to be corrected because of cooling process when the bending continues.
- Obtained shape is fitted by quadratic polynomial well.
- Deviation from circle fit was from 20 μm to 30 μm and it is too high for Wolter I optics.



## References:

- 1) René Hudec, IXO-Obří kosmický dalekohled s českou účastí, 3 pól, březen 2010
- 2) <http://www2.iaa.cs.cu/bulletin/news/press-releases/2009-2009/200710>
- 3) <http://www.snsa.cas.cz/5802-nano-mirrors-3mirrors-nan-nv-telescopie.html>
- 4) <http://www.st.bham.ac.uk/xmm/mirrors.html>

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