Summary of Herwig Bretis's Master's Thesis

Basic principles for the systematic generation of freely-shaped membrane shells made from sheet-metal

The idea for manufacturing membrane structures from sheet-metal is not a new one. The potential, which such structures offer for applications in technology, architecture and design, has, however, not been exhausted by far.

The aim of this Master's Thesis is to develop a process chain for the systematic production of freely-shaped membrane shells made from sheet-metal, using highly-developed computer technology (CAD and FEM). The term freely-shaped membrane shells is used here to apply to thin-walled shells in any user-defined form, as opposed to classical mathematically defined forms such as spheres, cones, cylinders, etc.

In order to exclude "trial and error" in production (which usually leads to unaffordable costs), a "trial and error"- method during the planning stage has been chosen.

An important step in this iteration cycle is the approximation of the free form, with the aid of mono-flexuous, developable surfaces. Subsequently, the production method is chosen. In this thesis, hydroforming is applied. Before the final (real) shaping takes place, the transformation of this composition of flat surfaces is simulated with a finite element analysis. At this stage, a real component fails to exist. Everything is only in a virtual state. This virtual transformation may only be possible with a number of iteration cycles for complicated objects. In doing so, the approximation of the free form is altered with an improved composition of mono-flexuous, developable surfaces. Metal thicknesses or qualities can be changed and the production method or boundary conditions such as restraints and fixings can be introduced. Ideally, this process should be able to run partially automatically. The FE and CAD systems are able to execute this iteration via individual additional programming. If the transformation process can be steered such that the outline proves to be exact enough after the numerical simulation, the actual production process can then begin.

Reasonable assumptions must be made within the chain. Discretisations for engineers exist within the calculation model, which are concerned with e.g. welds, geometric imperfections, anisotropism and manufacturing tolerances.
The intention is to recognise and minimise mistakes during planning. Therefore, the focus of this paper has been put upon the simulation of the transformation procedure, with the aid of the finite element method.

In this paper, chapter one is concerned with the mechanical principles of the theory of plasticity, with a short excursus to geometry fundamentals, as well as to materials suited to the procedure.
Chapter two illustrates the applied FE programme. It gives an overview of the structural elements used there and their available adjustment options.
The main chapter, three, looks into the question as to whether the FE programme is capable of calculating correctly or precisely enough within the stated limits, by using simple examples, the analytical solution of which is already known.
Chapter four details reshaping experiments on a length of pipe and a free form. This provides the transition into praxis.
Chapter five gives an outlook on future prospects.

It has been proven that this concept is very promising and that it can be worthwhile propagating this manufacturing technique in the fields of design, architecture and industry.