Inflated Membrane Structures on the Ground, in the Air and in Space - A Classification

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Summary. *In the following an introduction to basic principles of inflated structures, their potential and their limitation is given. Geometry and Shapes are investigated as well as structural differences within high and low pressure structures and their typical pressure control problems. A brief morphological sketch of inflated structures is presented, which opens the room to further development in the future.*

Key words: Membrane structures, inflated structures

Introduction

Membranes are known as very thin walled flexible surfaces, shaped and stabilised by pretensioning. They are a promising solution for covering and spanning wide spaces. In contrast to thin shells, which also carry their loads mainly by in-surface forces, they are not able to withstand compression loads, which result in folds. The pretension can be built up either by an external tension field or by internal pressurisation. Membranes have the advantage of foldability. They can be packed and trans- ported easy and can be erected by inflation to serve as a permanent or a temporary building. The variability in construction can be classified as follows:

1. Permanent membrane structures with external pretension
2. Permanent and temporary membrane structures with inflated walls
3. Structures with full gas volume
4. Buoyancy structures
5. Interesting combinations

1 Permanent Membrane Structures with External Pretension

The outside tension field is normally erected by cables, struts and bearings. Examples therefore are the Olympic roof in Munich, see Fig. 1 or the cooling tower of Schmehausen, see Fig. 2. This type of construction results in huge struts and bearings, since all pretension forces have to be grounded.

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Fig. 1. Olympic stadium roof Munich [1], permanent

Fig. 2. Cooling tower Schmehausen [2], permanent

2 Permanent and Temporary Membrane Structures with Inflated Walls

Another class are the inflated structures. There are two different types, the structures with inflated walls and the structures with inflated volumes. The walls can be inflated by high or low pressure. For high pressure closed wall-chambers are used with the pressure probably exeeding 1 bar requiring rein- forced membrane materials. An example is the Festo-building at Stuttgart, see Fig. 3. Pressure and manufacturing required a rubber coated Polyester fabric. In the case of low pressure, about 50 mbar, an open wall can be used, whereby the pressure is permanently imposed by a blower, which is capable to erect the structure. See e.g. the temporary Builtair-roof in Barcelona Fig. 4. Recently the inflated wall principle was also introduced by Russian reserchers to reentry vehicles for the return from space to earth.

Fig. 3. Festo-building in Stuttgart [3], permanent

Fig. 4. Build-Air-building in Barcelona [4], temporary

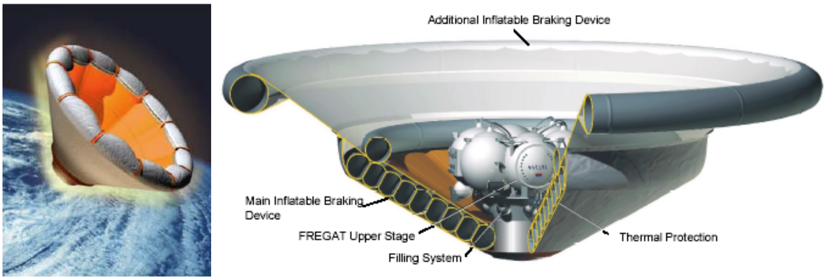

Fig. 5. Inflated reentry capsule [5]

3 Structures with Full Gas Volume

The inflated tennis court-halls of the last century are a well known example for this class of structures, see Fig. 6. Since the air pressure has to be maintained permanently for the stability of the structure, the doors are designed as double door pressure lock. Another example to overcome the totally inflated space inside is to inflate only the roof. Fig. 7 gives an example. For adaptation to different load cases, e.g. snow, a spherical pressure chamber is included.

Fig. 6. Tennis court cover [6], permanent

4 Buoyancy-Structures

If the inside space of the structure is filled with a gas lighter than air, an upward force is created, which is called buoyancy. The buoyancy depends on the density difference between the internal and the external medium. The principle has been used since the 18th Century. 1 m^3 buoyancy gas, e.g. helium, can roughly carry 1 kg

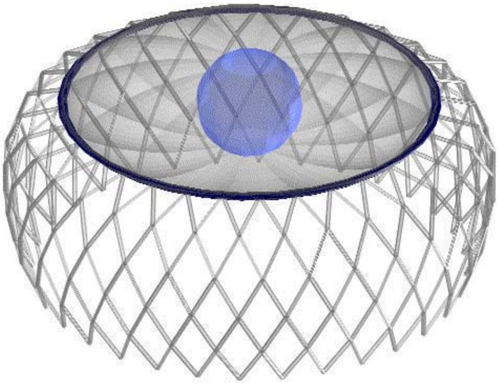

Fig. 7. Inflated roof with pressure chamber [7]

Fig. 8. High altitude balloon [8]

at mean sea level. The buoyancy is a natural energy potential. Its activation needs no energy. Nevertheless the potential for “flying structures” seems to be not fully explored yet.

The classical example is the high altitude balloon. It can be seen from Fig. 8, that in this case the shape depends on the expansion of the buoyancy gas, which expands when the outside air density diminishes during the ascent.

If the shape of the body should be kept constant at all altitudes, e.g. for aerodynamic drag reasons, a ballonet-technique can be used, see Fig. 9. Inside the body air inflated balloons are placed, which release their volume to the outside in the same manner as the air pressure decreases during ascent and the buoyancy gas expands. During decent air has to be pumped into the ballonets in order to keep the gas pressure in the body at a certain level. The differential pressure level is typically around 500 Pascal.

The ballonet principle can be used as pressure control in ground structures also as external ballonet outside the structure. A hall of his type has been built 1992 at the International Garden Exhibition in Stuttgart, see Fig. 10. The full roof of the structure, which can be opened including the supporting ring-structure, is carried by buoyancy.

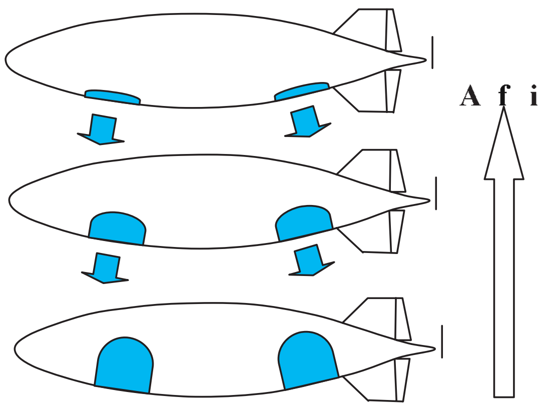

Fig. 9. Ballonet system in an airship [9]

Fig. 10. HELION - Buoyancy structure Stuttgart 1993 [10]

5 Interesting Combinations

In order to optimize the structure further different principles might be coupled. For this three examples are given:

The AirChain An interesting and efficient concept is obtained, if a number of high altitude balloons is coupled to a chain and covered by a aerodynamically smooth surface. The vehicle flies controlled by engines in each segment, see Fig. 11.

Fig. 11. AirChain Stuttgart, Test Flight 1999 [11]

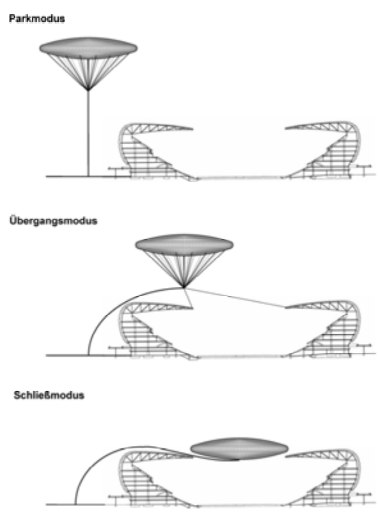

Fig. 12. Flying Roof, Munich 2000 [12]

The Flying Roof The mixture of the buoyancy principle and the Japanese Kite tradition lead to the design of a station roof. The stadium can be closed or opened within half an hour. The roof is parked in the air outside of the station and is stabilized like a kite, see Fig. 12.

The Paraglider Finally the good old parachute combines the externally prestessed membrane and the inflated membrane and receives from an intelligent combination of both its stability and its flight control see Fig. 13.

Fig. 13. Double Wing Paraglider at automatically guided flight [13] Stuttgart 2003

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