A morphing structure comprises an outer wall defining an outer surface of the morphing structure. The outer surface can change shape between a predetermined first and second shape. The morphing structure comprises a first and second row of interconnected cells which extend substantially adjacent to the outer surface of the morphing structure. The cells of the first and second row extend adjacent to each other and are connected to each other. Each cell has a polygonal cross-section and comprises a plurality of walls which are pivotally connected to each other by joints. Each cell comprises a substantially pressure-tight chamber. The pressure-tight chambers of the cells of each row are in fluid communication with each other by means of fluid passages. Each cell can change shape between a first and second cross-sectional shape. The polygonal cross-sections of a plurality of the cells of the first row differ from each other and the polygonal cross-sections of a plurality of the cells of the second row differ from each other. The polygonal cross-sections of the cells of the first and second rows are configured such that, for predetermined pressure ratios between the pressure in the pressure-tight chambers of the cells of the first row and the pressure in the pressure-tight chambers of the cells of the second row, the cells of the first and second row assume their first or second cross-sectional shape and the outer surface of the morphing structure assumes the predetermined first or second shape.
Title: A morphing structure and method for morphing a structure

The invention relates to a morphing structure comprising:
- an outer wall defining an outer surface of the morphing structure, which outer surface can change shape between a predetermined first shape and a predetermined second shape,
- a first row of interconnected cells extending substantially adjacent to the outer surface of the morphing structure, each cell of the first row having a polygonal cross-section and comprising a plurality of walls which are pivotally connected to each other by joints, each cell of the first row comprising a substantially pressure-tight chamber, the pressure-tight chambers of the cells of the first row being in fluid communication with each other by means of fluid passages, each cell of the first row being able to change shape between a first shape and a second shape,
- a second row of interconnected cells extending adjacent to the first row of cells, the cells of the second row being connected to the cells of the first row, each cell of the second row having a polygonal cross-section and comprising a plurality of walls which are pivotally connected to each other by joints, each cell of the second row comprising a substantially pressure-tight chamber, the pressure-tight chambers of the cells of the second row being in fluid communication with each other by means of fluid passages, each cell of the second row being able to change shape between a first shape and a second shape.

In this patent application, the term “joint” should be understood as a pivotal connection between the walls of a cell. For example, each joint defines a pivot axis or pivot centre line. The joints may be constructed in various ways. For example, the joints of a cell may comprise hinge pins or the joints of a cell may be integrated into the walls of said cell as weakened portions which have a smaller bending stiffness than the adjacent portions of the walls, such as film hinges. It is also noted that according to the invention the walls of each cell of the first row and/or the walls of each cell of the second row may be planar or curved, for example slightly elliptic.

US 2005/0029406 describes a cellular actuator device for actuating a control surface of an aircraft or spacecraft. The device is made from a number of elementary cells which are combined to form a common elementary cell arrangement. The elementary cells contain at least one first pressure-tight chamber and at least one second pressure-tight chamber. The elementary cells can be acted upon by a pressure medium to be deformed in at least one working direction while changing their length. When the pressure in the first chamber of the
elementary cell is increased in comparison to the pressure in the second chamber of the elementary cell, the volume rises in the first chamber in comparison to the volume in the second chamber, which results in a contraction of the elementary cell in the working direction. If, on the other hand, the pressure in the second chamber is increased with respect to the pressure in the first chamber, this results in an expansion of the volume in the second chamber with respect to the volume in the first chamber and the elementary cell expands in the working direction. For combining their length changes in the working direction to an overall movement of the elementary cell arrangement, the elementary cells are mutually coupled. The cellular actuator device can be used to replace a hydraulic cylinder.

In the case of a rudder, for example, the rudder includes two cellular actuator devices on opposite sides of the hinge axis of the rudder. Each cellular actuator device is deformable in the working direction while changing its length in a direction transversely to the hinge axis of the rudder, essentially in the direction parallel to the chord, i.e. the straight line from the leading edge to the trailing edge of the rudder. For a deflection of the rudder in one direction, one cellular actuator device is contracted and the other cellular actuator device is expanded, or vice versa.

The individual elementary cells may be combined such that they result in different shapes of the cellular actuator device. If the elementary cells are arranged in a plane, a plate-shaped cellular actuator device is obtained. By means of other spatial arrangements of the elementary cells, spherically or generally three-dimensionally curved actuators may be contemplated. However, irrespective of the spatial arrangement of the elementary cells, the cellular actuator device changes its shape mainly in the plane of the elementary cells. The cellular actuator device cannot be used to accurately adapt the shape of an outer surface of a morphing structure between two predetermined desired shapes, for example two aerodynamic profiles relating to different flight conditions.

It is an object of the invention to provide an improved morphing structure, in particular a morphing structure which allows the outer shape of the morphing structure to be adapted between two predetermined shapes in an accurate manner.

This object is achieved according to the invention by a morphing structure comprising:

- an outer wall or skin wall defining an outer surface of the morphing structure, which outer surface can change shape between a predetermined first shape and a predetermined second shape,

- a first row of interconnected cells extending substantially adjacent to the outer surface of the morphing structure, each cell of the first row having a polygonal cross-section
and comprising a plurality of walls which are pivotally connected to each other by joints, each cell of the first row comprising a substantially pressure-tight chamber, the pressure-tight chambers of the cells of the first row being in fluid communication with each other by means of fluid passages, each cell of the first row being able to change shape between a first shape and a second shape, in particular a first cross-sectional shape and a second cross-sectional shape,

- a second row of interconnected cells extending adjacent to the first row of cells, the cells of the second row being connected to the cells of the first row, each cell of the second row having a polygonal cross-section and comprising a plurality of walls which are pivotally connected to each other by joints, each cell of the second row comprising a substantially pressure-tight chamber, the pressure-tight chambers of the cells of the second row being in fluid communication with each other by means of fluid passages, each cell of the second row being able to change shape between a first shape and a second shape, in particular a first cross-sectional shape and a second cross-sectional shape,

wherein

the cells of the first and second rows are configured such that the polygonal cross-sections of a plurality of the cells of the first row differ from each other and the polygonal cross-sections of a plurality of the cells of the second row differ from each other, and

the polygonal cross-sections of the cells of the first and second rows are configured such that,

for a first predetermined pressure ratio between the pressure in the pressure-tight chambers of the cells of the first row and the pressure in the pressure-tight chambers of the cells of the second row, the cells of the first row assume their first shape and the cells of the second row assume their second shape, and the outer surface of the morphing structure assumes the predetermined first shape, and

for a second predetermined pressure ratio between the pressure in the pressure-tight chambers of the cells of the first row and the pressure in the pressure-tight chambers of the cells of the second row, the cells of the first row assume their second shape and the cells of the second row assume their first shape, and the outer surface of the morphing structure assumes the predetermined second shape.

It should be noted that the invention is not limited to a morphing structure with two rows of interconnected cells – the morphing structure according to the invention may comprise any number of additional rows of interconnected cells. Thus, where the description below refers to the first and second rows of cells of the morphing structure, it should be
understood that the morphing structure may also comprise additional rows of cells similar to the first and second rows of cells.

According to the invention, each single cell of the first and second rows is individually tailored to enable the morphing structure as a whole to be adaptive between the predetermined first and second target shapes of the outer surface of the morphing structure. Thus, when the predetermined first and second shapes of the outer surface of the morphing structure are given, for example by two different functions, the associated polygonal cross-sections of each of the cells of the first and second rows are individually defined, for example by means of a computer program, for the first and second predetermined pressure ratios.

Therefore, the cells of the first and second rows are configured in a substantially unstructured or irregular manner such that the polygonal cross-sections of a plurality of the cells of the first row differ from each other and the polygonal cross-sections of a plurality of the cells of the second row differ from each other, although it should be noted that the resulting polygonal cross-sections of the cells may include a number of substantially identical polygonal cross-sections.

In other words, the polygonal cross-sections of a plurality of the cells of the first row and of a plurality of the cells of the second row are not identical to each other, but substantially different from each other. This is unlike the state of the art as described above, in which all the first chambers of the elementary cells are substantially identical to each other and all the second chambers of the elementary cells are also substantially identical to each other, i.e. the first and second chambers of the elementary cells, respectively, all have equal dimensions and define a structured, repetitive pattern.

Thus, the cells of the first and second rows have different polygonal cross-sections.

In addition, according to the invention, the different polygonal cross-sections of the cells are not arbitrarily defined, but the polygonal cross-sections of the cells are designed such that the combination of the individually tailored cells of the first and second rows result in an overall morphing structure which morphs into the predetermined first and second target shapes for the first and second predetermined pressure ratios between the pressure in the cells of the first row and the pressure in the cells of the second row.

For example, when the first row of cells is pressurized to a pressure $p_1$ and the second row of cells is subjected to a pressure $p_2$, defining the first predetermined pressure ratio $p_1/p_2$, the cells of the first row take their first shape and the cells of the second row have their second shape. The pressures $p_1$ and $p_2$ may have various values, for example, the pressure $p_1$ is 5 bar and the pressure $p_2$ is 1 bar, but other pressures may be used.
Accordingly, the first predetermined pressure ratio \( p_1/p_2 \) may be equal to 5 or any other number, including 1. Thus, the first predetermined pressure ratio \( p_1/p_2 \) between the first row of cells and the second row of cells leads to the first and second shapes of the cells of the first and second rows, respectively. The geometries of the cells of the first and second rows are designed such that the outer surface of the morphing structure then defines the predetermined first shape.

Furthermore, if the pressure ratio between the pressure in the cells of the first row and the pressure in the cells of the second row \( p_1/p_2 \) is changed from the first predetermined pressure ratio \( p_1/p_2 \) to the second predetermined pressure ratio \( p_1/p_2 \), i.e. the first row of cells is pressurized to a pressure \( p_1 \), and the second row of cells is subjected to a pressure \( p_2 \) defining the second predetermined pressure ratio \( p_1/p_2 \), the cells of the first row are transformed into their second shape and the cells of the second row are transformed into their first shape. Again, the pressure \( p_1 \) in the first row of cells and the pressure \( p_2 \) in the second row of cells may have various values, for example, the pressure \( p_1 \) is 1 bar and the pressure \( p_2 \) is 5 bar, but other pressures may be used. Accordingly, the second predetermined pressure ratio \( p_1/p_2 \) may be equal to 0.2 or any other number, including 1. For the second predetermined pressure ratio \( p_1/p_2 \) between the first row of cells and the second row of cells, the outer surface of the morphing structure morphs into the predetermined second shape as a result of the design of the geometries of the cells. Thus, by changing the pressure ratio \( p_1/p_2 \) between the first row of cells and the second row of cells from the first predetermined value to the second predetermined value and vice versa, the morphing structure can morph between the predetermined first and second target shapes.

In other words, the geometries of the cells of the morphing structure according to the invention are completely tailored to the predetermined first and second target shapes of the outer surface of the morphing structure for the first and second predetermined pressure ratios \( p_1/p_2 \). As a result, the shape of the morphing structure according to the invention may be adaptive to the desired first and second shapes in a very accurate manner.

In an embodiment, each cell of the first and/or second row has a hexagonal or pentagonal cross-section. Thus, it is possible for each cell of the first row to have a hexagonal cross-section, and it is also possible for each cell of the first row to have a pentagonal cross-section, and it is furthermore possible for the cells of the first row to have either a hexagonal or pentagonal cross-section. Furthermore, it is possible for each cell of the second row to have a hexagonal cross-section, and it is also possible for each cell of the second row to have a pentagonal cross-section, and it is furthermore possible for the cells of the second row to have either a hexagonal or pentagonal cross-section. With a morphing
structure having additional rows of interconnected cells, each cell of any intermediate row preferably has a hexagonal cross-section. When the cells of the first and second rows, and optionally additional rows, have hexagonal or pentagonal cross-sections, it is possible to very accurately tailor the geometries of the cells such that the overall morphing structure morphs into the predetermined first and second target shapes for the specific predetermined pressure ratios.

In an embodiment, each cell of the first row has a pentagonal cross-section, in which the outer surface of the outer wall comprises one of the walls of each cell of the first row. When each cell of the first row has a pentagonal cross-section, it comprises five walls which are pivotally connected to each other by five joints. In this case, one of the walls of each cell of the first row defines a portion of the outer surface of the outer wall of the morphing structure. Thus, the outer surface of the outer wall of the morphing structure is formed integrally with the cells of the first row of the morphing structure. This leads to a large strength to self-weight ratio for the morphing structure.

In an embodiment, the hexagonal or pentagonal cross-section of each cell is substantially convex. In this case, the cells have a substantially convex hexagonal or pentagonal cross-sectional shape. When the pressure-tight chamber of such a cell is pressurized, the geometry of said cell is modified so as to maximize the volume of said cell. As the hexagonal or pentagonal cross-section of the cell is substantially convex, the morphing structure changes its shape in a controlled and accurate manner between the predetermined first and second shapes of the outer surface of the outer wall.

In an embodiment, the walls of the cells of the first and second rows are substantially rigid, in which the cells of the first and second rows are able to change shape by rotation of the walls around the joints. The walls of the cells define the cell sides in cross-section. The walls of the cells are substantially rigid, i.e. they have a substantially inextensional length. By pressurizing the pressure-tight chambers of the cells, the walls of the cells are rotated about the joints so as to modify the geometry of the cells while the lengths of the walls of the cells remain substantially fixed. Using cells with substantially rigid planar walls simplifies the computation of the polygonal cross-sections of the cells which are adapted to the predetermined first and second shapes of the outer surface of the outer wall.

In an embodiment, the cells of the first row are connected to each other by means of common walls, and/or in which the cells of the second row are connected to each other by means of common walls, and/or in which the cells of the first row and the cells of the second row are connected to each other by means of common walls. The side lengths of the polygonal cross-sections of the interconnected cells are defined by the common walls, i.e.
the lengths of said side lengths are equal. As the cells of the first row and the cells of the second row share common walls, the cells of the first and second rows are linked up with each other in an interacting manner.

In an embodiment, the outer surface of the outer wall defines, as seen in cross-section, at least a portion of an airfoil comprising a leading edge, a trailing edge, an upper side and a lower side, and in which the cells of the first row extend along the upper side, at least one of the edges and the lower side, and in which the cells of the second row extend adjacent to the first row of cells along the upper side, said at least one of the edges and the lower side.

In this case, the morphing structure may comprise a linkage mechanism which is pivotally connected to one of the joints of one of the cells of the second row along the upper side and to one of the joints of one of the cells of the second row along the lower side. When the morphing structure comprises a rigid base structure, which supports the first row of cells and the second row of cells, the linkage mechanism may also be pivotally connected to the rigid base structure. The linkage mechanism may be a passive or active linkage mechanism. For example, the linkage mechanism consists of a rigid body.

When the geometries of the cells of the first and second rows are individually tailored to the predetermined first and second target shapes of the outer surface of the morphing structure for given, predetermined pressure ratios, the solution is not unique, i.e. there are a number of possibilities to design the geometries of the cells in such a manner. The non-uniqueness in the form-finding process allows the enforcement of additional constraints in the form of the linkage mechanism. The linkage mechanism provides displacement constraints for certain joints of the cells and increases the stiffness of the morphing structure.

The morphing structure may be constructed in various manners. For example, the cells of the morphing structure may be formed by steel plates which are connected to each other by hinges, in which a rubber tube or a specially tailored membrane is fitted into each cell so as to pressurize said cell. Advantageously, the morphing structure is a monolithic structure, in which the walls and the joints of the cells are integrated and the joints are formed by weakened portions of the walls, for example by reducing the wall thickness locally at the cell corners. In this case, the walls of the cells may be rotated about the pivot centre lines defined by the joints being integrally formed with the walls. This results in a large strength to self-weight ratio. The monolithic structure can be made of different materials. For example, the monolithic structure comprises carbon.
The morphing structure can be used in many different applications, for example for shape changing structures such as keels, rudders of high performance ships, regeneratively cooled nozzles for jet planes or rockets. In particular, the morphing structure may be arranged in an aircraft, for example, in an aircraft wing.

The invention also relates to a method for changing the shape of a morphing structure as described above. In a particular embodiment, the morphing structure is arranged in a fluid, and the morphing structure generates a propulsion force when the morphing structure changes shape from the predetermined first shape to the predetermined second shape and vice versa. For example, the predetermined first and second shapes are defined by a sin and cos function. Thus, the morphing structure may be used for propulsion.

The invention will now be explained, merely by way of example, with reference to the figures.

Figures 1a, 1b show schematic cross-sectional views of a first embodiment of a morphing structure according to the invention, in which the outer surface of the morphing structure has a predetermined first and second shape, respectively.

Figures 2a, 2b show enlarged details IIa and IIb of figures 1a and 1b.

Figure 3 schematically shows a pressurization system for pressurizing the cells of the morphing structure shown in figures 1a, 1b.

Figures 4a, 4b show schematic cross-sectional views of a second embodiment of a morphing structure according to the invention, in which the outer surface of the morphing structure has a predetermined first and second shape, respectively, and in which a linkage mechanism is incorporated into the morphing structure.

Figures 5a, 5b, 5c schematically show a third embodiment of a morphing structure according to the invention.

The morphing structure according to the invention is designated by reference numeral 1. In this exemplary embodiment, the morphing structure 1 is integrated into a wing structure of an aircraft. The wing structure comprises an outer wall or skin wall 3 which defines an outer surface 5 of the morphing structure 1. As seen in cross-section, the wing structure defines an airfoil having a leading edge 6, a trailing edge 7, an upper side or suction side 8 and a lower side or pressure side 9.

The wing structure is equipped with high-lift devices so as to increase the lift coefficient, in particular during landing. The wing structure comprises a flap 10 which can be displaced from a retracted position to an extended position and vice versa, as shown in figures 1a and 1b. The operation of such a flap 10 is generally known. The flap 10 may

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increase the lift coefficient of the aircraft significantly. However, the actuation of the flap 10 leads to additional weight, complexity and cost penalties.

It is also generally known to use a slat to increase the lift coefficient of the wing (not shown). Instead of such a conventional slat, the wing structure comprises the morphing structure 1 according to the invention. Using the morphing structure 1 the shape of the outer surface 5 of the nose of the wing structure can be changed. Thus, the wing structure can be adapted to different flight conditions.

Although the morphing structure 1 in this exemplary embodiment is integrated into the nose of a wing structure, it should be understood that the morphing structure 1 can also be arranged, for example, at the trailing edge 7 so that the flap 10 can be omitted.

Furthermore, the morphing structure 1 may be adapted to change the shape of the entire wing structure. In addition, the morphing structure 1 can also be applied to other shape changing structures.

The morphing structure 1 can be adapted so that the outer surface 5 changes shape from a predetermined first shape as shown in figures 1a, 2a to a predetermined second shape as shown in figures 1b, 2b, and vice versa. In this exemplary embodiment, the predetermined first and second shapes are imposed by different flight conditions. In other applications, the predetermined first and second shapes may relate to other desired specifications.

In order to enable said shape change the morphing structure 1 comprises a first row of interconnected cells 11 extending substantially adjacent to the outer surface 5 of the morphing structure 1. The morphing structure 1 also includes a second row of interconnected cells 12 extending adjacent to the first row of cells 11 on the inside of the first row of cells 11, i.e. on the side of the first row of cells 11 which is facing away from the outer surface 5. As the morphing structure 1 in this exemplary embodiment is integrated into the nose of the wing structure, the cells 11, 12 of the first and second rows extend along the upper side 8, the leading edge 6 and the lower side 9 of the airfoil.

Each cell 11, 12 of the first and second rows has a polygonal cross-section. In the exemplary embodiment shown in figures 1a, 1b, the cells 11 of the first row have a pentagonal cross-section, whereas the cells 12 of the second row have a hexagonal cross-section. As shown in the figures, the pentagonal or hexagonal cross-sections of each cell 11, 12 are each substantially convex.

Each cell 11, 12 of the first and second rows comprises a plurality of walls 14 which are pivotally connected to each other by joints 15 which define pivot axes for the walls 14.

The cells 11 of the first row have common walls 14. Similarly, the cells 12 of the second row
include common walls 14. In addition, the cells 11 of the first row and the cells 12 of the second row are interconnected by common walls 14. As a result, the cells 11 of the first row and the cells 12 of the second row are joint together in an interacting manner.

The walls 14 of the cells 11, 12 of the first and second rows are substantially rigid, i.e. each side length of the pentagonal and hexagonal cross-sections of the cells 11, 12 is substantially invariable. However, the pentagonal and hexagonal cross-sections of the cells 11, 12 can be changed, i.e. the geometry of the individual cells is adaptive. As the walls 14 of the cells 11, 12 are substantially rigid, the cells 11, 12 of the first and second rows are able to change shape by rotation of the walls 14 about the joints 15 which define pivot centre lines for the walls 14.

In this exemplary embodiment, as the cells 11 of the first row are pentagonal in cross-section, the base walls 14 of the cells 11 of the first row being aligned with each other form the outer surface 5. It is noted that the cells 11 of the first row may also have a hexagonal cross-section (not shown), in which case the outer wall 3 may cover the cells 11 of the first row.

In order to transform the cells 11, 12 of the first and second rows, each cell 11, 12 comprises a substantially pressure-tight chamber 16. For example, each cell 11, 12 comprises an inflatable member being configured to be subjected to internal pressure. The pressure-tight chambers 16 of the cells 11 of the first row are in fluid communication with each other by means of fluid passages 17. Similarly, the pressure-tight chambers 16 of the cells 12 of the second row are in fluid communication with each other by means of fluid passages 17.

The cells 11, 12 of the first and second rows can change shape by controlling the pressure in the pressure-tight chambers 16 of the cells 11 of the first row with respect to the pressure in the pressure-tight chambers 16 of the cells 12 of the second row. When the pressure-tight chamber 16 of a cell 11, 12 is pressurized, the pentagonal or hexagonal cross-sectional shape of said cell 11, 12 is changed so as to maximize the cross-sectional area. However, the cells 11, 12 of the first and second rows are interconnected so that each cell 11, 12 is influenced by surrounding cells 11, 12. Consequently, the pentagonal or hexagonal cross-sectional shape of each cell 11, 12 may be urged to deviate from the maximum cross-sectional area under the influence of surrounding cells 11, 12.

Thus, the pentagonal or hexagonal cross-sectional shape of each individual cell 11, 12 can be adapted from a first cross-sectional shape to a second cross-sectional shape, and vice versa. For example, the first cross-sectional shape of each cell 11, 12 has a first cross-sectional area and the second cross-sectional shape of each cell 11, 12 has a second cross-
sectional area which is smaller than the first cross-sectional area. However, the first cross-sectional area and the second cross-sectional area defined by the first and second cross-sectional shapes, respectively, may also be, for example, equal while the geometries of the first and second cross-sectional shapes are different.

According to the invention, the pentagonal or hexagonal cross-section of each individual cell 11, 12 of the first and second rows is designed such that the outer surface 5 of the morphing structure 1 as a whole can be controlled to morph between the predetermined first and second shapes shown in figures 1a, 1b for a first and second predetermined pressure ratio between the pressure \( p_1 \) in the pressure-tight chambers 16 of the cells 11 of the first row and the pressure \( p_2 \) in the pressure-tight chambers 16 of the cells 12 of the second row.

As already indicated above, the predetermined first and second shapes of the outer surface 5 of the morphing structure 1 are imposed. They may be given, for example, by two different functions. Based on the predetermined first and second shapes of the outer surface 5 of the morphing structure 1 and the first and second predetermined pressure ratios, the associated pentagonal and hexagonal cross-sections of each of the cells 11, 12 of the first and second rows are individually determined, for example by means of a computer program.

Therefore, the cells 11, 12 of the first and second rows of the morphing structure according to the invention are configured in a substantially unstructured or irregular manner. As a result, the pentagonal cross-sections of a plurality of the cells 11 of the first row differ from each other and the hexagonal cross-sections of a plurality of the cells 12 of the second row also differ from each other. However, it should be noted that, depending on the desired first and second target shapes and constraints of the cell geometries, there may still be a number of identical or similar pentagonal or hexagonal cross-sections of the cells 11, 12.

For example, for a first predetermined pressure ratio \( p_1/p_2 = 5 \) between the pressure in the cells 11 of the first row and the pressure in the cells 12 of the second row, for example when the pressure \( p_1 \) in the first row of cells 11 is 5 bars, and the pressure \( p_2 \) in the second row of cells 12 is 1 bar, the cells 11 of the first row take their first shape while the cells 12 of the second row take their second shape. With the cells 11, 12 of the first and second rows being subjected to the first predetermined pressure ratio \( p_1/p_2 \), the cells 11, 12 of the first and second rows take their first and second shapes, respectively. According to the invention, the geometries of the cells 11, 12 of the first and second rows are designed such that the outer surface 5 of the morphing structure 1 defines the predetermined first shape for said first predetermined pressure ratio \( p_1/p_2 \) (see figures 1a and 2a).
The second predetermined pressure ratio $p_1/p_2$ is different from the first predetermined pressure ratio $p_1/p_2$. In this exemplary embodiment, the second predetermined pressure ratio $p_1/p_2 = 0.2$, for example the first row of cells 11 is pressurized to the pressure $p_1 = 1$ bar, and the second row of cells 12 is subjected to the pressure $p_1 = 5$ bar. Then, the cells 11 of the first row are transformed into their second shape and the cells 12 of the second row obtain their first shape. As a result, for said second predetermined pressure ratio, the outer surface 5 of the morphing structure 1 is transformed into the predetermined second shape shown in figures 1b and 2b. Of course, the values of the pressures $p_1$ and $p_2$ mentioned above are merely illustrative and the pressures $p_1$ and $p_2$ may have different values.

The cells 11, 12 of the morphing structure 1 can be constructed in various manners. For example, the walls 14 of the cells 11, 12 of the first and second rows may be formed by steel plates which are connected to each other by hinges. However, the cells 11, 12 may also be integrally formed in a monolithic structure, for example made of carbon. In a monolithic structure, the joints 15 may be integrally formed with the walls 14 by regions with low bending stiffness at the corners of each cell. A high strength to self-weight ratio may be obtained by using a monolithic structure.

Figure 3 shows a pressurization system 20 for controlling the pressure in the cells 11, 12 of the first and second rows. The pressurization system 20 comprises a pressure source 21, which may be connected, for example, to one of the compressor stages of the jet engine of an aircraft. The pressure source 21 is connected via a filter 22, which is optional, to two parallel pressure lines 30, 31.

The pressure line 30 includes a first pressure regulator 24 to regulate a predetermined pressure, in this example 5 bars, and a first control valve 25 to control the mass flow in the pressure line 30. The pressure line 31 is provided with a second pressure regulator 23 to regulate a predetermined pressure, in this example 1 bar. The pressure line 31 also includes a one-way valve 26, an outflow valve 27, which opens at a pressure higher than 1 bar, and a second control valve 28 to control the mass flow in the pressure line 31, in particular for backflow.

The pressure lines 30, 31 are connected to a command valve 29 which is in fluid communication to the cells 11, 12 of the first and second rows. Using the pressurization system 20, the desired pressure differential between the cells 11 of the first row and the cells 12 of the second row can be generated.

Figures 4a, 4b show a second embodiment of the morphing structure according to the invention. The same and similar features are designated by the same reference.
numerals. In this second embodiment, the morphing structure 1 comprises a linkage mechanism 18 which is pivotally connected to one of the joints 15 of one of the cells 12 of the second row along the upper side 8 and to one of the joints 15 of one of the cells 12 of the second row along the lower side 9. The linkage mechanism 18 is also pivotally connected by means of a joint 19 to a rigid base structure which supports the first row of cells 11 and the second row of cells 12. In this exemplary embodiment, the linkage mechanism consists of a rigid body.

There is a degree of freedom when the geometries of the cells 11, 12 of the first and second rows are individually tailored to the predetermined first and second shapes of the outer surface 5 of the morphing structure 1 for predetermined differential pressures. In other words, the design of the geometries of the cells 11, 12 is not unique and there are still a number of possibilities to design the geometries of the cells in such a manner. This non-uniqueness allows the linkage mechanism 18 to provide displacement constraints for certain joints 15 of the cells 12 of the second row. This increases the stiffness of the morphing structure 1.

Figures 5a, 5b, 5c show a third embodiment of the morphing structure according to the invention. The same and similar features are designated by the same reference numerals. The outer surface 5 of the outer wall 3 of the morphing structure 1 can change shape between the predetermined first shape shown in figure 5b and the predetermined second shape shown in figure 5c. The predetermined first shape corresponds to a sin function, whereas the predetermined second shape corresponds to a cos function. Figure 5a shows an object 30 which is attached to the morphing structure 1. It is noted that both predetermined first and second shapes of the morphing structure 1 are shown in figure 5a. With this third embodiment, the morphing structure 1 may generate a propulsion force when the morphing structure 1 is surrounded by a fluid.

The invention is not limited to the exemplary embodiments described above. The skilled person may design various modifications without departing from the scope of the invention. In addition, it is noted that the features of the description of the exemplary embodiments and the features of the introduction to the description can be combined, separately or in any combination, with one or more of the features of one or more of the claims.
CONCLUSIES

1. Constructie (1) met veranderbare vorm omvattende:
   - een buitenwand (3) die een buitenoppervlak (5) van de constructie (1) met
     veranderbare vorm bepaalt, welk buitenoppervlak (5) van vorm kan veranderen tussen een
     vooraf bepaalde eerste vorm en een vooraf bepaalde tweede vorm,
   - een eerste rij van onderling verbonden cellen (11) die zich in hoofdzaak
     aangrenzend aan het buitenoppervlak (5) van de constructie (1) met veranderbare vorm
     uitstrekken, waarbij elke cel (11) van de eerste rij een polygonale dwarsdoorsnede heeft en
     meerdere wanden (14) omdat die scharnierbaar met elkaar zijn verbonden door verbindingen
     (15), waarbij elke cel (11) van de eerste rij een in hoofdzaak drukdichte kamer (16) omvat,
     waarbij de drukdichte kamers (16) van de cellen (11) van de eerste rij in fluidumverbinding
     met elkaar zijn door middel van fluidumdoorgangen (17), waarbij elke cel (11) van de eerste
     rij van vorm kan veranderen tussen een eerste dwarsdoorsnedevorm en een tweede
     dwarsdoorsnedevorm,
   - een tweede rij van onderling verbonden cellen (12) die zich aangrenzend aan de
     eerste rij van cellen (11) uitstrekken, waarbij de cellen (12) van de tweede rij zijn verbonden
     met de cellen (11) van de eerste rij, waarbij elke cel (12) van de tweede rij een polygonale
     dwarsdoorsnede heeft en meerdere wanden (14) omvat die scharnierbaar met elkaar zijn
     verbonden door verbindingen (15), waarbij elke cel (12) van de tweede rij een in hoofdzaak
     drukdichte kamer (16) omvat, waarbij de drukdichte kamers (16) van de cellen (12) van de
     tweede rij in fluidumverbinding met elkaar zijn door middel van fluidumdoorgangen (17),
     waarbij elke cel (12) van de tweede rij van vorm kan veranderen tussen een eerste
     dwarsdoorsnedevorm en een tweede dwarsdoorsnedevorm,
   met het kenmerk, dat
   de cellen (11, 12) van de eerste en tweede rijen zodanig zijn uitgevoerd dat de
   polygonale dwarsdoorsneden van meerdere cellen (11) van de eerste rij onderling
   verschillen en de polygonale dwarsdoorsneden van meerdere cellen (12) van de tweede rij
   onderling verschillen, en
   de polygonale dwarsdoorsneden van de cellen (11, 12) van de eerste en tweede rijen
   zodanig zijn uitgevoerd dat,
   voor een eerste vooraf bepaalde drukverhouding tussen de druk in de
   drukdichte kamers (16) van de cellen (11) van de eerste rij en de druk in de drukdichte
   kamers (16) van de cellen (12) van de tweede rij, de cellen (11) van de eerste rij de eerste
   dwarsdoorsnedevorm daarvan aannemen en de cellen (12) van de tweede rij de tweede
dwarsdoorsnedevorm daarvan aannemen, en het buitenoppervlak (5) van de constructie (1) met veranderbare vorm de vooraf bepaalde eerste vorm aanneemt, en voor een tweede vooraf bepaalde drukverhouding tussen de druk in de drukdichte kamers (16) van de cellen (11) van de eerste rij en de druk in de drukdichte kamers (16) van de cellen (12) van de tweede rij, de cellen (11) van de eerste rij de tweede dwarsdoorsnedevorm daarvan aannemen en de cellen (12) van de tweede rij de eerste dwarsdoorsnedevorm daarvan aannemen, en het buitenoppervlak (5) van de constructie (1) met veranderbare vorm de vooraf bepaalde tweede vorm aanneemt.

2. **Constructie met veranderbare vorm volgens conclusie 1**, waarbij elke cel (11) van de eerste rij een hexagonale of pentagonale dwarsdoorsnede heeft.

3. **Constructie met veranderbare vorm volgens conclusie 1 of 2**, waarbij elke cel (12) van de tweede rij een hexagonale of pentagonale dwarsdoorsnede heeft.

4. **Constructie met veranderbare vorm volgens conclusie 2 of 3**, waarbij elke cel (11) van de eerste rij een pentagonale dwarsdoorsnede heeft, en waarbij het buitenoppervlak (5) van de buitenwand ten minste gedeeltelijk is gevormd door wanden van elke cel van de eerste rij.

5. **Constructie met veranderbare vorm volgens een van de conclusies 2-4**, waarbij de hexagonale of pentagonale dwarsdoorsnede van elke cel (11, 12) in hoofdzaak bol is.

6. **Constructie met veranderbare vorm volgens een van de voorgaande conclusies**, waarbij de wanden (14) van de cellen (11, 12) van de eerste en tweede rijen in hoofdzaak stijf zijn, en waarbij de cellen (11, 12) van de eerste en tweede rijen van vorm kunnen veranderen door rotatie van de wanden (14) om de verbindingen (15).

7. **Constructie met veranderbare vorm volgens een van de voorgaande conclusies**, waarbij de cellen (11) van de eerste rij onderling zijn verbonden door middel van gemeenschappelijke wanden (14), en/of waarbij de cellen (12) van de tweede rij onderling zijn verbonden door middel van gemeenschappelijk wanden (14), en/of waarbij de cellen (11) van de eerste rij en de cellen (12) van de tweede rij onderling zijn verbonden door middel van gemeenschappelijke wanden (14).

8. **Constructie met veranderbare vorm volgens een van de voorgaande conclusies**, waarbij het buitenoppervlak (5) van de buitenwand (3), gezien in dwarsdoorsnede, ten
minste een gedeelte van een vleugelprofiel bepaalt, omvattende een voorrand (6), een
achterrand (7), een bovenzijde (8) en een onderzijde (9), en waarbij de cellen (11) van de
eerste rij zich uitstrekken langs de bovenzijde (8), ten minste een van de randen (6, 7) en de
onderzijde (9), en waarbij de cellen (12) van de tweede rij zich uitstrekken aangrenzend aan
de eerste rij van cellen (11) langs de bovenzijde (8), die ten minste ene van de randen (6, 7)
én de onderzijde (9).

9. Constructie met veranderbare vorm volgens conclusie 8, waarbij de constructie (1)
met veranderbare vorm een verbindingen mechanisme (18) omvat, dat scharnierbaar is
verbonden met een van de verbindingen (15) van een van de cellen (12) van de tweede rij
langs de bovenzijde (8) en met een van de verbindingen (15) van een van de cellen (12) van
de tweede rij langs de onderzijde (9).

10. Constructie met veranderbare vorm volgens conclusie 9, waarbij de constructie (1)
met veranderbare vorm een stijve basis omvat, die de eerste rij van cellen (11) en de tweede
rij van cellen (12) draagt, en waarbij het verbindingen mechanisme (18) scharnierbaar is
verbonden met de stijve basis.

11. Constructie met veranderbare vorm volgens een van de voorgaande conclusies,
waarbij de constructie (1) met veranderbare vorm een monolithische constructie is.

12. Vliegtuig omvattende een constructie (1) met veranderbare vorm volgens een van de
voorgaande conclusies.

13. Werkwijze voor het veranderen van de vorm van een constructie (1) met
veranderbare vorm omvattende:
   - het verschaffen van een buitenwand (3) die een buitenoppervlak (5) van de
     constructie (1) met veranderbare vorm bepaalt, welk buitenoppervlak (5) van vorm kan
     veranderen tussen een vooraf bepaalde eerste vorm en een vooraf bepaalde tweede vorm,
   - het verschaffen van een eerste rij van onderling verbonden cellen (11) die zich in
     hoofdzaak aangrenzend aan het buitenoppervlak (5) van de constructie (1) met
     veranderbare vorm uitstrekken, waarbij elke cel (11) van de eerste rij een polygonale
dwarsdoorsnede heeft en meerdere wanden (14) omvat die scharnierbaar met elkaar zijn
     verbonden door verbindingen (15), waarbij elke cel (11) van de eerste rij een in hoofdzaak
     drukdichte kamer (16) omvat, waarbij de drukdichte kamers (16) van de cellen (11) van de
     eerste rij in fluidumverbinding met elkaar zijn door middel van fluidumdoorgangen (17),


waarbij elke cel (11) van de eerste rij van vorm kan veranderen tussen een eerste dwarsdoorsnedevorm en een tweede dwarsdoorsnedevorm,

- het verschaffen van een tweede rij van onderling verbonden cellen (12) die zich aangrenzend aan de eerste rij van cellen (11) uitstrekt, waarbij de cellen (12) van de tweede rij zijn verbonden met de cellen (11) van de eerste rij, waarbij elke cel (12) van de tweede rij een polygonale dwarsdoorsnede heeft en meerdere wanden (14) omvat die scharnierbaar met elkaar zijn verbonden door verbindingen (15), waarbij elke cel (12) van de tweede rij een in hoofdzaak drukdichte kamer (16) omvat, waarbij de drukdichte kamers (16) van de cellen (12) van de tweede rij in fluïdumverbinding zijn met elkaar door middel van fluïdumdoorgangen (17), waarbij elke cel (12) van de tweede rij van vorm kan veranderen tussen een eerste dwarsdoorsnedevorm en een tweede dwarsdoorsnedevorm, waarbij de cellen (11, 12) van de eerste en tweede rijen zodanig zijn uitgevoerd dat de polygonale dwarsdoorsneden van meerdere cellen (11) van de eerste rij onderling verschillen en de polygonale dwarsdoorsneden van meerdere cellen (12) van de tweede rij onderling verschillen, en de polygonale dwarsdoorsneden van de cellen (11, 12) van de eerste en tweede rijen zodanig zijn uitgevoerd dat voor een eerste vooraf bepaalde drukverhouding tussen de druk in de drukdichte kamers (16) van de cellen (11) van de eerste rij en de druk in de drukdichte kamers (16) van de cellen (12) van de tweede rij, de cellen (11) van de eerste rij de eerste dwarsdoorsnedevorm daarvan aannemen en de cellen (12) van de tweede rij de tweede dwarsdoorsnedevorm daarvan aannemen, en het buitenoppervlak (5) van de constructie (1) met veranderbare vorm de vooraf bepaalde eerste vorm aannemen, en voor een tweede vooraf bepaalde drukverhouding tussen de druk in de drukdichte kamers (16) van de cellen (11) van de eerste rij en de druk in de drukdichte kamers (16) van de cellen (12) van de tweede rij, de cellen (11) van de eerste rij de tweede dwarsdoorsnedevorm daarvan aannemen en de cellen (12) van de tweede rij de eerste dwarsdoorsnedevorm daarvan aannemen, en het buitenoppervlak (5) van de constructie (1) met veranderbare vorm de vooraf bepaalde tweede vorm aannemen,

- het regelen van de druk in de drukdichte kamers (16) van de cellen (11, 12) van de eerste rij en de tweede rij om de vorm van de constructie (1) met veranderbare vorm te veranderen van de vooraf bepaalde eerste vorm naar de vooraf bepaalde tweede vorm.

14. Werkwijze volgens conclusie 13, waarbij de constructie (1) met veranderbare vorm is aangebracht in een fluïdum, en waarbij de constructie (1) met veranderbare vorm een voortstuwingkracht genereert als de constructie (1) met veranderbare vorm van vorm
verandert van de vooraf bepaalde eerste vorm naar de vooraf bepaalde tweede vorm en omgekeerd.
### SAMENWERKINGSVERDRAG (PCT)

**RAPPORT BETREFFENDE NIEUWHEIDSONDERZOEK VAN INTERNATIONAAL TYPE**

<table>
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<th>KENMERK VAN DE AANVRAGER OF VAN DE GEMACHTIGDE</th>
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**Aanvrager (Naam)**

*Technische Universiteit Delft*

**Datum van het verzoek voor een onderzoek van internationaal type**

| 13-08-2011 |

**Door de Instantie voor Internationaal Onderzoek aan het verzoek voor een onderzoek van internationaal type toegekend nr.**

| SN 56671 |

### I. CLASSIFICATIE VAN HET ONDERWERP (bij toepassing van verschillende classificaties, alle classificatiesymbolen opgeven)

**Volgens de internationale classificatie (IPC)**

| B32B3/12 | B63H1/36 | B64C3/46 | F03D1/06 |

### II. ONDERZOCHE GEBIEDEN VAN DE TECHNIEK

**Onderzochte minimumdocumentatie**

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Onderzochte andere documentatie dan de minimum documentatie, voor zover dergelijke documenten in de onderzochte gebieden zijn opgenomen

### III. GEEN ONDERZOEK MOGELIJK VOOR BEPAALDE CONCLUSIES (opmerkingen op aanvullingsblad)

### IV. GEBREK AAN EENHEID VAN UITVINDING (opmerkingen op aanvullingsblad)

Form PCT/ISA 201 A (11/2000)
**ONDERZOEKSRAPPORT BETREFFENDE HET RESULTAAT VAN HET ONDERZOEK NAAR DE STAND VAN DE TECHNIEK VAN HET INTERNATIONALE TYPE**

**Nummer van het verzoek**

NL 2006936

### A. CLASSIFICATIE VAN HET ONDERWERP

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Volgens de Internationale Classificatie van ontrooien (IPC) of zowel volgens de nationale classificatie als volgens de IPC.

### B. ONDERZOEKDE GEBIEDEN VAN DE TECHNIEK

Onderzochte minimum documentatie (classificatie gevolgd door classificatiesymbolen)

- B64C F03D B63H B32B

Onderzochte andere documentatie dan de minimum documentatie, voor dergelijke documenten, voor zover dergelijke documenten in de onderzochte gebieden zijn opgenomen

Tijdens het onderzoek geraadpleegde elektronische gegevensbestanden (naam van de gegevensbestanden en, waar uitvoerbaar, gebruikte trfwoorden)

EPO-Internal, WPI Data

### C. VAN BELANG GEACHTE DOCUMENTEN

<table>
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<td>WO 2008/003330 A1 (DANMARKS TEKNIKSE UNI TECHNICA [DK]; MADSEN HELGE AAGAARD [DK]; RASMUS) 10 januari 2008 (2008-01-10) * bladzijde 3, regel 21 - regel 36 * * bladzijde 8, regel 8 - bladzijde 9, regel 31 * * bladzijde 13, regel 6 - bladzijde 14, regel 3; figuren 1-3,7-13</td>
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* Speciale categorieën van aangehaalde documenten

**“A”** niet tot de categorie X of Y behorende literatuur die de stand van de techniek beschrijft

**“D”** in de ontrooianvrage vermeld

**“E”** eerdere ontrooianvrage, gepubliceerd op of na de indieningsdatum, waarin dezelfde uitwinding wordt beschreven

**“L”** om andere redenen vermelde literatuur

**“O”** niet-schriftelijke stand van de techniek

**“P”** tussen de voorrangsaanduiding en de indieningsdatum gepubliceerde literatuur

**“T”** na de indieningsdatum of de voorrangsaanduiding gepubliceerde literatuur die niet bezwarend is voor de ontrooianvrage, maar wordt vermeld ter verheldering van de theorie of het principe dat ten grondslag ligt aan de uitwinding

**“X”** de conclusie wordt als nieuw of niet inventief beschouwd ten opzichte van deze literatuur

**“Y”** de conclusie wordt als niet inventief beschouwd ten opzichte van de combinatie van deze literatuur met andere geeciteerde literatuur van dezelfde categorie, waarbij de combinatie voor de vakman voor de hand liggend wordt gezien

**“*”** lid van dezelfde ontrolfamilie of overeenkomstige ontrolpublicatie

Datum waarop het onderzoek naar de stand van de techniek van internationaal type werd voltooid

2 februari 2012

Verzendsdatum van het rapport van het onderzoek naar de stand van de techniek van internationaal type

Naam en adres van de instantie

European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk

Tel. (+31-70) 340-2040. Fax: (+31-70) 340-3016

De bevoegde ambtenaar

Hofmann, Udo

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Formules: PCT/SA/001 (tweede blad) (Januari 2004)
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<tr>
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<td>WO 99/61313 A1 (PROSPECTIVE CONCEPTS AG [CH]; TO FREDERICK E [CH]; KAMMER RES [CH]) 2 december 1999 (1999-12-02) * bladzijde 3, regel 25 - bladzijde 7, regel 24; figuren 1-8 *</td>
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WRITTEN OPINION

File No. SN56671
Filing date (day/month/year) 15.06.2011
Priority date (day/month/year) 
Application No. NL2006936

International Patent Classification (IPC)
INV. B32B3/12 B63H1/36 B64C3/46 F03D1/06

Applicant
Technische Universiteit Delft

This opinion contains indications relating to the following items:

☑ Box No. I Basis of the opinion
☐ Box No. II Priority
☐ Box No. III Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
☐ Box No. IV Lack of unity of invention
☑ Box No. V Reasoned statement with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement
☐ Box No. VI Certain documents cited
☐ Box No. VII Certain defects in the application
☐ Box No. VIII Certain observations on the application

Examiner
Hofmann, Udo

Form NL237A (Dekblad) (July 2006)
Box No. I  Basis of this opinion

1. This opinion has been established on the basis of the latest set of claims filed before the start of the search.

2. With regard to any nucleotide and/or amino acid sequence disclosed in the application and necessary to the claimed invention, this opinion has been established on the basis of:
   a. type of material:
      □ a sequence listing
      □ table(s) related to the sequence listing
   b. format of material:
      □ on paper
      □ in electronic form
   c. time of filing/furnishing:
      □ contained in the application as filed.
      □ filed together with the application in electronic form.
      □ furnished subsequently for the purposes of search.

3. □ In addition, in the case that more than one version or copy of a sequence listing and/or table relating thereto has been filed or furnished, the required statements that the information in the subsequent or additional copies is identical to that in the application as filed or does not go beyond the application as filed, as appropriate, were furnished.

4. Additional comments:

Box No. V  Reasoned statement with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Statement

   | Novelty       | Yes: Claims | 2-6, 8-10, 14 |
   |               | No: Claims  | 1, 7, 11-13  |

   | Inventive step| Yes: Claims | 1-14         |
   |               | No: Claims  |              |

   | Industrial applicability | Yes: Claims | 1-14 |
   |                            | No: Claims  |      |

2. Citations and explanations

   see separate sheet
Re Item V

Reasoned statement with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

Reference is made to the following documents:


D6  WO 03/026954 A1 (INOCEAN AS [NO]; BORGEN JON ERIK [NO]; APNESETH CLAUS CHRISTIAN [GB];) 3 april 2003 (2003-04-03)

1  Independent Claims 1 and 13

1.1 The present application does not meet the criteria of patentability, because the subject-matter of claims 1 and 13 is not new.

1.2 D1 discloses (see page 3, lines 21-36; page 8, line 8 - page 9, line 31; page 13, line 6 - page 14, line 3; figures 1-3, 7-13)

- an outer wall defining an outer surface of the morphing structure (3), which outer surface can change shape between a predetermined first shape and a predetermined second shape,

- a first row (6) of interconnected cells (5) extending substantially adjacent to the outer surface of the morphing structure (3), each cell (5) of the first row having a polygonal cross-section and comprising a plurality of walls which are pivotally connected to each other by joints (the structure of the trailing edge is flexible, therefore it must have flexible walls, which are interpreted as joints in line with the description of the application, page 1, lines 19-24), each cell (5) of the first row comprising a substantially pressure-tight chamber, the pressure-tight chambers of the cells (5) of the first row being in fluid communication with each other by means of fluid passages (implicit with subsystems accor-
ding to figure 3, page 9, lines 10-12), each cell (5) of the first row being able to change shape between a first cross-sectional shape and a second cross-sectional shape,

- a second row (7) of interconnected cells (5) extending adjacent to the first row (6) of cells (5), the cells (5) of the second row (7) being connected to the cells (5) of the first row, each cell (5) of the second row having a polygonal cross-section and comprising a plurality of walls which are pivotally connected to each other by joints (the structure of the trailing edge is flexible, therefore it must have flexible walls, which are interpreted as joints in line with the description of the application, page 1, lines 19-24), each cell (5) of the second row comprising a substantially pressure-tight chamber, the pressure-tight chambers of the cells (5) of the second row (7) being in fluid communication with each other by means of fluid passages (implicit with subsystems according to figure 3, page 9, lines 10-12), each cell (5) of the second row being able to change shape between a first cross-sectional shape and a second cross-sectional shape, whereby

the cells (5) of the first and second rows are configured such that the polygonal cross-sections of a plurality of the cells (5) of the first row (6) differ from each other and the polygonal cross-sections of a plurality of the cells (5) of the second row (7) differ from each other (see page 8, lines 17-19), and

the polygonal cross-sections of the cells (5) of the first and second rows are configured such that, for a first predetermined pressure ratio between the pressure in the pressure-tight chambers of the cells (5) of the first row (6) and the pressure in the pressure-tight chambers of the cells (5) of the second row (7), the cells (5) of the first row assume their first cross-sectional shape and the cells (5) of the second row assume their second cross-sectional shape, and

the outer surface of the morphing structure (3) assumes the predetermined first shape, and

for a second predetermined pressure ratio between the pressure in the pressure-tight chambers of the cells (5) of the first row and the pressure in the pressure-tight chambers of the cells (5) of the second row (7), the cells (5) of the first row (6) assume their second cross-sectional shape and the cells (5) of the second row (7) assume their first cross-sectional shape, and the outer surface of the morphing structure (3) assumes the predetermined second shape (see figures 2a and 9 for first and second shapes).
1.3 The subject matter of claim 13 is a method for changing the shape of a morphing structure, whereby the features of the morphing structure are the same as in claim 1. Therefore D1 discloses also, at least implicitly, all the features of claim 13.

2 Dependent claims 2-12 and 14

2.1 Dependent claims 2-12 and 14 do not contain any features which, in combination with the features of any claim to which they refer, meet the requirements of novelty or inventive step, see D1, D2 and D6 (see references in the search report)

2.2 In claims 2-5 a slight constructional change in the morphing structure of claim 1 is defined which comes within the scope of the customary practice followed by persons skilled in the art, especially as the advantages thus achieved can readily be foreseen. Consequently, the subject-matter of claims 2-5 lacks an inventive step.

2.3 The features of dependent claims 6 and 9 have already been employed for the same purpose in a similar morphing structure (see D2, column 2, line 40 - column 4, line 51, figures 4, 5). It would therefore be obvious to the person skilled in the art to apply these features with corresponding effect to a morphing structure according to D1, thus arriving at a morphing structure according to claims 6 and 9.

2.4 D1 further discloses the additional features of claims 7, 11 and 12 (see figures 1, 2a). Therefore the subject matter of these claims is not new.

2.5 The subject matter of claim 8 does not contain an inventive step. With regard to the teachings of D1 (see page 3, lines 21-36, page 8, lines 14-24) it is obvious for the skilled person, that the cells (cavities) can be arranged as described in claim 8.

2.6 The invention of claim 14 consists merely in a different use of the morphing structure as a propulsion unit. However, the use of morphing structures for propulsion is generally known (see merely as an example D6) and does not involve more than the employment of properties of a morphing structure which are also already known from D1. Hence, no inventive step is present in the subject-matter of claim 14.