

VALVE SHEET FOR HERMETIC COMPRESSOR

TECHNICAL FIELD

- 5 The present disclosure relates to hermetic compressors and in particular to valve sheets for hermetic compressors.

BACKGROUND

- 10 Hermetic compressors typically comprise a cylinder which houses a piston. The piston reciprocates in the cylinder and compresses a refrigerant. In order to regulate the compression of the refrigerant, hermetic compressors have a valve assembly arranged in a cylinder head that controls flow of the refrigerant into and out of a compression space within the cylinder. This valve assembly includes a valve sheet
15 that comprises one or more reeds that open and close a suction hole to allow refrigerant to be drawn into the compression space.

- The diameter of the cylinder of a compressor is known as the bore of the cylinder. Hermetic compressors are manufactured with different bore sizes depending on required capacity. Valve sheets may be comprise multiple reeds as this allows for a
20 range of operating speeds. Further, increasing the number of reeds allows the compressor to operate at a higher capacity.

The variety of bore sizes and number of reeds results in a large number of different valve sheet designs. Thus, manufacturers of hermetic compressors are required to maintain a large inventory of different valve sheet designs.

25

SUMMARY OF THE INVENTION

- The present disclosure provides valve sheets that can be used in compressors having different bore sizes. The valve sheets have a plurality of reeds which
30 comprises a primary reed and one or more secondary reeds. When the valve sheet is mounted in a valve assembly of a hermetic compressor with a cylinder having a small bore size, the secondary reed overlaps with the edge of the bore of the

cylinder and therefore the secondary reed is constrained from moving. The primary reed is free to move and to allow flow of a refrigerant into a compression space of the cylinder. When the valve sheet is mounted in a valve assembly of a hermetic compressor having a large bore size, both the primary reed and the secondary reed are free to move and therefore allow flow of the refrigerant into the compression space of the cylinder.

Thus embodiments of the present invention provide a valve sheet that can be used with multiple bore sizes. This reduces the number of different valve sheet designs that must be maintained in the inventory of a manufacturer of hermetic compressors.

According to a first aspect of the present invention a hermetic compressor is provided. The hermetic compressor comprises: a cylinder block forming a cylinder having a bore, the cylinder being configured to house a piston movable in the cylinder in a reciprocating manner; a valve plate disposed at an opening end of the cylinder, the valve plate having a suction hole; and a valve sheet comprising a plurality of reeds, the plurality of reed comprising a primary reed having an end portion configured to open and close the suction hole, the plurality of reeds further comprising a secondary reed arranged on the valve sheet the secondary reed overlaps with an edge of the bore and movement of the secondary reed is constrained by the cylinder block.

In an embodiment, the secondary reed comprises an end portion and the end portion of the secondary reed is arranged vertically below the end portion of the primary reed.

In an embodiment, the secondary reed comprises a first arm portion and a second arm portion arranged on respective first and second sides of the primary reed.

In an embodiment, the end portion of the secondary reed has a greater area than the end portion of the primary reed.

In an embodiment, the primary reed and the secondary reed are configured to have different natural frequencies.

In an embodiment, the plurality of reeds comprises a first secondary reed and a second secondary reed arranged on respective first and second sides of the primary reed.

In an embodiment, each of the first secondary reed and the second secondary reed overlap with an edge of the bore and movement of each of the first secondary reed and the second secondary reed is constrained by the cylinder block.

In an embodiment, the primary reed is configured to have a different natural frequency from the first secondary reed and the second secondary reed.

According to a second aspect of the present invention a valve sheet for a hermetic compressor is provided. The valve sheet comprises a plurality of reeds. The plurality of reeds comprises a primary reed and a secondary reed. The valve sheet is configured to form part of a valve assembly to be mountable on cylinder blocks of hermetic compressors having different cylinder bores. The plurality of reeds are arranged on the valve sheet such that respective end portions of the plurality of reeds open and close respective suction holes the valve assembly when the cylinder block of the hermetic compressor has a first bore size, and an end portion of the primary reed opens and closes a suction hole and the movement of the secondary reed is constrained when the cylinder block of the compressor has a second bore size, smaller than the first bore size.

In an embodiment, the secondary reed comprises an end portion and the end portion of the secondary reed is arranged vertically below the end portion of the primary reed.

In an embodiment, the secondary reed comprises a first arm portion and a second arm portion arranged on respective first and second sides of the primary reed.

In an embodiment, the end portion of the secondary reed has a greater area than the end portion of the primary reed.

In an embodiment, the primary reed and the secondary reed are configured to have different natural frequencies.

5 In an embodiment, the plurality of reeds comprises a first secondary reed and a second secondary reed arranged on respective first and second sides of the primary reed.

In an embodiment, the primary reed is configured to have a different natural frequency from the first secondary reed and the second secondary reed.

10

BRIEF DESCRIPTION OF THE DRAWINGS

15 In the following, embodiments of the present invention will be described as non-limiting examples with reference to the accompanying drawings in which:

FIG. 1 is a cross-sectional view of a hermetic compressor according to an embodiment of the present invention;

20 FIG. 2 is an exploded perspective view showing a valve assembly of the hermetic compressor shown in FIG.1;

FIG. 3 shows a valve sheet of a hermetic compressor according to an embodiment of the present invention;

25

FIG. 4A shows the primary reed of the valve plate shown in FIG. 3 and the cylinder bore of a compressor having a small bore size;

30 FIG. 4B shows the primary and secondary reeds of the valve plate shown in FIG. 3 and the cylinder bore of a compressor having a large bore size;

FIG. 5 shows a valve sheet of a hermetic compressor according to an embodiment of the present invention;

FIG. 6A shows the primary reed of the valve plate shown in FIG. 5 and the cylinder bore of a compressor having a small bore size; and

- 5 FIG. 6B shows the primary and secondary reeds of the valve plate shown in FIG. 5 and the cylinder bore of a compressor having a large bore size.

DETAILED DESCRIPTION

- 10 Figure 1 shows a hermetic compressor according to an embodiment of the present invention. The hermetic compressor comprises a sealed container 101. Mineral oil having a low viscosity is accumulated on a bottom portion of the sealed container 101 as refrigeration oil 102. A refrigerant, for example, R600a or the like which is a hydrocarbon refrigerant having a low global warming coefficient is filled in sealed
15 container 101 as a working fluid 103. The sealed container 101 is formed from a steel plate.

- The hermetic compressor comprises: a suction pipe 150 and a discharge pipe 157. The suction pipe 150 has one end in communication with the inside of the sealed
20 container 101 and the other end connected to a low-pressure side of a refrigeration system (not shown). The discharge pipe 157 has one end penetrating the sealed container 101 and communicating with a discharge muffler (not shown) and the other end connected to a high-pressure side of the refrigeration system (not shown).

- 25 Inside the sealed container 101, a compressor body 104 is housed in a resiliently supported manner with respect to the sealed container 101 by suspension springs 105. The compressor body 104 comprises a compressing element 109 and an electromotive element 106.

- 30 The compressing element 109 is formed of a crankshaft 112, a cylinder block 115, a piston 116, a connecting portion 122, and the like. The crankshaft 112 includes an eccentric shaft 110 and a main shaft 111. The crankshaft 112 also includes an oil

supply mechanism 151 formed of a spiral groove formed on a surface of the main shaft 111.

The electromotive element 106 is formed of: a stator 107 fixed to a lower side of the cylinder block 115 by bolts (not shown), and a rotor 108 which is disposed coaxially inside the stator 107 and is fixed to the main shaft 111 by shrinkage fitting. The electromotive element 106 is driven by an inverter drive circuit at a plurality of operation frequencies including an operation frequency (for example, 25Hz=1500r/min) below a commercial power source frequency.

In the cylinder block 115 forms a cylinder 114 and a bearing portion 123 which are integrally formed with each other. The cylinder forms a compression chamber 113. The bearing portion 123 rotatably and pivotally supports the main shaft 111.

On an end surface of the cylinder 114 a valve plate 117, a valve sheet 120 and a cylinder head 152 are mounted. The valve plate 117 is formed by moulding using a sintered metal material. A suction hole 118 and a discharge hole 119 are formed in the valve plate 117. The suction hole 118 and the discharge hole 119 allow the inside and the outside of compression chamber 113 to communicate with each other.

The valve sheet 120 opens and closes the suction hole 118. The cylinder head 152 forms a lid for valve plate 117. A suction muffler 154 is held and fixed between valve plate 117 and a cylinder head 152.

FIG. 2 shows an exploded view of the valve assembly of the hermetic compressor shown in FIG. 1.

As shown in FIG. 2, the valve plate 117, the valve sheet 120, and the cylinder head 152 are pressed and fixed to the end surface of cylinder 114 by head bolts 153 so as to seal the end surface of cylinder 114. A cylinder gasket 160 is clamped between the end surface of the cylinder and the valve sheet 120 and a cylinder head gasket 161 is clamped between the valve plate 117 and the cylinder head 152.

A suction valve seat is formed around suction hole 118 of valve plate 117 such that suction valve seat surrounds suction hole 118, and a discharge valve seat 142 is

formed around discharge hole 119 such that discharge valve seat 142 surrounds discharge hole 119.

On a surface of valve plate 117 disposed on cylinder head 152 side, a discharge valve unit is mounted. The discharge valve unit is formed of: spring lead 130 on which discharge valve 121 which opens and closes discharge hole 119 is disposed and which resiliently supports discharge valve 121; and valve stop 131 which fixes discharge valve 121 and spring lead 130. The discharge valve unit fits into a cut out portion 132 in the surface of the valve plate 117. A head space 156 is formed by valve plate 117 and the cylinder head 152.

The operation and function of the hermetic compressor having the above-mentioned configuration will now be described. In the hermetic compressor, when a magnetic field is generated by supplying an electric current to the stator 107 so that the rotor 108 fixed to the main shaft 111 rotates. This causes the crankshaft 112 to rotate and the piston 116 reciprocates in the cylinder 114 driven by the connecting portion 122 coupled to the eccentric shaft 110. Due to the reciprocating movement of the piston 116, the working fluid 103 is sucked into the compression chamber 113 through the suction muffler 154, and after being compressed, the working fluid 103 is discharged to a refrigeration system through the discharge hole 119 and head space 156.

Next, a suction stroke, a compression stroke, and a discharge stroke of the hermetic compressor will be described.

In the suction stroke, when the piston 116 is operated in a direction that a volume of the compression chamber 113 is increased, working fluid 103 in the inside of the compression chamber 113 is expanded, and a pressure in the compression chamber 113 becomes lower than a pressure in the suction muffler 154, due to the difference between the pressure in compression chamber 113 and the pressure in suction muffler 154, a suction formed by the valve sheet 120 starts to open. Then, a reed (or reeds) of the valve sheet 120 is operated and hence, working fluid 103 of a low temperature which has returned from the refrigeration system (not shown) is temporarily released into sealed container 101 from suction pipe 150 and, thereafter, flows into compression chamber 113 through suction muffler 154.

Thereafter, in the compression stroke, when the direction of movement of the piston 116 changes at a bottom dead centre position, the pressure in compression chamber 113 is elevated, and due to the difference between the pressure in compression chamber 113 and the pressure in suction muffler 154, the suction valve formed by the valve sheet 120 is closed. Then, compression chamber 113 is closed, and piston 116 is operated in the direction that the volume of compression chamber 113 is decreased and hence, working fluid 103 is compressed, and the pressure in compression chamber 113 is elevated to a predetermined pressure.

Then, in the discharge stroke, when the pressure of the working fluid 103 in the compression chamber 113 is elevated and becomes higher than a pressure in the head space 156 formed by the valve plate 117 and the cylinder head 152. When a force generated by the pressure difference exceeds a force for resiliently deforming discharge valve 121, discharge hole 119 is opened. Then, an arm portion of the discharge valve 121 is operated and hence, working fluid 103 in the compression chamber 113 passes through the discharge hole 119 and flows out into the head space 156.

Thereafter, the working fluid 103 passes through a discharge muffler (not shown) from the head space 156, and is discharged to a high-pressure side of the refrigeration system (not shown) through the discharge pipe 157.

When the pressure difference between the head space 156 and the compression chamber 113 is decreased, a force which is generated by the pressure difference and is applied to the discharge valve 121 becomes smaller than a restoring force of the spring lead 130 and discharge valve 121, discharge valve 121 is closed so that compression chamber 113 is closed. Following this, the piston 116 moves in a direction toward the bottom dead centre, and the hermetic compressor enters the suction stroke again.

FIG. 3 shows a valve sheet according to an embodiment of the present invention. The valve sheet 120 is designed to be usable in compressors having different bore sizes. The valve sheet 120 corresponds to the valve sheet 120 described above in

relation to FIG. 2. The valve sheet 120 is substantially square and formed from a metal such as steel. A primary reed 310 and a secondary reed 320 are formed in the valve sheet 120 by slits cut out of the valve sheet 120. The primary reed 310 is formed from an arm portion 312 and an end portion 314. The arm portion 312 of the primary reed 310 is attached to the main body of the valve sheet 120 and is defined by slits in the valve sheet 120 which slightly tapered towards each other. The end portion 314 of the primary reed 310 is circular and is attached to the body of the valve sheet 120 by the arm portion 312 of the primary reed 310. The secondary reed 320 comprises two arm portions: a first arm portion 322 and a second arm portion 324. The first arm portion 322 of the secondary reed 320 is located on the left-hand side of the primary reed 310. The second arm portion 324 of the secondary reed 320 is located on the right-hand side of the primary reed 310. The secondary reed 320 has an end portion 326 which is attached to both the first arm portion 322 of the secondary reed 320 and the second end portion 324 of the secondary reed 320. The end portion 326 of the secondary reed 320 is elongated and curved such that the middle part of the end portion is closer to a lower edge of the valve sheet 120 than the parts that join to the first arm portion 322 and the second arm portion 324 of the secondary reed 320.

As shown in FIG. 3, the primary reed 310 and the secondary reed 320 are formed by two slits in the valve sheet 120. Each of the two slits are approximately U-shaped. An inner slit forms the outside of the primary reed 310 and also an inside of the secondary reed 320 and an outer slit forms the outside of the secondary reed 320. The valve sheet 120 has a discharge hole 330 which is located in the arm portion 312 of the primary reed. Four fixing holes 340 are located close to respective corners of the valve sheet 120. Two additional fixing holes 342 are located on the sides of the valve sheet.

The valve plate 120 shown in FIG. 3 is designed to be usable in compressors having different bore sizes. This is described in more detail below with reference to FIG. 4A, and FIG. 4B.

FIG. 4A shows the primary reed of the valve plate shown in FIG. 3 and the cylinder bore of a compressor having a small bore size. FIG. 4B shows the primary and secondary reeds of the valve plate shown in FIG. 3 and the cylinder bore of a compressor having a large bore size.

5

As shown in FIG. 4A, the cylinder has a small bore size, for example, the bore 410, which corresponds to the diameter of the cylinder is 17.2mm. In this configuration, the primary reed 310 is within the bore 410 of the cylinder and therefore the end portion 314 of the primary reed 310 is free to move. The secondary reed 320 however, overlaps with the edge of the bore 410 of the cylinder and therefore, the secondary reed 320 is blocked from moving by the bore 410 of the cylinder.

10

The configuration shown in FIG. 4A corresponds to the valve assembly shown in FIG. 2. As shown in FIG. 2, the valve plate 117 has a single suction hole 118. The end portion 314 of the primary reed 310 opens and closes the suction hole 118. During a suction stroke, the primary reed 310 opens and allows the working fluid 103 to be drawn into the compression chamber 113. In the compression stroke, the primary reed 310 closes the suction hole 118 and thus the working fluid 103 is compressed in the compression chamber 113.

15

20

As shown in FIG. 4B, the cylinder has a large bore size, for example, the bore 420, which corresponds to the diameter of the cylinder is 23.4mm. In this configuration, the primary reed 310 and the secondary reed 320 are within the bore 420 of the cylinder and therefore the end portion 314 of the primary reed 310 and the end portion 326 of the secondary reed 320 are both free to move.

25

The configuration shown in FIG. 4B differs from the valve assembly shown in FIG. 2. In the valve assembly corresponding to the configuration shown in FIG. 4B, the valve plate has first suction hole that corresponds to the end portion 314 of the primary reed 310 and a second suction hole that corresponds the end portion 326 of the secondary reed 320. During a suction stroke, the primary reed 310 and the secondary reed 320 both open and allow the working fluid to be drawn into the compression chamber. Thus, a greater flow rate of working fluid is possible since both suction holes open. In the compression stroke, the primary reed 310 the first

30

suction hole and the secondary reed closes the second suction hole and thus the working fluid 103 is compressed in the compression chamber 113. In the embodiment shown in FIG. 3, the length of the first arm portion 322 and the second arm portion 324 of the secondary reed 320 is different from the length of the arm portion 312 of the primary reed 310. This causes the natural frequency of the primary reed 310 to be different from the natural frequency of the secondary reed 320. As a result of this difference in natural frequency, the timing of the opening of the primary reed 310 and the secondary reed 320 may be different.

In an alternative embodiment, the primary reed and the secondary reed may be configured to have the same natural frequency.

FIG. 5 shows a valve sheet of a hermetic compressor according to an embodiment of the present invention. The valve sheet 600 is designed to be usable in compressors having different bore sizes. The valve sheet 600 is substantially square and formed from a metal such as steel. A primary reed 610, a first secondary reed 620 and a second secondary reed 630 are formed in the valve sheet 600 by slits cut out of the valve sheet 600. The first secondary reed 620 and the second secondary reed 630 are arranged symmetrically on each side of the primary reed 610.

The primary reed 610 is formed from an arm portion 612 and an end portion 614. The primary reed 610 runs along the vertical central axis of the valve sheet 600. The arm portion 612 of the primary reed 610 is attached to the main body of the valve sheet 600 and is defined by slits in the valve sheet 600 which slightly tapered towards each other. The end portion 614 of the primary reed 610 is circular and is attached to the body of the valve sheet 600 by the arm portion 612 of the primary reed 610. The first secondary reed 620 is located on the left-hand side of the primary reed 610. The first secondary reed 620 comprises an arm portion 622 and an end portion 624. The arm portion 622 of the first secondary reed 620 is curved and the width of the arm portion 622 is approximately constant. The end portion 624 of the first secondary reed 620 is on the same horizontal level as the end portion 614 of the primary reed 610. The second secondary reed 630 is located on the right-hand side of the primary reed 610. Like the first secondary reed 620, the second secondary reed 630 comprises an arm portion 632 and an end portion 634. The arm portion 632

of the second secondary reed 630 is curved and the width of the arm portion 632 is approximately constant. The end portion 634 of the second secondary reed 630 is in the same horizontal level as the end portion 614 of the primary reed 610 and the end portion 624 the first secondary reed 620.

5

The valve sheet 600 has a discharge hole 640 which is located in the arm portion 612 of the primary reed 610. Four fixing holes 650 are located close to respective corners of the valve sheet 600. Two additional fixing holes 652 are located on the sides of the valve sheet.

10

The valve plate 600 shown in FIG. 5 is designed to be usable in compressors having different bore sizes. This is described in more detail below with references to FIG. 6A, and FIG. 6B.

15

FIG. 6A shows the primary reed of the valve plate shown in FIG. 5 and the cylinder bore of a compressor having a small bore size. FIG. 6B shows the primary and secondary reeds of the valve plate shown in FIG. 5 and the cylinder bore of a compressor having a large bore size.

20

As shown in FIG. 6A, the cylinder has a small bore size, for example, the bore 710, which corresponds to the diameter of the cylinder is 17.2mm. In this configuration, the primary reed 600 is within the bore 710 of the cylinder and therefore the end portion 614 of the primary reed 610 is free to move. The first secondary reed 620 and the second secondary reed 630 overlap with the edge of the bore 710 of the cylinder and therefore, the first secondary reed 620 and the second secondary reed 630 are blocked from moving by the bore 710 of the cylinder.

25

30

The configuration shown in FIG. 6A corresponds to a similar valve assembly to that shown in FIG. 2. In such an assembly as shown in FIG. 2, the valve plate 117 has a single suction hole 118. The end portion 614 of the primary reed 610 opens and closes the suction hole 118. During a suction stroke, the primary reed 610 opens and allows the working fluid 103 to be drawn into the compression chamber 113. In the

compression stroke, the primary reed 610 closes the suction hole 118 and thus the working fluid 103 is compressed in the compression chamber 113.

As shown in FIG. 6B, the cylinder has a large bore size, for example, the bore 720, which corresponds to the diameter of the cylinder is 20.6mm or 23.4mm. In this configuration, the primary reed 610, the first secondary reed 620 and the second secondary reed are within the bore 720 of the cylinder and therefore the end portion 614 of the primary reed 610, and the end portion 624 of the first secondary reed 620 and the end portion 634 of the second secondary reed 630 are all free to move.

The configuration shown in FIG. 6B differs from the valve assembly shown in FIG. 2. In the valve assembly corresponding to the configuration shown in FIG. 6B, the valve plate has first suction hole that corresponds to the end portion 614 of the primary reed 610, a second suction hole that corresponds to the end portion 624 of the first secondary reed 620 and a third suction hole that corresponds to the end portion 634 of the second secondary reed 330. During a suction stroke, the primary reed 610, the first secondary reed 620, and the second secondary reed 630 each open and allow the working fluid to be drawn into the compression chamber. Thus, a greater flow rate of working fluid is possible since each of the three suction holes open. In the compression stroke, the primary reed 610 closes the first suction hole, the first secondary reed 620 closes the second suction hole and the second secondary reed 630 closes the third suction hole and thus the working fluid 103 is compressed in the compression chamber 113. In the embodiment shown in FIG. 5, the length of the arm portion 622 of the first secondary reed 620 and the arm portion 632 of the second secondary reed 630 is different from the length of the arm portion 612 of the primary reed 610. This causes the natural frequency of the primary reed 610 to be different from the natural frequency of the first secondary reed 620 and the second secondary reed 630. As a result of this difference in natural frequency, the timing of the opening of the primary reed 610 and the first secondary reed 620 and the second secondary reed may be different. Embodiments are envisaged in which the first secondary reed and the second secondary reed are configured to have different natural frequencies.

Whilst the foregoing description has described exemplary embodiments, it will be understood by those skilled in the art that many variations of the embodiments can be made within the scope and spirit of the present invention.

CLAIMS

1. A hermetic compressor comprising:
 - a cylinder block forming a cylinder having a bore, the cylinder being configured to house a piston movable in the cylinder in a reciprocating manner;
 - a valve plate disposed at an opening end of the cylinder, the valve plate having a suction hole; and
 - a valve sheet comprising a plurality of reeds, the plurality of reed comprising a primary reed having an end portion configured to open and close the suction hole, the plurality of reeds further comprising a secondary reed arranged on the valve sheet the secondary reed overlaps with an edge of the bore and movement of the secondary reed is constrained by the cylinder block.
2. A hermetic compressor according to claim 1, wherein the secondary reed comprises an end portion and the end portion of the secondary reed is arranged vertically below the end portion of the primary reed.
3. A hermetic compressor according to claim 2, wherein the secondary reed comprises a first arm portion and a second arm portion arranged on respective first and second sides of the primary reed.
4. A hermetic compressor according to claim 2 or claim 3, wherein the end portion of the secondary reed has a greater area than the end portion of the primary reed.
5. A hermetic compressor according to any preceding claim wherein the primary reed and the secondary reed are configured to have different natural frequencies.
6. A hermetic compressor according to claim 1, wherein the plurality of reeds comprises a first secondary reed and a second secondary reed arranged on respective first and second sides of the primary reed.
7. A hermetic compressor according to claim 5, wherein each of the first secondary reed and the second secondary reed overlap with an edge of the bore

and movement of each of the first secondary reed and the second secondary reed is constrained by the cylinder block.

8. A hermetic compressor according to claim 6 or claim 7, wherein the primary reed is configured to have a different natural frequency from the first secondary reed and the second secondary reed.

9. A valve sheet for a hermetic compressor, the valve sheet comprising a plurality of reeds, the plurality of reeds comprising a primary reed and a secondary reed, the valve sheet being configured to form part of a valve assembly to be mountable on cylinder blocks of hermetic compressors having different cylinder bores, the plurality of reeds being arranged on the valve sheet such that respective end portions of the plurality of reeds open and close respective suction holes the valve assembly when the cylinder block of the hermetic compressor has a first bore size, and an end portion of the primary reed opens and closes a suction hole and the movement of the secondary reed is constrained when the cylinder block of the compressor has a second bore size, smaller than the first bore size.

10. A valve sheet according to claim 9, wherein the secondary reed comprises an end portion and the end portion of the secondary reed is arranged vertically below the end portion of the primary reed.

11. A valve sheet according to claim 10, wherein the secondary reed comprises a first arm portion and a second arm portion arranged on respective first and second sides of the primary reed.

12. A valve sheet according to claim 10 or claim 11, wherein the end portion of the secondary reed has a greater area than the end portion of the primary reed.

13. A valve sheet according to any one of claims 9 to 12, wherein the primary reed and the secondary reed are configured to have different natural frequencies.

14. A valve sheet according to claim 9, wherein the plurality of reeds comprises a first secondary reed and a second secondary reed arranged on respective first and second sides of the primary reed.

15. A valve sheet according to claim 14, wherein the primary reed is configured to have a different natural frequency from the first secondary reed and the second secondary reed.