

COOLING ELEMENT

The present invention relates to a cooling element for a vacuum pump and a vacuum pumping such a cooling element.

Common cooling elements for vacuum pumps are built by pressed in or cast in stainless steel pipes in an aluminum block. However, the mating face contact between aluminum and the stainless steel pipe in the cooling block is not perfect neither if pressed in or cast into the aluminum block. Therefore, the thermal transfer from the housing of the vacuum pump to the coolant flowing through the pipe is not sufficient. Further, the thermal transfer is further reduced since usually there is a laminar flow within the pipe diminishing the heat conductance from the vacuum pump to the coolant.

Further, the aluminum blocks are assembled to the housing of the vacuum pump by alloy steel bolts at room temperature. During operation, the cooling block temperature cycles between usually 20 to 160 °C. Since the alloy steel bolts have a lower thermal expansion than the aluminum, stress is induced into the bolts causing fatigue failure on the bolt. Thus, cooling effect can be diminished, and service of the vacuum pump may become necessary.

Thus, it is an object of the present invention to provide a cooling element providing an efficient heat transfer of the heat to the coolant and performing its function more reliably.

A solution to the given problem is provided by the cooling element according to claim 1 as well as the vacuum pump according to claim 13.

In accordance to the present invention the cooling element for vacuum pump comprises a base element wherein by the base element an internal void is defined. Further, an inlet is connected to the base element and is in fluid connection with the void. An outlet is connected to the base element and is in fluid

connection with the void such that a coolant can flow from the inlet through the void to the outlet to dissipate the heat transferred from the housing of the vacuum pump to the coolant. Therefore, the base element is connectable to the housing of the vacuum pump. Due to the coolant flowing through the internal void of the base element heat produced by the vacuum pump is dissipated and reliably carried away from the vacuum pump.

Preferably, the void is tubular. In particular the base element is provided by a pipe for ease of construction. Therein, the pipes can be shaped in different forms in order to provide a sufficient length to transfer heat from the vacuum pump to the coolant.

Preferably, the void has a flat shape. In this sense flat means that the height of the void is smaller than the width of the void. In particular, the width is more than twice as large as the height, preferably more than four-times as large as the height and even more preferably more than 10-times as large as the height. In particular, the height of the void is less than 3 mm, preferably less than 2 mm and even more preferably less than 1 mm. In comparison the width of the void can be several tens of mm, preferably more than 25 mm and more preferably more than 40 mm. Thus, by the flat void a large surface is created that is in contact with the coolant when the coolant is flowing through the void. Thus, efficiency of the heat transfer from the vacuum pump to the coolant may be improved.

Preferably, also the base element has flat shape thereby reduction of the amount of material and thus the costs of fabrication may be achieved. Therein, the shape of the base element may be adapted to the shape of the void. Therein, the term flat has the same meaning, i.e. that the base element has a height which is much smaller than the width of the element.

Preferably, the void has a length exceeding the width of the void, preferably exceeding the width of the a factor of two, more preferably by a factor of 4 and most preferably by a factor of 8. Thus, the coolant may have a sufficient time in order to take up the heat from the vacuum pump which is then dissipated by the coolant.

Preferably, the base element comprises a bottom surface to be directly attached to the surface of the housing of the vacuum pump. Thus, the base element is in direct contact with the housing of the vacuum pump which may provide sufficient heat conductivity in order to transfer the heat from the housing of the vacuum pump to the bottom surface of the base element, to the coolant in the internal void that is defined by the base element. In particular, the bottom surface is flat in order provide full contact with the surface of the housing of the vacuum pump.

In particular, the material thickness between the bottom surface of the base element and the void is less than 3 mm, preferably less than 2 mm and more preferably less than 1 mm. Thus, sufficient heat conductivity may be provided. Even if the base element is made from stainless steel, there might be sufficient heat conductivity due to the small material thickness of the bottom of the base element.

Preferably, the internal void comprises at least one corrugated surface to create turbulent flow within the void. Therein, the corrugated surface might be provided at least at the upper surface which is at the opposite site of the bottom surface away from the surface of the housing of the vacuum pump. More preferably, the upper surface as well as the bottom surface might comprise a corrugated surface.

Preferably, therein the corrugated surface can be provided by grooves which are arranged perpendicular to the direction of flow through the void. Alternatively

or additionally, the corrugated surface might be provided by ribs arranged perpendicular to the direction of flow. Thus, if only one corrugated surface is present, the corrugated surface can be built as grooves or ribs. If two corrugated surfaces are present, the two surfaces can be built both with grooves or both with ribs or one corrugated surface can be built as ribs and one corrugated surface can be built as grooves.

Preferably, if no connecting element is present, the corrugated surface of the upper surface is built as grooves wherein the corrugated surface of the bottom surface is built as ribs. In particular, if the base element is surrounded by a connecting element as described below then the bottom surface may be built as grooves or ribs in order to ensure turbulent flow within the void. By the turbulent flow in the void heat transfer to coolant might be improved.

Preferably the features of the corrugated surface of the upper surface and the features of the corrugated surface of the bottom surface are arranged alternating along the direction of flow.

Preferably, a turbulator element is disposed within the void to create turbulent flow within the void. Preferably, the turbulator element is built as wire mesh introduced into the void as separate element. In particular, if the void is constructed as pipe the turbulator element can be easily introduced into the pipes in order to ensure turbulent flow within the pipes enhancing the heat transfer to the coolant.

Preferably, the base element is built as one piece. Thus, there is no possibility of leakage of the coolant. Alternatively, the base element is composed of two pieces or more which are glued, welded, screwed or otherwise leaktight attached together.

Preferably, the base element is fabricated by 3D printing. In particular, if the base element is built in one piece by 3D printing it may provide the possibility to create internal voids with complex shapes such as a corrugated surface. Thus, 3D printing facilitates fabrication of the cooling element.

Preferably, the base element is surrounded by a connecting element. In particular, if the base element is not directly connected to the housing of the vacuum pump, the connecting element connects the base element with the housing of the vacuum pump. Therein, preferably, the connecting element is made from aluminum wherein the connecting element is directly connected to the housing of the vacuum pump. Therein, the base element can be cast-in or pressed-in into the connecting element to provide sufficient contact between the base element and the connecting element.

Preferably, the base element is made of stainless steel. In particular, if aggressive coolants are used stainless steel provides the benefit of being in use and long-lasting. Thus, if the cooling element is attached by alloy steel screws, cooling element and screws have the same or similar thermal expansion. Thus, thermal stress induced might be reduced.

Further, the present invention relates to a vacuum pump comprising a housing and cooling element as previously described.

The present invention will be described in detail with reference to the embodiments according to the accompanied drawings.

It is shown:

Figure 1 a perspective view of the cooling element in accordance to the present invention,

Figure 2 a cross section of the cooling element according to figure 1,

Figure 3 another embodiment of the cooling element according to the present invention and

Figure 4 an exemplary turbulator element.

The cooling element 10 according to the present invention comprises a base element 12 which is according to Figure 1 built as flat base element 12. Further, to the base element an inlet 14 and an outlet 16 is connected. A coolant is flowing through the inlet 14 as depicted by the arrow 18, flowing through an internal void 20 built in the base element (Figure 2) and leaving the cooling element 10 through the outlet 16 as depicted by the arrow 22. Therein the base element 12 comprises a bottom surface 24 which is in direct contact with the surface 26 of the housing 28 of the vacuum pump as depicted in figure 2.

Due to the flat shape of the void 20 in the base element 12 most of the coolant is close to the bottom surface 24 and able to take up heat energy transferred from the housing 28 of the vacuum pump to the cooling element 10. Therein, the cooling element 10 might be built from stainless steel. Even though stainless steel has a low heat conductivity, enough heat is transferred from the vacuum pump to the coolant since the material thickness D between the bottom surface 24 of the cooling element 10 and the lower surface of the internal void 20 is small and in particular less than 2 mm.

In accordance to the present invention an upper surface 30 of the internal void 20 is built as corrugated surface by a plurality of grooves 32 which are perpendicular to the direction of flow (as indicated by arrow 34). In addition, the lower surface 31 of the internal void 20 also comprises a corrugated surface as depicted in Fig. 2, wherein the corrugated surface in Fig. 2 is built by ribs 33 arranged perpendicular to the direction of flow and interchangeably arranged to

the grooves 32 of the upper surface 30. Thereby, the coolant is forced into turbulent flow enhancing the possibility of the coolant to take up heat from the vacuum pump.

Preferably, the base element 12 is built as one piece by 3D printing. Thereby, the complex shape of the void 20 can be easily achieved and further a leak tight design is provided.

The method of fabrication of the cooling element comprises the steps of:

- a) Printing a base element by 3D printing from stainless steel, wherein the base element comprises an internal void; and
- b) Attaching an inlet and an outlet to the base element in fluid communication to the internal void either also by 3D printing of any other method, such as welding, brazing or the like.

Therein the cooling element may have the features as described above or below.

Figure 3 shows another embodiment wherein the base element 12 comprises a first corrugated surface 32 as the embodiment of Figures 1 and 2 and also has a second corrugated surface 36 opposite to the first corrugated surface 32 wherein both are built identically by grooves. Thus, the opposite surface, i.e. the lower surface defining the void in between are built as corrugated surfaces. Therein, the base element 12 is placed into a connecting element 38 which is then connected to the surface 26 of a housing 28 of the vacuum pump. Therein the base element 12 might be casted into the connecting element 28 which is preferably made from aluminum. Thereby, both surfaces can be built as corrugated surfaces enhancing the possibility to take up heat by the coolant. In addition, features of Figure 3 which are the same or similar to features of the former figures are indicated by the same reference numbers.

Therein, in Figure 3, the flat base element is parallel arranged in the connecting element 38 to the surface 26 of the housing of the vacuum pump. Therein, parallel means that the bottom surface 24 and/or the top surface 30 of the base element 12 are parallel to the surface of the housing of the vacuum pump. Alternatively, the base element 12 can be arranged perpendicular within the connecting element 38 relative to the surface of the housing of the vacuum pump.

Figure 4 shows a wire mesh turbulator as turbulator element 40 which can be introduced into the void, in particular, if the void is built as pipe in order to ensure turbulent flow within the void, i.e. pipe.

CLAIMS

1. Cooling element for a vacuum pump, comprising

a base element, wherein by the base element an internal void is defined,

an inlet connected to the base element and in fluid connection with the void and

an outlet connected to the base element and in fluid connection with the void such that a coolant can flow from the inlet through the void to the outlet to dissipate heat,

wherein the base element is connectable to a housing of the vacuum pump.
2. Cooling element according to claim 1 characterized in that the void is tubular.
3. Cooling element according to claim 1 characterized in that the void has a flat shape.
4. Cooling element according to any of claims 1 to 3, characterized in that the base element has a flat shape.
5. Cooling element according to any of claims 1 to 4, characterized in that the base element comprises a bottom surface to be directly attached to the surface of the housing of the vacuum pump.

6. Cooling element according to claim 5, characterized in that the material thickness between the bottom surface and the void is less than 3mm, preferably less than 2mm and more preferably less than 1mm.
7. Cooling element according to any of claims 1 to 6, characterized in that the internal void comprises at least one corrugated surface to create turbulent flow within the void.
8. Cooling element according to any of claims 1 to 7, characterized by a turbulator element disposed within the void to create turbulent flow within the void.
9. Cooling element according to any of claims 1 to 8, characterized in that the base element is one piece.
10. Cooling element according to any of claims 1 to 9, characterized in that the base element is fabricated by 3D printing.
11. Cooling element according to any of claims 1 to 10, characterized in that the base element is surrounded by a connecting element, preferably made from aluminum, wherein the connecting element is directly connected to the housing of the vacuum pump.
12. Cooling element according to any of claims 1 to 11, characterized in that the base element is made of stainless steel.
13. Vacuum pump comprising a housing and a cooling element according to any of claims 1 to 12 connected to the housing.