Thermal insulation for a turbine housing

The invention relates to a thermal insulation 1 for a turbine housing 2, in particular for a steam turbine housing, wherein the thermal insulation 1 consists of an insulating material or comprises an insulating material whose insulating properties are essentially based on nanostructures of the insulating material. The invention further relates to a turbomachine having such a thermal insulation.

![Diagram of a turbine housing with thermal insulation]
Description

[0001] The invention relates to a thermal insulation for a turbine housing and to a turbomachine having such a thermal insulation.

[0002] Turbine housings, particularly turbine housings of steam turbines, are equipped with a thermal insulation. The thermal insulation is used to minimize the loss of heat via the turbine housing into the environment, since thermal losses result in reduced efficiency. In the case of turbines that are switched off overnight, such as e.g. steam turbines in solar power plants, the thermal insulation is also used to maintain the temperature of the components for as long as possible, in order to avoid lengthy heating up of the components of the steam turbine before it becomes operational in the morning. This means that the solar energy can be utilized more quickly, thereby resulting in more efficient operation of the turbine. The turbine housing of a steam turbine is usually insulated using mineral wool in the form of mats. These insulating mats are fastened to the turbine housing by means of wires. Due to the heavy weight of these insulating mats, the mat will often sag on the underside of the turbine housing. This results in an air gap, between the turbine housing and the insulating mat, in which the air can circulate. This results in reduced thermal insulation and, particularly when the turbine is being run down, can result in uneven cooling of the turbine components, whereby the danger arises of warping of the rotor. In order to prevent this gap from forming between turbine housing and thermal insulation, DE 10 2009 013 083 A1 of the applicant proposes that, instead of insulating mats made of mineral wool, a turbine housing insulation be designed using a composite material consisting of a temperature-resistant rigid foam. The design using rigid foam ensures an essentially all-over close fit of the thermal insulation on the turbine housing, whereby air gaps between thermal insulation and turbine housing can be largely prevented.

[0003] The rigid foams still have a high specific weight, however, and therefore a stable and secure fastening to the turbine housing must be ensured. Furthermore, the rigid foams only have a relatively modest thermal insulation.

[0004] Taking the existing prior art as its starting point, the object of the invention is to provide a thermal insulation for a turbine housing, in particular for a steam turbine housing, which offers improved thermal insulation and lower specific weight at the same time. In addition, the object of the present invention is to provide a turbomachine featuring an improved thermal insulation.

[0005] In respect of the thermal insulation, the object is achieved by the features in the independent claim 1. In respect of the turbomachine, the object is achieved by the features in the claim 12.

[0006] Further advantages and embodiments of the invention, which can be implemented alone or in combination, are the subject of the subclaims.

[0007] The inventive thermal insulation for a turbine housing, in particular for a steam turbine housing, is distinctive in that the thermal insulation consists of an insulating material or comprises an insulating material whose insulating properties are based essentially on nanostructures of the insulating material. In this case, the structural properties can derive from the particle size, which lies in the nanometer range, from fibers whose diameter lies in the nanometer range, or from pore sizes in the nanometer range within the thermal insulation. The thermal insulation can also be achieved by a combination of the individual structural measures. As a result of using thermal insulation featuring nanostructures, both significantly better insulating properties and a lower specific weight are produced in comparison with conventional insulating materials such as mineral fibers, for example.

[0008] According to an embodiment of the invention, the thermal insulation in its assembled state fits closely and essentially positively onto a corresponding contact surface of the turbine housing, either indirectly or directly. By virtue of the close fit of the thermal insulation against the turbine housing, air gaps in which air circulation could occur are avoided. This produces a particularly effective thermal insulation.

[0009] According to a further embodiment of the invention, the thermal insulation is connected to the turbine housing in such a way that it can be non-destructively disassembled. By virtue of the possible non-destructive disassembly, the thermal insulation can easily be disassembled and then attached to the turbine housing again, particularly for the purpose of maintenance to the turbine. The assembly time is shortened and the costs are considerably reduced in this way.

[0010] According to a further embodiment of the invention, the thermal insulation consists of an aerogel or comprises an aerogel. Aerogels are highly porous solids whose volume consists of up to 99.8% pores. Aerogels have a dendritic structure, meaning that there is significant branching of particle chains with numerous intermediate spaces in the form of open pores. This results in a stable sponge-like structure. The aerogel has high strength and can be cut into a corresponding shape that matches the turbine housing, thereby ensuring all-over contact on the turbine housing. The pore size of aerogels is in the nanometer range, and therefore large inner surfaces of up to 1000 sq.m/g can be achieved. Consequently, aerogels are particularly suitable for use as an insulating material.

[0011] According to a preferred embodiment of the invention, the aerogel is a silica aerogel. Silica aerogels have a melting point of approximately 1200° and are non-combustible and nontoxic. They are therefore particularly suitable for use as a thermal insulation for turbomachines in which high housing temperatures occur.

[0012] According to a preferred embodiment of the invention, the individual particles of the silica aerogel have an average diameter of 1 to 10 nm. The small particle size results in a fine branching of particle chains and
hence a large number of intermediate spaces in the form of open pores in which air can be enclosed, wherein this contributes to particularly good thermal insulation.

According to a further advantageous embodiment of the invention, the porosity of the silica aerogel is between 80 and 99.8%. As described above, the high porosity contributes to a high inclusion of air and hence to better thermal insulation.

According to a further embodiment of the invention, the thermal conductivity of the silica aerogel is between 0.017 and 0.021 W/mK. This ensures that the silica aerogel has high temperature stability, even under extreme conditions, and ensures good thermal insulation.

According to a further embodiment of the invention, the thermal insulation consists of a nanofiber or comprises nanofibers. A fiber whose average diameter is in the nanometer range is referred to as a nanofiber in this case.

According to an embodiment of the invention, the nanofibers have an average diameter between 50 and 500 nm. The nanofiber is preferably a carbon fiber.

According to a further embodiment, the nanofibers are woven into a textile thermal insulating mat. The weaving of the nanofibers into a thermal insulating mat results in a very porous thermal insulating mat featuring the finest pores, in which air is enclosed, contributing to very good thermal insulation. The insulating mats can be attached to the turbine housing easily. By virtue of the material that is used, the insulating mats have a very low specific weight and therefore sagging of the mat, as frequently occurs in the case of mineral fiber mats, can be avoided. Due to the increased porosity, they also exhibit significantly better thermal insulation than the mineral fiber insulating mats that were used previously.

The inventive turbomachine, in particular a steam turbine, is distinctive in that the turbomachine features a thermal insulation as claimed in one of the preceding claims, i.e., it comprises a thermal insulation whose insulating properties are essentially based on nanostructures of the insulating material. The nanostructures of the insulating material result in a particularly good thermal insulation and a very low specific weight at the same time. By virtue of the improved thermal insulation, improved efficiency of the turbomachine is achieved because thermal losses into the environment can be kept at a low level. By virtue of the low specific weight of the insulating material, sagging of the insulating material is avoided, thereby preventing air gaps and therefore air circulation between insulating material and turbine.

Further embodiments and advantages of the invention are explained below with reference to the schematic drawings, in which:

Figure 1 shows a longitudinal section through a turbine housing having a thermal insulation according to the invention;

Figure 2 shows a frontal view of the turbine housing shown in Figure 1.

The figures are schematic representations, in which only those components essential to the invention are illustrated. Since the basic structure of turbomachines and the way in which they function are not required for the understanding of the invention, these are not described in any detail here. In principle, the turbomachine can be any type of turbomachine in which thermal insulation of the turbine housing relative to the environment is beneficial. Such thermal insulation is beneficial for steam turbines housings in particular, and here in particular for steam turbines which are used for solar thermal applications.

Figure 1 shows the exhaust-steam housing 2 of a steam turbine in a lateral sectional view. The exhaust steam housing 2 has the form of a cone. In order to ensure that the smallest possible portion of the thermal energy of the steam is emitted into the environment via the exhaust steam housing 2, the exhaust steam housing 2 is designed to have a thermal insulation 1. The thermal insulation 1 consists of an insulating material, whose insulating properties are based essentially on nanostructures of the insulating material. In particular, suitable insulating materials include a silica aerogel or a textile thermal insulating mat woven from nanofibers, particularly carbon fibers. When using silica aerogel, the individual particles of the silica aerogel preferably have an average diameter of 1 to 10 nm. The individual nanoparticles adhere to form finely branched particle chains, wherein the distance between the chains is preferably approximately 10 to 100 nm. This results in a multiplicity of fine pores in the nanometer range, whereby surfaces of up to 1000 sq.m/g insulating material can be achieved. The porosity is between 80 and 99.8% in this case. The high porosity results in a very low specific density of approximately 0.1 g/cm3. The high porosity also results in a very low thermal conductivity of approximately 0.02 W/m*K in air at 300 °K. This results in a very high level of thermal insulation.

The silica aerogel has the additional advantage of a very high melting point, this being approximately 1200 °C. As a result, the thermal insulation can be used not only for the relatively cool low-pressure region of steam turbines, but also for those steam turbine stages which are maintained at a considerably higher temperature or for other turbomachines such as gas turbines, for example.

With regard to its consistency, the silica aerogel is a sponge-like but stable structure, which can be cut to shape or molded according to the requirements. As a result, it can be cut exactly to the contours of the turbine housing 2, thereby ensuring an all-over close fit of the thermal insulation 1 on the turbine housing 2 in the assembled state. The positive fit of the thermal insulation 1 on the turbine housing 2 is realized by the corresponding contact surface 3 on the turbine housing 2 and on the thermal insulation 1. This prevents an air gap from developing between the turbine housing 2 and the thermal
insulation 1. Air circulation could occur in the air gap and this would result in an increased heat emission into the environment.

[0024] The silica aerogel also has the advantage that it allows a high level of sound insulation. It is therefore possible to dispense with additional sound absorbing materials, thereby allowing cost savings. For example, a sound reduction of approximately 50% can be achieved at 100 Hz. Moreover, the silica aerogel is completely hydrophobic and weather-resistant, thereby eliminating the need for further coatings or protective measures such as those required for mineral wool, for example.

[0025] Due to the extraordinarily low specific weight of the thermal insulation 1, sagging of the thermal insulation is completely prevented. Due to its development as a solid shaped part, the thermal insulation 1 can be assembled and disassembled easily and non-destructively, thereby offering particular advantages in the context of servicing. The thermal insulation 1 can easily be removed and then fastened to the turbine housing 2 again without great effort after servicing is complete. The service time and the service costs are reduced as a result of this. The thermal insulation is advantageously designed in two parts. In this case, the fastening can be done by means of wires or Velcro connection or by other suitable means.

[0026] Figure 2 shows the front view of the turbine housing 2 with the thermal insulation 1. The figure shows how the thermal insulation 1 divided axially into two parts, consisting of an upper shell and a lower shell. The upper shell 1" and the lower shell 1" can be connected together or fixed individually to the turbine housing 2 in each case. The two-part design consisting of upper shell 1" and the lower shell 1" allows a simple and fully enclosing arrangement of the thermal insulation on the turbine housing 1. A single-part solution would also be possible, but it would be necessary to ensure in this case that the thermal insulation could be pulled over the turbine housing 1 completely from the side.

[0027] As an alternative to using the silica aerogel as a thermal insulation 1, it is also possible to use a thermal insulating mat which is made of nanofibers, in particular carbon fibers. The thermal insulating mat is woven from nanofibers which have a diameter between 50 and 500 nm. As a result of the fine fibers, air is stored in the thermal insulating mat, thereby providing very good thermal insulation. The thermal insulating mats can be fastened to the turbine housing 2 in a similar manner to the mineral fiber mats. Due to the significantly lower density of the thermal insulating mats, these being woven from nanofibers, sagging of the thermal insulating mats is effectively prevented.

[0028] In summary, it can therefore be stated that the inventive thermal insulation significantly increases the thermal insulation, in comparison with conventional insulating materials, by means of an insulating material which exhibits insulating properties that are based essentially on the nanostructure of the insulating material.

[0029] The specific weight of the insulating material is clearly lower than in the case of previously used insulating materials. The thermal insulation according to the invention allows increased efficiency to be achieved in the case of steam turbines in particular. In addition to the improved thermal insulation, it is also possible to achieve improved sound insulation and particularly good weather resistance. The thermal insulation according to the invention can be disassembled non-destructively and can therefore be reused following servicing work on the turbine.

Claims

1. A thermal insulation (1) for a turbine housing (2), in particular for a steam turbine housing, characterized in that the thermal insulation (1) consists of an insulating material or comprises an insulating material whose insulating properties are based essentially on nanostructures of the insulating material.

2. The thermal insulation (1) as claimed in claim 1, characterized in that in its assembled state, the thermal insulation (1) fits closely and essentially positively onto a corresponding contact surface (3) of the turbine housing (2), either indirectly or directly.

3. The thermal insulation (1) as claimed in claim 1 or 2, characterized in that the thermal insulation (1) is connected to the turbine housing (2) in such a way that it can be non-destructively disassembled.

4. The thermal insulation (1) as claimed in one of the preceding claims, characterized in that, the thermal insulation (1) consists of an aerogel or comprises an aerogel.

5. The thermal insulation (1) as claimed in claim 4, characterized in that the aerogel is a silica aerogel.

6. The thermal insulation (1) as claimed in claim 5, characterized in that the individual particles of the silica aerogel have an average diameter of 1 to 10 nm.

7. The thermal insulation (1) as claimed in claim 5 or 6, characterized in that the porosity of the silica aerogel is between 80 and 99.8%.

8. The thermal insulation (1) as claimed in claim 5 to 7, characterized in that the thermal conductivity of the silica aerogel is be-
between 0.017 and 0.021 W/(mK).

9. The thermal insulation (1) as claimed in one of the claims 1 to 3, characterized in that the thermal insulation (1) consists of a nanofiber or comprises nanofibers.

10. The thermal insulation (1) as claimed in claim 9, characterized in that the nanofibers have an average diameter between 50 and 500 nm.

11. The thermal insulation (1) as claimed in one of the claims 9 or 10, characterized in that the nanofiber is a carbon fiber.

12. The thermal insulation (1) as claimed in one of the claims 9 to 11, characterized in that the nanofibers are woven into a textile thermal insulating mat.

13. A turbomachine, in particular steam turbine, characterized in that the steam turbine comprises a thermal insulation as claimed in one of the claims 1 to 11.
The present search report has been drawn up for all claims.

**DOCUMENTS CONSIDERED TO BE RELEVANT**

<table>
<thead>
<tr>
<th>Category</th>
<th>Citation of document with indication, where appropriate, of relevant passages</th>
<th>Relevant to claim</th>
<th>CLASSIFICATION OF THE APPLICATION (IPC)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Y</td>
<td>* paragraphs [0073] - [0076]; figures *</td>
<td>5-8</td>
<td></td>
</tr>
<tr>
<td></td>
<td>* paragraph [0087] - paragraph [0088] *</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>* paragraph [0113] *</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Y</td>
<td>GB 2 267 329 A (ROLLS-ROYCE PLC [GB]) 1 December 1993 (1993-12-01)</td>
<td>5-8</td>
<td></td>
</tr>
<tr>
<td></td>
<td>* page 3, paragraph 1st complete *</td>
<td></td>
<td></td>
</tr>
<tr>
<td>X</td>
<td>EP 1 927 728 A2 (GEN ELECTRIC [US]) 4 June 2008 (2008-06-04)</td>
<td>1,2,9-13</td>
<td></td>
</tr>
<tr>
<td></td>
<td>* paragraph [0019]; figures *</td>
<td></td>
<td></td>
</tr>
<tr>
<td>X</td>
<td>DE 10 2008 002847 A1 (GEN ELECTRIC [US]) 20 November 2008 (2008-11-20)</td>
<td>1,2</td>
<td></td>
</tr>
<tr>
<td></td>
<td>* paragraph [0034] - paragraph [0035]; figures *</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>* paragraph [0018] *</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>* pages 13,39 *</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>* paragraphs [0007], [0016], [0019]; figures *</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**TECHNICAL FIELDS SEARCHED (IPC)**

- F01D
This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on 27-02-2012.

The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

<table>
<thead>
<tr>
<th>Patent document cited in search report</th>
<th>Publication date</th>
<th>Patent family member(s)</th>
<th>Publication date</th>
</tr>
</thead>
<tbody>
<tr>
<td>US 2004109758 A1</td>
<td>10-06-2004</td>
<td>NONE</td>
<td></td>
</tr>
<tr>
<td>GB 2267329 A</td>
<td>01-12-1993</td>
<td>NONE</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>EP 1927728 A2</td>
<td>04-06-2008</td>
</tr>
<tr>
<td></td>
<td></td>
<td>JP 2008128250 A</td>
<td>05-06-2008</td>
</tr>
<tr>
<td></td>
<td></td>
<td>KR 20080046111 A</td>
<td>26-05-2008</td>
</tr>
<tr>
<td></td>
<td></td>
<td>US 2008115454 A1</td>
<td>22-05-2008</td>
</tr>
<tr>
<td></td>
<td></td>
<td>FR 2916224 A1</td>
<td>21-11-2008</td>
</tr>
<tr>
<td></td>
<td></td>
<td>JP 2008286298 A</td>
<td>27-11-2008</td>
</tr>
<tr>
<td></td>
<td></td>
<td>US 2008286099 A1</td>
<td>20-11-2008</td>
</tr>
<tr>
<td>US 2011052382 A1</td>
<td>03-03-2011</td>
<td>CA 2713627 A1</td>
<td>26-02-2011</td>
</tr>
<tr>
<td></td>
<td></td>
<td>US 2011052382 A1</td>
<td>03-03-2011</td>
</tr>
<tr>
<td></td>
<td></td>
<td>WO 2011039050 A2</td>
<td>07-04-2011</td>
</tr>
</tbody>
</table>

For more details about this annex: see Official Journal of the European Patent Office, No. 12/82.
REFERENCES CITED IN THE DESCRIPTION

This list of references cited by the applicant is for the reader’s convenience only. It does not form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.

Patent documents cited in the description

• DE 102009013083 A1 [0002]