United States Patent Application Publication	20250257680
Kind Code	A1
Publication Date	August 14, 2025
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EXHAUST ASSEMBLY HEAT MITIGATION SYSTEM

Abstract

This disclosure describes, in part, systems and structures for an exhaust assembly that includes an exhaust tube and an insulation structure surrounding the exhaust tube. The insulation structure is offset from the exhaust tube to create an air gap around the exhaust tube and the insulation structure. The air gap is used to transport forced air by a fan system to mitigate and remove heat from the exhaust tube to a disposal location. The insulation structure includes an inner shell and an outer shell that contain an insulation component to provide a reduced surface temperature during steady state operation within a threshold range.

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Appl. No.: **18/440401**

Filed: **February 13, 2024**

Publication Classification

Int. Cl.: **F01N13/14** (20100101)

U.S. Cl.:

CPC **F01N13/14** (20130101); F01N2310/02 (20130101); F01N2470/24 (20130101)

Background/Summary

TECHNICAL FIELD

[0001] The present application relates generally to internal combustion engines. More particularly, the present application relates to temperature regulation and heat mitigation for exhaust assemblies of internal combustion engines to prevent thermal stress and failure in exhaust pipes.

BACKGROUND

[0002] Internal combustion engines may be configured to convert diesel fuel, natural gas, hydrogen gas, landfill gas, gasoline, or other fuel into mechanical energy. Large-scale internal combustion engines often include thermal insulation and thermal control systems to mitigate heat and reduce or prevent heat transfer to surrounding components of the internal combustion engine or other related systems. Exhaust systems include shielding for reducing heat radiation, providing a screen or protection against sprayed fuel and/or lubricating oil, and to reduce a risk of injury through contact. Thermal insulation systems for exhaust heat can be expensive, complex, and prone to failure. Additionally, thermal insulation systems may be bulky and occupy space in an engine space.

[0003] Thermal stresses increase in exhaust components when heat is retained in the exhaust system. Therefore, to prevent failure of the exhaust components or impact to other components of the internal combustion engine, exhaust heat mitigation is needed to reduce thermal stresses.

[0004] An example system for an exhaust assembly with a heat insulation structure is described in U.S. Pat. No. 10,519,844 to Lehtonen et al., titled “Heat Insulation Structure” (hereinafter referred to as “the '844 document”). In particular, the '844 document describes a heat insulation structure for a piston engine arrangeable around an exhaust component such that an air space is formed between the exhaust component and the heat insulation structure. The heat insulation structure of the '844 document includes an outer shell layer, a middle shell layer arranged inside the outer shell layer, and an inner shell layer arranged inside the middle shell layers. The heat insulation structure of the '844 documents provides a first air gap between the inner shell layer and the exhaust component and a second air gap between the outer shell layer and the middle shell layer with an insulation layer arranged between the middle shell layer and the inner shell layer. The first air gap and the second air gap are both naturally ventilated.

[0005] Although the system described in the '844 document is configured to provide heat shielding and insulation for the exhaust component, with particular emphasis on a surface temperature of the insulation system for the exhaust component, for example when implemented in marine environments, the heat insulation system of the '844 document is not able to prevent thermal stresses due to retained heat in the exhaust system, which may lead to premature failure of the exhaust components. As a result, the system described in the '844 document is not configured to provide heat mitigation to the exhaust component as well as reduce surface temperatures and radiation to local components from the exhaust component. Accordingly, the system described in the '844 document may be prone to elevated maintenance costs due to thermal stresses and heat buildup in the exhaust assembly and premature failure due to damage associated with such heat buildup and thermal stresses.

[0006] Examples of the present disclosure are directed toward overcoming the deficiencies described above.

SUMMARY OF THE INVENTION

[0007] The description provided herein describes an exhaust assembly that includes an exhaust tube defining a substantially central axis, where the exhaust tube is configured to direct an exhaust gas away from an engine to which the exhaust tube is fluidly connected. The assembly also includes an insulation structure positioned concentrically around the exhaust tube, the insulation structure including a standoff coupled to the exhaust tube and providing an air gap between the exhaust tube and the insulation structure. The insulation structure further includes an inner shell coupled to the standoff and concentric about the exhaust tube and an outer shell concentric about the inner shell. In a space between the inner shell and the outer shell an insulation layer is disposed.

The assembly may also include a forced air system that drives air through the air gap along a length of the exhaust tube.
[0008] In some examples, the insulation layer may include aerogel. The standoff may also include a porous metal mesh disposed in the air gap between the inner shell and the exhaust tube. The insulation layer may, in some examples, include rock wool insulation or mineral wool insulation. In some examples, the exhaust gas travels along the exhaust tube in a first direction and the forced air system drives the air in a second direction opposite the first direction. In some examples, the exhaust gas travels along the exhaust tube in a first direction and the forced air system drives the air in a second direction parallel to the first direction. The forced air system may include a fan at a first end of the insulation structure configured to pull air through the air gap from a second end to the first end.

Description

BRIEF DESCRIPTION OF THE DRAWINGS
[0009] The detailed description is set forth with reference to the accompanying figures. In the figures, the left-most digit(s) of a reference number identifies the figure in which the reference number first appears. The use of the same reference numbers in different figures indicates similar or identical items or features.
[0010] FIG. **1** illustrates an exhaust assembly with a heat mitigation and insulation system for an internal combustion engine, according to at least one example.
[0011] FIG. **2** illustrates a section view of an exhaust assembly with a heat mitigation system for an internal combustion engine, according to at least one example.
[0012] FIG. **3** illustrates a cross-section view illustrating an exhaust assembly with a heat mitigation system for an internal combustion engine, according to at least one example.
[0013] FIG. **4** illustrates a cross-section view illustrating a portion of an exhaust assembly with a heat mitigation system, according to at least one example.
[0014] FIG. **5** illustrates a cross-section view illustrating a portion of an exhaust assembly with a heat mitigation system, according to at least one example.
[0015] FIG. **6** illustrates a detail view of a heat mitigation system for an exhaust assembly, according to at least one example.
DETAILED DESCRIPTION
[0016] Wherever possible, the same reference numbers will be used throughout the drawings to refer to the same or like parts. In the figures, the left-most digit(s) of a reference number identifies the figure in which the reference number first appears.
[0017] FIG. **1** illustrates an exhaust manifold **102** for an internal combustion engine **101**, according to at least one example. The internal combustion engine **101** may be any engine configured to generate electricity and/or mechanical energy using a fuel. Fuels for the internal combustion engine **101** may include fuels such as diesel, hydrogen, gaseous fuels, and other such fuels used to power internal combustion engines. Gaseous fuels may include fuels that are in a gaseous state under ordinary conditions such as at standard temperature and pressure. Gaseous fuels may include, for example, hydrogen, methane, ethane, liquified natural gas (LNG), propane, blends of these, and the like.
[0018] Though described herein with reference to internal combustion engines, the systems and methods described herein may be implemented with other heat-generating systems that may need heat mitigation to reduce wear and thermal stresses that lead to failure of components. For example, such systems may include an exhaust gas recirculation cooler, turbo, and other such systems.
[0019] The exhaust manifold **102** may include an insulation structure that provides for heat

mitigation as well as lower surface temperatures of the internal combustion engine **101**, for example. The exhaust manifold **102** includes ports **104** for receiving exhaust gases from the internal combustion engine **101**, for example through exhaust ports of the internal combustion engine **101**. The ports **104** provide conduits for exhaust gases to travel from the engine exhaust ports to an exhaust tube **106** of the exhaust manifold **102**. The exhaust manifold **102** provides an exit **108** for transporting exhaust gases away from the internal combustion engine **101** for treatment and/or dispersal.

[0020] In some examples, the insulation may be effective at preventing the exterior temperature of the exhaust assembly from exceeding 300 degrees Celsius. The use of aerogel or other such insulation may make such a temperature differential possible in a compact space such that the thickness of the insulation and the thickness of the air gap is less than a thickness of a typical insulation that may have a lower thermal resistance than the aerogel. Accordingly, the configuration included herein provides for a more compact profile surrounding the exhaust assembly while maintaining or exceeding the performance of typical exhaust systems.

[0021] The exhaust manifold **102** includes an insulation structure **110** that surrounds the exhaust tube **106**. The insulation structure **110** includes multiple layers and provides for heat mitigation through forced convection as well as reduced surface temperatures and radiation to surrounding components. The insulation structure **110** provides for forced convection through an air gap **118** between the exhaust tube **106** and an insulation layer **120**. The forced convection is a result of fans **112** that draw air **114** into the air gap **118** at a first end of the exhaust manifold **102** and expels the air **116** at a second end of the exhaust manifold **102**. The forced convection provides heat mitigation as heat is transferred to the air as it is forced through the air gap **118** and expelled at a waste heat disposal location. In some examples, the fan **112** may force the air away from the internal combustion engine **101** such as out of an engine compartment and/or past a radiator or other heat transfer system. In some examples, the air gap **118** may have a thickness of approximately five millimeters around the exhaust tube **106** such that the insulation layer **120** is offset from the exhaust conduit by approximately five millimeters around the circumference of the exhaust conduit.

[0022] The insulation layer **120** may be positioned concentrically about the exhaust tube **106** by one or more standoffs positioned between the insulation layer **120** and the exhaust tube **106**. The standoffs may include fins, pins, or structural members that span the air gap **118** without blocking and/or preventing airflow through the air gap **118**. The standoffs may, for example include stainless steel or other ribs that couple to an inner shell of the insulation layer **120** and to the exhaust tube **106**. In some examples, the standoffs may include a metal mesh or other porous material that fills a gap between the insulation layer **120** and the exhaust tube **106** and supports the insulation layer **120** being spaced away from the exhaust tube **106**. In an example, the metal mesh may include a stainless steel mesh that is porous to allow airflow through the air gap **118** while also providing support for maintaining the position of the insulation layer **120** relative to the exhaust tube **106**. In an example, the metal mesh may include an open-cell metal foam, metal webbing, or other such material that allows airflow while also providing structural support to the insulation layer **120**.

[0023] In some examples, the metal mesh and/or other standoff may provide for additional heat transfer to the air in the air gap **118** as air is forced through the air gap **118**. As the air flows through the air gap **118**, the additional surface area of the standoffs may enable heat transfer from the exhaust tube **106** to the air to be carried away from the exhaust system for disposal.

[0024] In some examples, the standoffs may include a heat bridge interruption to prevent or reduce heat transferred from the exhaust tube **106** to the insulation layer **120** through the standoffs. For example, the standoffs may include a material having a low thermal conductivity, for example at a middle portion of the standoff and/or be formed of a material with a relatively (compared with stainless steel) low thermal conductivity.

[0025] The exhaust manifold **102** is designed with steel, stainless steel, and/or cast-iron components, in some examples. The exhaust manifold **102** may reach temperatures up to and in excess of 760 degrees Celsius. The high temperatures may cause typical insulation to break down or fail and/or cause a high temperature gradient across a short distance that results in expansion and stresses and failure in the exhaust manifold **102**.

[0026] The exhaust manifold **102** and/or the insulation layer (e.g., the inner shell and the outer shell) may include expansion gaps and/or flexible portions to allow for thermal expansion during operation at elevated temperatures.

[0027] The insulation structure **110** provides for a step down in temperature between the surface of the exhaust tube **106** and the insulation layer **120** such that an insulating material such as an aerogel may be used for the insulation layer. Aerogel insulation, such as silica-based aerogel and composite pyrogels may operate and be effective up to a temperature of about 650 degrees Celsius. Accordingly, the insulations structure **110** provides an ability to implement insulation such as aerogels within the insulation layer **120** without the insulation breaking down or failing. The insulation structure includes the air gap **118** with forced convection occurring through the air gap **118** and resulting in a stepped down temperature occurring at the insulation layer **120**.

[0028] The insulation layer **120** may be sandwiched between an inner layer and an outer layer, such as an inner shell and an outer shell. In an example, the inner layer or inner shell and the outer layer or outer shell for the insulation layer **120** may be formed for stainless steel or another suitable material. The insulation layer **120** may have a thickness of up to ten millimeters in some examples, such as examples that include an aerogel insulation in the insulation layer **120**. The thickness of the insulation layer **120** may be based on reducing the external surface temperature to approximately 300 degrees Celsius or less. In some examples, the insulation layer **120** may be greater than ten millimeters to reach a desired temperature on the outer shell.

[0029] The insulation layer **120** may include aerogel, as mentioned previously, and may include shredded aerogel particles fit between the inner shell and the outer shell, for example by filling a space between the shells with the aerogel particles. The space may be sealed off to retain the aerogel particles, for example with end caps connecting between the inner shell and the outer shell. In some examples, the insulation layer **120** may include an aerogel blanket with aerogel particles suspended or retained in an organic binder. In some examples, the insulation layer **120** may include other types of insulation such as mineral wool insulation, rock wool insulation, vacuum insulation between the inner shell and the outer shell, and other suitable insulation that may withstand the temperatures of the exhaust manifold **102**.

[0030] The air gap **118** provides for air to be forced or driven through the air gap **118**, heated by proximity with the exhaust tube **106**, and expelled at an end and/or an exit of the insulation structure **110**. The air gap **118** may extend along a length of the exhaust tube **106**, and may include along an entire length of the exhaust tube **106**, across a portion of a length of the exhaust tube **106**, and/or include multiple insulation structures to span the length of the exhaust tube **106**. An entry for air **114** at one end of the exhaust tube **106** and/or insulation structure **110** allows air to enter the air gap **118** from an air source. In some examples, the air source may be connected to ducting to provide air from an external source rather than a local source, such as within an engine compartment. The air source may be external to a vehicle and/or engine compartment and may pass through ducting and/or filters before reaching the air gap **118**. The filter may prevent particles, impurities, oils, fuels, and other contaminants from contacting the exhaust tube **106** and potentially igniting.

[0031] The fans **112** are depicted drawing air **114** through the entry and expelling air **116** from the air gap **118** at an exit. The fans **112** may be configured to pull air through the air gap **118** as depicted and/or to push air through the air gap **118** (e.g., in the opposite direction pictured in FIG. **1**. The fans may be driven by a power source, and may include electric fans or fans driven using a belt connected to an output shaft of the internal combustion engine **101**. In some examples, the fans **112** may include cooling fans for the internal combustion engine **101**, with ducting leading from the air gap **118** to the existing cooling fans, such as fans at or adjacent a radiator for a cooling system of the internal combustion engine **101**. The fans **112** may also include passive fans, such as fans driven by passive means such as a heat engine. For instance, the fans **112** may include fans driven based on a heat difference such as by a Peltier device and/or Stirling engine that use a heat difference and/or dissimilar metals to produce a voltage for powering the fan and/or use a heat difference to expand and compress a working gas to produce motion of the fans **112**. The fans **112** may be positioned at or near the end of the insulation structure **110** with a hot end positioned against and/or adjacent the exhaust tube **106** and a cold end including one or more radiator fins extending away from the exhaust tube **106** such as into the engine compartment.

[0032] FIG. **2** illustrates a section view of an exhaust manifold **102**, according to at least one example. The exhaust manifold **102** includes, within the insulation structure **110**, an inner shell **124** and an outer shell **126**. The inner shell **124** and the outer shell **126** define volume for containing insulation **122** such as the insulation layer **120** described with respect to FIG. **1**. The insulation **122** may have a consistent thickness and/or a variable thickness (such as depicted in FIG. **2**) around the circumference of the exhaust tube **106**. The exhaust manifold **102** extends along an axis, e.g., an axis that aligns with or follows the direction of flow of the exhaust within the exhaust tube **106**.

[0033] The inner shell **124** and the outer shell **126** may be joined together at ends of the insulation structure **110** such as with end caps or plates that enclose the insulation **122** within the volume formed between the inner shell **124** and the outer shell **126**. In some examples, the insulation may include aerogel, shredded aerogel, aerogel particles, mineral wool insulation, rock wool insulation, aerogel blanket, or other such insulative particles and/or blankets. In an example, the insulation **122** may include vacuum insulation. For instance, in the example, the inner shell **124** and the outer shell **126**, when coupled with the end caps of the insulation layer **120**, may enclose the insulation **122** such that the volume may be evacuated to provide vacuum insulation across the insulation structure. In some examples, the end caps may be formed, at least partially of an insulative material to prevent heat being transferred across the end caps of the insulation structure **110**.

[0034] In examples and systems described herein, the exhaust manifold **102** may be implemented in any internal combustion engine **101** without requiring any changes to the internal combustion engine **101** or downstream exhaust system.

[0035] FIG. **3** illustrates a cross-section view illustrating an exhaust manifold **102** for an internal combustion engine **101**, according to at least one example. The exhaust manifold **102** includes an exhaust tube **300** and an insulation structure **302** that may be similar and/or identical to the insulation structure **110** described with respect to FIGS. **1** and **2**. The exhaust manifold **102** includes exhaust inlets **306** *a*-**306** *h*, an exhaust outlet **308**, and an exhaust conduit **316**. Exhaust gases are received through the exhaust inlets **306** *a*-**306** *h*, for example, and flow to the exhaust outlet **308** through the exhaust conduit **316**.

[0036] The insulation structure **302** includes an inner shell **312** and an outer shell **314**. Inner shell **312** and the outer shell **314** enclose the insulation **320**. The insulation **320** may include the insulation described herein, such as aerogel particles and other such insulation products. For example, the insulation **320** may include aerogel insulation, such as silica-based aerogel and composite pyrogels may operate and be effective up to a temperature of about 650 degrees Celsius. Accordingly, the insulations structure **302** provides an ability to implement insulation **320** without the insulation breaking down or failing. The insulation structure includes the air gap **304** with forced convection occurring through the air gap **304** and resulting in a stepped down temperature occurring at the insulation **320**.

[0037] The insulation structure **302** is retained in position about the exhaust tube **300** by one or more standoffs **322**. The standoffs **322** position the insulation structure **302** radially outward of the exhaust tube **300**. The standoffs **322** may include fins, pins, or structural members that span the air gap **304** without blocking and/or preventing airflow through the air gap **304**. The standoffs **322** may, for example include stainless steel or other ribs that couple to the inner shell **312** and to the exhaust tube **300**. In some examples, the standoffs **322** may include a metal mesh or other porous material that fills a gap between the inner shell **312** and the exhaust tube **300** and supports the insulation **320** being spaced away from the exhaust tube **300**. In an example, the metal mesh may include a stainless steel mesh that is porous to allow airflow through the air gap **304** while also providing support for maintaining the position of the inner shell **312** and/or the insulation **320** relative to the exhaust tube **300**. In an example, the metal mesh may include an open-cell metal foam, metal webbing, or other such material that allows airflow while also providing structural support to the insulation **320**.

[0038] In some examples, the metal mesh and/or other standoff **322** may provide for additional heat transfer to the air in the air gap **304** as air is forced through the air gap **304**. As the air flows through the air gap **304**, the additional surface area of the standoffs **322** may enable heat transfer from the exhaust tube **300** to the air to be carried away from the exhaust system for disposal.

[0039] In some examples, the standoffs **322** may include a heat bridge interruption to prevent or reduce heat transferred from the exhaust tube **300** to the insulation **320** through the standoffs **322**. For example, the standoffs **322** may include a material having a low thermal conductivity, for example at a middle portion of the standoff and/or be formed of a material with a relatively (compared with stainless steel) low thermal conductivity.

[0040] The insulation **320** is positioned between the inner shell **312** and the outer shell **314**. In an example, the inner shell and the outer shell may be formed for stainless steel or another suitable material. The insulation **320** may have a thickness of up to ten millimeters or more in some examples, such as examples that include an aerogel insulation in the insulation **320**. The thickness of the insulation **320** may be based on reducing the external surface temperature to approximately 300 degrees Celsius or less. In some examples, the insulation **320** may be greater than ten millimeters to reach a desired temperature on the outer shell.

[0041] The insulation **320** may include aerogel, as mentioned previously, and may include shredded aerogel particles fit between the inner shell and the outer shell, for example by filling a space between the shells with the aerogel particles. The space may be sealed off to retain the aerogel particles, for example with end caps connecting between the inner shell and the outer shell. In some examples, the insulation **320** may include an aerogel blanket with aerogel particles suspended or retained in an organic binder. In some examples, the insulation **320** may include other types of insulation such as mineral wool insulation, rock wool insulation, vacuum insulation between the inner shell and the outer shell, and other suitable insulation that may withstand the temperatures of the exhaust manifold **102**.

[0042] The exhaust manifold **102** also includes an air system **310** that enables forced convection through the air gap **304** between the exhaust conduit **316** and the inner shell **312**. The forced convection is a result of the air system **310** that draws air into the air gap **304** at a first end of the exhaust manifold **102** and expels the air at a second end of the exhaust manifold **102**. The forced convection provides heat mitigation as heat is transferred to the air as it is forced through the air gap **304** and expelled at a waste heat disposal location. In some examples, the fan air system may force the air away from the internal combustion engine **101** such as out of an engine compartment and/or past a radiator or other heat transfer system. In some examples, the air gap **304** may have a thickness of approximately five millimeters around the exhaust conduit **316** such that the insulation **320** and/or inner shell **312** is offset from the exhaust conduit by approximately five millimeters around the circumference of the exhaust conduit. In some examples, the air gap **304** may be spaced less than or greater than about five millimeters from the exhaust conduit **316**.

[0043] The air gap **304** provides for air to be forced or driven through the air gap **304**, heated by proximity with the exhaust conduit **316**, and expelled at an end and/or an exit of the insulation structure **302**. The air gap **304** may extend along a length of the exhaust tube, and may include along an entire length of the exhaust tube, across a portion of a length of the exhaust tube, and/or include multiple insulation structures to span the length of the exhaust tube. An entry for air at one end of the exhaust tube and/or insulation structure allows air to enter the air gap **304** from an air source. In some examples, the air source may be connected to ducting to provide air from an external source rather than a local source, such as within an engine compartment. The air source may be external to a vehicle and/or engine compartment and may pass through ducting and/or filters before reaching the air gap **304**. The filter may prevent particles, impurities, oils, fuels, and other contaminants from contacting the exhaust tube and potentially igniting.

[0044] The air system is depicted drawing air through the air gap **304** in a first direction opposite the direction of travel **318** of the exhaust gases. The direction of travel of the air through the air gap **304** may be in the same direction or the opposite direction of the direction of travel **318**.

[0045] A section **324** of the exhaust manifold **102** provides a detail view as depicted in FIGS. **4-6**, of the layers of the air gap **304**, inner shell **312**, insulation **320**, and outer shell **314**.

[0046] FIG. **4** illustrates a cross-section view illustrating a portion of an exhaust manifold **102** with a heat mitigation system, according to at least one example. The exhaust manifold **102** includes components described above such as the exhaust tube **300**, air gap **304**, inner shell **312**, outer shell **314**, insulation **320**, standoff **322**, and other such components as described herein. As seen in FIG. **4**, the exhaust tube **300** is oriented annularly about an axis CL.

[0047] The inner shell **312** is oriented annularly about the axis CL and radially outward of the exhaust tube **300** and of an optional radiation shield (not depicted) that may be positioned in the air gap **304** between the exhaust tube **300** and the inner shell **312** and supported by the standoffs **322**. The outer shell **314** is radially outward of the inner shell **312**. The insulation **320** is positioned between the inner shell **312** and the outer shell **314** in a passage that may have an annular shape.

[0048] The air **402** flows into the air gap **304** as described herein and travels in a first direction **404**. Exhaust gases flow through the exhaust tube in a second direction **406**. The first direction and second direction may be opposite to each other such that the air **402** flows in the opposite direction of the exhaust gases. In some examples, the first direction **404** and the second direction **406** may be parallel with an in the same direction as each other such that the air **402** flows in the same direction as the exhaust gases.

[0049] FIG. **5** illustrates a cross-section view illustrating a portion of an exhaust manifold **102** with a heat mitigation system, according to at least one example. The exhaust manifold **102** includes components described above such as the exhaust tube **300**, air gap **304**, inner shell **312**, outer shell **314**, insulation **320**, standoff **322**, and other such components as described herein. As seen in FIG. **5**, the exhaust tube **300** is oriented annularly about an axis CL.

[0050] In FIG. **5**, the standoffs are shown as a mesh **502**. In some examples, such as depicted in FIG. **5**, the standoffs may include a metal mesh or other porous material that fills a gap between the inner shell **312** and the exhaust tube **300** and supports the inner shell **312** being spaced away from the exhaust tube **300**. In an example, the mesh **502** may include a stainless steel mesh that is porous to allow airflow through the air gap **304** while also providing support for maintaining the position of the insulation structure relative to the exhaust tube **300**. In an example, the mesh **502** may include an open-cell metal foam, metal webbing, or other such material that allows airflow while also providing structural support to the insulation **320**.

[0051] FIG. **6** illustrates a detail view of a heat mitigation system for an exhaust manifold **102** for example at section **324** of FIG. **3**, according to at least one example. The detail view shows the structure and layers of the insulation structure **302** including at least the exhaust tube **300**, air gap **304**, exhaust conduit **316**, inner shell **312**, outer shell **314**, insulation **320** as described above. The detail view shows an example of the spacing between the exhaust tube **300** and the insulation structure including at least a height or thickness of the air gap **304** and the thickness of the inner shell **312** and the outer shell **314**.

[0052] The air gap is depicted with a thickness **608** indicating a distance between the inner shell **312** and the exhaust tube **300**. The thickness **608** may be in a range of up to five millimeters. In some examples the thickness may be in a range of up to about ten millimeters. In some examples the thickness may be in a range of up to about fifteen millimeters. In some examples the thickness may be in a range of up to about twenty millimeters. The air gap **304** provides enough space to cause a decrease in temperature between the exhaust tube **300** and the inner shell **312** such that the insulation **320** remains below a degradation temperature of the insulation **320**. The insulation **320**, as described herein may include aerogels or other such insulation and/or organic binders that may break down at temperatures at or above 650 degrees Celsius. Accordingly, the air gap **304** may have the thickness **608** sized such that the temperature of the inner shell remains below the threshold temperature.

[0053] The insulation **320** may have a thickness **610** from an interior of the inner shell **312** to an interior of the outer shell **314** in a range of up to ten millimeters. In some examples, the thickness **610** may be in a range of ten to fifteen millimeters. In some examples, the thickness **610** may be in a range of fifteen to twenty millimeters. In some examples, the thickness **610** may be greater than twenty millimeters. The inner shell **312** may similarly have a thickness **604** that may be less than three millimeters, less than two millimeters, less than one millimeter, or any other suitable range.

[0054] In some examples, the insulation **320** may be effective at preventing the exterior temperature of the exhaust assembly from exceeding 300 degrees Celsius. The use of aerogel or other such insulation may make such a temperature differential possible in a compact space such that the thickness **610** of the insulation **320** and the thickness **608** of the air gap **304** is less than a thickness of a typical insulation that may have a lower thermal resistance than the aerogel. Accordingly, the configuration included herein provides for a more compact profile surrounding the exhaust assembly while maintaining or exceeding the performance of typical exhaust systems.

INDUSTRIAL APPLICABILITY

[0055] The present disclosure provides systems and methods for providing insulation to exhaust assemblies to provide heat mitigation without complex insulation systems and techniques such as liquid cooling that involves pumps or insulation that may be bulky or occupy excessive space in an engine compartment. The insulation systems involve the use of insulations types that may have operating temperatures below the range of temperatures typically experienced in an exhaust system. The insulation systems use an air gap and forced convection to step down the temperature between the exhaust tube and the insulation to a level that is within the operating range of the insulation and thereby use a more effective insulation that may otherwise be unavailable for such uses.

[0056] Accordingly, the exhaust manifold assembly described herein, provides for preventing thermal buildup in and around the exhaust system and thereby prevents thermal stresses and cracking in the exhaust assemblies by using forced air in an air gap surrounded by an insulation structure to provide an external surface temperature at or below a threshold such as 300 degrees Celsius without additional complexity of liquid cooling or bulky insulation systems.

[0057] The systems and techniques described herein provide for a thermal insulative and heat mitigation system that is inexpensive, simple, and resistant to failure. Retaining heat increases thermal stress on the exhaust tube and therefore heat must be mitigated and removed. Accordingly, the use of a fan to pull air through the air gap between the insulation and the exhaust tube allows the air to be moved to a location where heat can be dissipated. Further, shells surrounding the insulation provide for the use of different insulation types including particulate, blanket, granular, fibrous, and other such insulation types that may not otherwise be possible to implement. The shells surrounding the insulation additionally provide for the heat to be stepped down or reduced to a level where insulation such as aerogels may be used without causing degradation.

[0058] While aspects of the present disclosure have been particularly shown and described with reference to the embodiments above, it will be understood by those skilled in the art that various additional embodiments may be contemplated by the modification of the disclosed machines, systems and methods without departing from the spirit and scope of what is disclosed. Such embodiments should be understood to fall within the scope of the present disclosure as determined based upon the claims and any equivalents thereof.

Claims

1. An exhaust assembly comprising: an exhaust tube defining a substantially central axis, wherein the exhaust tube is configured to direct an exhaust gas away from an engine to which the exhaust tube is fluidly connected; an insulation structure positioned concentrically around the exhaust tube, the insulation structure including: a standoff coupled to the exhaust tube and providing an air gap between the exhaust tube and the insulation structure; an inner shell coupled to the standoff and concentric about the exhaust tube; an outer shell concentric about the inner shell; and an insulation layer disposed between the inner shell and the outer shell; and a forced air system that drives air through the air gap along a length of the exhaust tube.
2. The exhaust assembly of claim 1, wherein the insulation layer comprises aerogel.
3. The exhaust assembly of claim 1, wherein the standoff comprises a porous metal mesh disposed in the air gap between the inner shell and the exhaust tube.
4. The exhaust assembly of claim 1, wherein the insulation layer comprises rock wool insulation.
5. The exhaust assembly of claim 1, wherein the exhaust gas travels along the exhaust tube in a first direction and the forced air system drives the air in a second direction opposite the first direction.
6. The exhaust assembly of claim 1, wherein the exhaust gas travels along the exhaust tube in a first direction and the forced air system drives the air in a second direction parallel to the first direction.
7. The exhaust assembly of claim 1, wherein the forced air system comprises a fan at a first end of the insulation structure configured to pull air through the air gap from a second end to the first end.
8. An exhaust insulation system comprising: an inner shell disposed radially outward from an exhaust tube; an outer shell disposed radially outward from the inner shell; an insulation layer disposed between the inner shell and the outer shell; a support coupled between the inner shell and the exhaust tube that supports the inner shell and provides an air gap between the inner shell and the exhaust tube; and a forced air system comprising: a first opening at a first end of the exhaust insulation system providing access to the air gap; a second opening at a second end of the exhaust insulation system providing access to the air gap; and a fan positioned adjacent the first opening and configured to drive air through the air gap.
9. The exhaust insulation system of claim 8, wherein the insulation layer comprises shredded aerogel insulation.
10. The exhaust insulation system of claim 8, wherein the fan is configured to drive the air through the air gap in a first direction opposite a direction of travel of exhaust within the exhaust tube.
11. The exhaust insulation system of claim 8, wherein the fan is configured to drive the air through the air gap in a second direction opposite a direction of travel of exhaust within the exhaust tube.
12. The exhaust insulation system of claim 8, wherein the support comprises metal fins coupled between the exhaust tube and the inner shell.
13. The exhaust insulation system of claim 8, further comprising a radiation shield positioned in the air gap between the exhaust tube and the inner shell, the radiation shield defining one or more openings.
14. The exhaust insulation system of claim 8, wherein the support comprises a metal mesh.
15. The exhaust insulation system of claim 8, wherein the inner shell and the outer shell define a plurality of openings along a length of the exhaust tube.
16. A system comprising: an internal combustion engine; and an exhaust assembly fluidly connected with the internal combustion engine, wherein the exhaust assembly comprises: an exhaust tube oriented about an axis, wherein an exhaust gas is configured to flow through the exhaust tube away from the internal combustion engine; an insulation structure positioned concentrically around the exhaust tube, the insulation structure including: a standoff coupled to the

exhaust tube and providing an air gap between the exhaust tube and the insulation structure; an inner shell coupled to the standoff and concentric about the exhaust tube; an outer shell concentric about the inner shell; and an insulation layer disposed between the inner shell and the outer shell; and a forced air system that drives air through the air gap along a length of the exhaust tube.

17. The system of claim 16, wherein the insulation layer comprises a shredded aerogel insulation.

18. The system of claim 16, wherein the standoff comprises a porous metal mesh.

19. The system of claim 16, wherein the forced air system is configured to drive the air through the air gap in a direction parallel with a direction of travel of the exhaust gas.

20. The system of claim 16, wherein the forced air system is configured to drive the air through the air gap in a direction opposite a direction of travel of the exhaust gas.