[0007] The operating temperature of a solid oxide fuel cell assembly is in principle high enough for steam reforming of a hydrocarbon fuel internally of the solid oxide fuel cell stack. Internal steam reforming would simplify the balance of plant of a solid oxide fuel cell assembly (or solid oxide fuel cell stack) and improve operating efficiency. However, reforming of a hydrocarbon fuel within the solid oxide fuel cell stack has a number of problems which have not been overcome. Full internal reforming of the hydrocarbon fuel in solid oxide fuel cell stacks is precluded by the strongly endothermic nature of the steam reforming reaction, and consequential thermal shocking of the delicate fuel cells. Internal reforming on nickel cermet anodes in solid oxide fuel cells tends to catalyse carbon formation.

[0008] Embodiments of the present invention seek to provide a novel fuel cell assembly having good thermal and mechanical compliance during cold start up to normal operating temperatures.

[0009] EP0668622B1 discloses a solid oxide fuel cell which comprises a plurality of modules. Some of these modules comprise hollow members, which have two parallel flat surfaces upon which the solid oxide fuel cells are arranged. The opposite ends of each module are connected to reactant manifolds by compliant bellow connections.

[0010] However, such an arrangement does not provide sufficient thermal and mechanical compliance in the solid oxide fuel cell stack to minimise the mechanical and thermal stresses in the solid oxide fuel cell stack.

[0011] EP1419547B1 discloses a solid oxide fuel cell stack, which comprises a plurality of modules, the modules comprising elongate hollow members, the hollow members having a passage for flow of reactant. The modules are arranged so that at least one end of each module is connected to an end of an adjacent module to allow reactant to flow sequentially through the modules in a serpentine type arrangement.

[0012] However, the arrangement only provides thermal and mechanical compliance within a bundle and does not prevent thermal and mechanical stresses building up across adjacent bundles. Furthermore, the arrangement does not address issues with fuel distribution from fuel cell tubes throughout a stack.

BRIEF SUMMARY

[0013] According to a first aspect, there is provided a fuel cell stack comprising at least one fuel cell strip, each strip comprising:

a fuel feed pipe;

a fuel outlet pipe; and

a plurality of bundles, each bundle comprising a plurality of tube sub-assemblies, each tube sub-assembly comprising a fuel cell tube, the tube sub-assemblies being separated longitudinally by end fittings connecting adjacent tube sub-assemblies, the end fittings provide a passage for fuel;

wherein one of a respective lowermost or uppermost tube sub-assembly of each bundle comprises a manifold end fitting connecting the bundle to the fuel feed pipe and the other of the respective lowermost or uppermost tube sub-assembly of each bundle comprises a manifold end fitting connecting the bundle to the fuel outlet pipe; and

wherein adjacent manifold end fittings from adjacent bundles are separated by an expansion gap.

[0014] The advantage of this arrangement of manifold end fittings being separated by an expansion gap is that thermal and mechanical stresses in each bundle may propagate from each bundle to the fuel feed pipe and the fuel outlet pipe and do not propagate from bundle to adjacent bundle. A mechanical load path is created by the combination of end fittings and the fuel inlet pipe and fuel outlet pipe such that mechanical loads within the stack propagate along the end fittings of each bundle (and not through the more delicate fuel cell tubes). The expansion gap between adjacent bundles may provide mechanical load isolation between adjacent bundles and, as such, any mechanical stresses in the bundle may be directed toward the fuel inlet pipe and the fuel outlet pipe. Furthermore, the expansion gap between adjacent bundles may accommodate thermal expansion of the bundles without creating additional mechanical loads on the strip architecture.

[0015] Optionally, the manifold end fittings may be connected to manifold end fittings of adjacent bundles, via a section of the fuel feed pipe and a section of the fuel outlet pipe.

[0016] The fuel feed pipe and fuel outlet pipe are formed in sections, such that the combination of sections of the fuel feed pipe and sections of the fuel outlet pipe forms a strip fuel feed pipe and a strip fuel outlet pipe. The fuel outlet pipe and the fuel feed pipe may be typically stronger than the tube sub-assemblies, and therefore more able to withstand thermal and mechanical stresses in the fuel cell strip. The arrangement therefore supports a mechanical load path through the end fittings of the tube sub-assemblies and towards the fuel feed pipe and fuel outlet pipe.

[0017] Optionally, the expansion gap between adjacent bundles may be configured to provide a clearance between adjacent bundles to accommodate thermal expansion of the bundles.

[0018] The expansion gap between adjacent bundles may provide sufficient clearance such that temperature differentials within the fuel cell strip that cause the bundles to expand and contract do not adversely affect the overall structure of the strip.

[0019] Optionally, the fuel feed pipe and fuel outlet pipe may be constrained within a fuel cell stack.

[0020] Constraining the fuel feed pipe and fuel outlet pipe in this manner may improve stack integrity during transportation.

[0021] Optionally, the arrangement of fuel feed pipe and fuel outlet pipe connected to the bundle may constrain movement of the tube sub-assemblies within the bundle.

[0022] Optionally, a coefficient of thermal expansion (CTE) of the end fittings may be matched to a CTE of the fuel cell tubes.

[0023] Matching the CTE of the end fittings to the CTE of the fuel cell tubes may reduce relative expansion and contraction of the end fittings and fuel cell tubes.

[0024] Optionally, a coefficient of thermal expansion (CTE) of the fuel feed pipe and the fuel outlet pipe may be matched to a CTE of the end fittings.

[0025] This may be particularly important during start-up of the fuel cell stack, when inlet and outlet fuel temperatures may differ.

[0026] Optionally, the first end fitting and the second end fitting are made from impervious magnesia magnesium aluminate (MMA) ceramic material.

[0027] MMA ceramic materials are particularly suitable for components because MMA may be formed using known techniques such as injection moulding. MMA ceramic materials may also be able to withstand the high temperatures experienced within the fuel cell.

[0028] Optionally, the fuel feed pipe and the fuel outlet pipe may be made from dense impervious ceramic material.

[0029] The dense impervious ceramic material may be able to withstand larger mechanical stresses than the fuel cell module ceramic material, and therefore the fuel feed pipe and the fuel outlet pipe are able to withstand the mechanical load throughout the strip.

[0030] Optionally, the end fittings may be provided with alignment features configured to couple with adjacent end fittings, facilitating alignment between adjacent end fittings.

[0031] Providing alignment features on the end fittings may enable easier build of the bundles and the fuel cell strip.