Thermoplastic Liner System Assembly Design, with Insulating Liner having Higher Coefficient of Thermal Expansion compared to that of Carbon Steel

Background

[0001] In the oil and gas industry, a common issue faced by many oil and gas producers is the corrosive condition experienced in “sour service” wells which contains significant amounts of corrosive agents, such as hydrogen sulphide, carbon dioxide, and water containing chloride ions. This corrosive medium would result in corrosion pitting and stress cracking when in contact with unprotected carbon steel piping systems resulting in high costs of maintenance and replacement. Other than using very costly corrosive-resistant alloys, various internal insulation methods were developed to extend the service life of tubular piping systems.

[0002] To reduce the effects of corrosion, one common method used in the industry is to clad or line the inner tubing diameter with a thin layer of corrosion-resistant material. This liner is usually lined internally through the entire length of the tubular pipe, ending with the pin connectors at both ends. The liner is then held in place at both pipe ends with an end cap, which ensures the fixed positioning of the liner relative to the pipe body. In a threaded and coupled connection, the pin connectors are threaded and made up with a box coupling, and the gap between the pin connectors is filled with an elastomeric seal ring, which is easily compressible to fill this gap. Theoretically, this should help to reduce corrosion occurring at the pin and box connector interface.

[0003] However such methods could only be applied to liner material with a coefficient of expansion very close with that of the steel tubular, or during low temperature applications. One common issue faced using such designs is the inward buckling or collapse of the liner along the pipe body. This inward buckling arises due to the different rates of thermal expansion between the liner material and the carbon steel pipe body at elevated temperatures. This could cause total collapse of the internal liner, rendering the corrosion prevention ineffective and decrease the flow rate of production fluid.

[0004] Thermoplastics are a commonly available material used to line the inner diameter of tubular piping systems due to their low cost, inert chemical properties, and fluid impermeability. Conventional liner designs require the liner to be held in place at both pipe ends using an end cap, which may not be suitable for thermoplastic liners in tubular piping systems with elevated temperatures due to their high coefficient of thermal expansion. The average coefficient of thermal expansion of thermoplastics e.g. high-density polyethylene (HDPE) or polytetrafluoroethylene (PTFE), is very much higher than that of carbon steel (HDPE: 150 x 10^{-6} / °C; PTFE: 120 x 10^{-6} / °C; carbon steel: 12 x 10^{-6} / °C). At elevated temperatures of up to 90°C in sour service wells, for an average pipe length of 9 metres, the expansion differential is around 60mm to 70mm between a PTFE liner and the carbon steel pipe; and around 75mm to 90mm between a HDPE liner and the carbon steel pipe. Due to this large expansion differential, it is not possible for a proposed thermoplastic liner to be capped at both pipe ends without incurring significant inward longitudinal buckling of the liner.

[0005] As such, there is a need for a novel thermoplastic liner system design that addresses the above-mentioned issue of inward buckling or collapse of the liner along

the pipe body due to different rates of thermal expansion between the liner and the carbon steel pipe body.

Summary of the Disclosure

[0006] The disclosed inventive design comprises a thermoplastic inner pipe liner held in place via an end flare design at the pin connector of one end (let this end be end A), with a free end at the other pin connector (let this other end be end B) which allows for longitudinal thermal expansion along the pipe axis. It is housed within a specially designed premium threaded and coupled connection, which is suitable for use in tubular piping systems. The carbon steel box coupling of the connection would have a recessed groove in the middle of the coupling to house a compressible elastomeric seal ring. The carbon steel pin connector design would remain unchanged from the original, other than the addition of the internal liner material.

[0007] For the first aspect of the disclosed inventive design, this involves a precisely-designed external shoulder on the carbon steel pin connector which would snugly fit the edge of the box connector upon final make-up, acting as a precise torque stop. This torque stop would help to set a fixed degree of compression for the elastomeric seal ring during said coupling make-up, preventing displacement of the seal ring due to over- or under-compression.

[0008] For the second aspect of the disclosed inventive design, there is a recessed groove in the middle of the carbon steel coupling. The groove is precisely designed to house and seat the T-shaped compressible elastomeric seal ring snugly in such a way to prevent displacement of the seal ring; even when the seal ring undergoes some thermal expansion in the elevated temperature conditions within the well, or when the seal ring is undergoing a fixed degree of compression upon final coupling make-up of the carbon steel connection.

[0009] The third aspect of the disclosed inventive design is a gas-tight (metal-to-metal) seal profile interaction between the carbon steel pin connector and the box coupling, designed for tubular piping systems with high internal pressure. This metal-to-metal seal profile arises due to a seal interference between both the pin connector and the box coupling, achieving full seal interference upon final make-up. This is important to achieve overall gas-tightness for the connection and prevent any gas leak paths from occurring. For tubular piping systems with low pressure, this gas-tight metal-to-metal seal profile would be an optional feature.

[0010] The fourth aspect of the disclosed inventive design is a corrosive-resistant, chemically inert and impermeable layer of thermoplastic liner, able to withstand elevated temperatures within the tubular piping system, with a higher coefficient of thermal expansion compared to that of carbon steel. This layer acts as an inner liner to insulate the carbon steel pipe body against corrosive conditions. The thermoplastic liner will be held in place via an end flare design at end A, with a free end at end B allowing for longitudinal thermal expansion or contraction of the thermoplastic liner along the pipe axis. The excess liner at the free end extends outwards beyond the pin connector at end B. The outer diameter of the excess liner at the free end would be smaller than the inner diameter of the liner end flare, to allow the excess liner to fit into

the end flare. This reduced liner diameter at the free end is achieved via an internal upset tapered design of the thermoplastic liner at end B.

[0011] The method of installation of the thermoplastic liner would be by running a pre-rolled thermoplastic tube into the carbon steel pipe and sealing the annulus with a filler material.

[0012] The fifth aspect of the disclosed inventive design is a stiff elastomeric end cap, placed at the pin connector of end B. The shape of the cross-section profile of the end cap is in a L-shaped geometry, wherein the tail extends a short distance inwards along the longitudinal pipe axis, and would serve as a reduced diameter reference for the internal upset of the thermoplastic liner. The end cap would also insulate the pin connector end against exposure to the corrosive fluid within the tubular piping system, and serve as the surface contact to compress and hold the compressible elastomeric seal ring in the middle of the connection upon final make-up.

[0013] The sixth aspect of the disclosed inventive design is a precisely-designed compressible elastomeric seal ring which would be placed in the middle of both pin connectors, and insulate the gap between both pin connectors and the centre of the carbon steel box coupling against corrosive fluid. Its precise position is aided by the presence of the recessed groove in the middle of the carbon steel coupling. The precise position is important to ensure a fixed degree of compression of the seal ring upon final make-up of the connection.

[0014] The seventh aspect of the disclosed inventive design is a thin layer of non-structural filler material that would fill the annulus between the thermoplastic liner and the carbon steel pipe body if the liner is installed via method (i) in paragraph **[0011]**. The filler material is meant to provide a backing for the thin layer of fibreglass-reinforced epoxy liner, allowing smooth transfer of the tubular piping system internal pressure forces from the fibreglass-reinforced epoxy liner, to the filler material, and finally to the carbon steel pipe body. A common filler material used in the industry is cement mortar, but other filler materials like grout or polymers may be suitable if they are corrosion-resistant and able to withstand the corrosive conditions and high temperatures within the tubular piping system.

Brief Description of Drawings

[0015] Figure 1 shows a cross sectional view of the overall disclosed inventive design of the Thermoplastic Liner System Assembly, illustrating embodiments of both pin connector ends A and B inclusive of the relevant components of the present disclosure;

[0016] Figure 2 shows a plan view of the overall disclosed inventive design of the Thermoplastic Liner System Assembly;

[0017] Figure 3 shows a perspective view of the overall disclosed inventive design of the Thermoplastic Liner System Assembly;

[0018] Figure 4 shows a perspective and sectioned view of the overall disclosed inventive design of the Thermoplastic Liner System Assembly, inclusive of the relevant components of the present disclosure;

[0019] Figure 5 shows a cross sectional view of an embodiment of the disclosed specially designed carbon steel pin connector, showing an external shoulder which would act as a torque stop during final make-up with the carbon steel coupling connector;

[0020] Figure 6 shows a plan view of an embodiment of the disclosed specially designed carbon steel pin connector;

[0021] Figure 7 shows a perspective view of an embodiment of the disclosed specially designed carbon steel pin connector;

[0022] Figure 8 shows a cross sectional view of an embodiment of the disclosed specially designed carbon steel coupling connector, showing a recessed groove at the centre of the coupling which would house the disclosed elastomeric seal ring;

[0023] Figure 9 shows a plan view of an embodiment of the disclosed specially designed carbon steel coupling connector;

[0024] Figure 10 shows a perspective and sectioned view of an embodiment of the disclosed specially designed carbon steel coupling connector, showing a recessed groove at the centre of the coupling which would house the disclosed elastomeric seal ring;

[0025] Figure 11 shows a perspective view of an embodiment of the disclosed specially designed carbon steel coupling connector;

[0026] Figure 12 shows a cross-sectional view of an embodiment of end A of the disclosed thermoplastic liner, illustrating clearly the liner end flare in contact with the pin connector, housed within a sectioned pin connector assembly;

[0027] Figure 13 shows a cross-sectional view of an embodiment of end B of the disclosed thermoplastic liner, illustrating clearly an internal upset taper, with excess material at the free end that extends outwards from the pin connector;

[0028] Figure 14 shows a perspective view of end A of the disclosed thermoplastic liner, illustrating the liner end flare, housed within a sectioned pin connector assembly;

[0029] Figure 15 shows a perspective view of end B of the disclosed thermoplastic liner, illustrating the internal upset taper and excess material at the free end, housed within a sectioned pin connector assembly;

[0030] Figure 16 shows a perspective view of the combined disclosed thermoplastic liner, illustrating how the liner free end at end B is able to fit into the liner end flare at end A, housed within a sectioned view of the overall disclosed inventive design of the Thermoplastic Liner System Assembly;

[0031] Figure 17 shows a cross sectional view of an embodiment of the disclosed stiff elastomeric end cap, illustrating the L-shaped geometry of the cross-section;

[0032] Figure 18 shows a plan view of an embodiment of the disclosed stiff elastomeric end cap;

[0033] Figure 19 shows a front view of an embodiment of the disclosed stiff elastomeric end cap;

[0034] Figure 20 shows a perspective view of an embodiment of the disclosed stiff elastomeric end cap;

[0035] Figure 21 shows a perspective view of an embodiment of the disclosed stiff elastomeric end cap placed at the pin connector of end B, illustrating how the thermoplastic liner internal upset taper is dependent on the end cap inner diameter as a centering guide, housed within a sectioned pin connector assembly;

[0036] Figure 22 shows a cross sectional view of an embodiment of the disclosed compressible elastomeric seal ring, showing the T-shaped geometry of the cross section of the seal ring;

[0037] Figure 23 shows a plan view of an embodiment of the disclosed compressible elastomeric seal ring;

[0038] Figure 24 shows a front view of an embodiment of the disclosed compressible elastomeric seal ring;

[0039] Figure 25 shows a perspective view of an embodiment of the disclosed compressible elastomeric seal ring;

[0040] Figure 26 shows a perspective view of an embodiment of the disclosed compressible elastomeric seal ring, housed within a sectioned view of the overall disclosed inventive design of the Thermoplastic Liner System Assembly.

Detailed Description

[0040] Figures 1, 2, 3, and **4** illustrate in various views the details of a typical prior art Thermoplastic Liner System Assembly design with its associated and relevant components. **Figure 1** shows a cross-sectional view of the overall disclosed inventive design, where the assembly is housed within a specially designed premium carbon steel threaded and coupled connection comprising two pin connectors **12**, and a box coupling **13**. The pin connectors **12** and the box coupling **13** achieve connection integrity upon final make-up using a compatible and specially designed thread profile **16**. This thread profile **16** has some degree of thread interference between the pin and coupling threads, where thread interference refers to a degree of tightness in the thread profile **16** requiring power-tightening upon final make-up.

[0041] Each pin connector **12** and box coupling **13** assembly has a metal-to-metal seal profile **14** which allows the connection assembly to achieve gas-tightness. This metal-to-metal seal profile **14** is achieved due to seal interference between both the pin connector **12** and box coupling **13**. Seal interference refers to a degree of tightness between both seal surfaces in the pin connectors **12** and the box coupling **13** requiring power-tightening upon final make-up to form a complete gas-tight seal.

[0042] Each pin connector **12** has an external shoulder **15** which acts as a torque stop during final make-up, preventing the connection from being over-torqued or over-tightened. Under-torque or under-tightening can also be easily identified via a gap between the external shoulder **15** and the coupling end. This can be resolved easily by further tightening the connection until the gap is closed and the coupling end touches the external shoulder **15**. This torque stop function need not be limited to the

external shoulder **15** design as shown in the typical prior art within **Figure 1**; an intermediate shoulder design between the pin and coupling would serve the same torque stop function as well. This external and/or intermediate shoulder would provide a snug fit and stop limit once the maximum number of turns to make-up is achieved, which is vital to prevent over- or under-compression of the compressible elastomeric seal ring **23** for it to fulfil its intended insulation purpose.

[0043] At the middle of the box coupling **13**, there is a recessed groove **17** specially designed to partially house the compressible elastomeric seal ring **23**. The recessed groove **17** would assist to hold the T-arms of the compressible elastomeric seal ring **23**, preventing the compressible elastomeric seal ring **23** from deviating from its intended location at the middle of the box coupling **13** even when the seal ring undergoes compression from each pin connector **12**, or during thermal expansion from the elevated temperature within the tubular piping system.

[0044] Figures 5, 6, and **7** illustrate in different views the cross-sectional and external details of the specially designed premium pin connector **12**. The features of the pin connector **12** include an external upset **26** with reference to the diameter of the pipe body **25**. This is to provide a thicker pipe cross-sectional area to cater for the machining of the external shoulder **15** area, allowing a firm and unyielding engagement between the coupling end and the external shoulder **15**. Situated near the external shoulder **15** is the metal-to-metal seal profile **14** which would interact with the seal profile of the box coupling **13** to form a gas-tight seal and prevent gases escaping via the connection from within the tubular piping system. This arises due to a purposefully designed seal interference between the pin connector **12** and box coupling **13**, reaching full seal interference and preventing gas from escaping the connection upon final make-up. Another feature of the pin connector **12** is the specially designed premium thread profile **16** which would interlock with the thread profile of the box coupling **13** as well, achieving connection integrity via thread engagement and interference when the connection is screwed into position upon final make-up.

[0045] Figures 8, 9, 10, and **11** illustrate in different views the cross-sectional and external details of the specially designed premium box coupling **13**. The features of the box coupling **13** which are similar to the features of the pin connectors **12** include the specially designed premium thread profile **16** and the metal-to-metal seal profile **14**. One notable and unique feature of the box coupling **13** is the recessed groove **17** which is illustrated clearly in **Figures 8** and **10**, of which its functions have been outlined in paragraph **[0042]** above. The coupling ends **27** are designed to snugly fit into the external shoulder **15** of the pin connector **12** during final make-up; usually with some degree of inward taper to prevent the coupling end **27** from flaring outward upon reaching final make-up position.

[0046] Figures 12, 13, 14, 15, and **16** illustrate in different views the cross-sectional and external details of the disclosed layer of thermoplastic liner **18**, relative to the cross-sectional view of the pin connector **12** assembly. **Figures 12** and **14** show the cross-sectional details of the thermoplastic liner in end A. In end A, a key feature of the thermoplastic liner is an end flare **20** that wraps around the pin connector end **12** and insulates it from corrosive fluids. This end flare **20** also serves as to hold the thermoplastic liner in place relative to the pin connector **12**; and has an inner diameter

large enough to encompass the outer diameter of the internal upset excess thermoplastic liner at end B, which would be elaborated below.

[0047] Figures 13 and **15** show the cross-sectional details of the thermoplastic liner **18** in end B. In end B, an internal upset taper **21** gradually reduces the inner and external diameter of the thermoplastic liner **18**. This is to allow the external diameter of the excess free end **19** of the thermoplastic liner **18** in end B to fit into the inner diameter of the liner end flare **20** at end A. The excess free end **19** is to allow for the longitudinal thermal expansion or contraction of the thermoplastic liner **18** and prevent inward buckling or collapse of the liner along the pipe body. The inner diameter of the stiff elastomeric end cap **22** would serve as a centering guide for the internal upset **21** external diameter of the thermoplastic liner **18**. A filler material **24** would fill the annular gap between the thermoplastic liner **18** and the carbon steel pin connector **12**. **Figure 16** shows another perspective view of the combined thermoplastic liner **18**, this time relative to the cross-sectional view of the overall disclosed inventive design of the Thermoplastic Liner System Assembly. It clearly illustrates how the excess free end **19** of the thermoplastic liner **18** at end B can fit into the inner diameter of the liner end flare **20** at end A. The chemically inert thermoplastic liner **18** would serve to insulate the carbon steel tubular piping system internally from corrosive fluids.

[0048] Figures 17, 18, 19, and **20** illustrate in different views the cross-sectional and external details of an embodiment of a prior art stiff elastomeric end cap **22**. The cross-section of the end cap **22** is in a L-shaped geometry, and clearly illustrates the cap end flare **28**. The cap end flare **28** is meant to insulate the pin connector **12** end from being exposed to the corrosive fluid within the tubular piping system. The inner diameter **29** of the end cap **22** would act as a reference for the external diameter of the internal upset **21** of the thermoplastic liner **18**.

[0049] Figure 21 illustrates a perspective view of the features of the stiff elastomeric end cap **22** relative to a cross-sectional view of the pin connector **12** assembly. It shows how the external diameter of the internal upset taper **21** along with the excess free end **19** of the thermoplastic liner **18** utilizes the inner diameter **29** of the end cap **22** as a reference. The annular gap caused by the internal upset taper **21** of the thermoplastic liner **18** would be filled by filler material **24**.

[0050] Figures 22, 23, 24, and **25** illustrate in different views the cross-sectional and external views of a typical prior art T-shaped compressible elastomeric seal ring **23**. In **Figure 22**, the main features of the compressible elastomeric seal ring **23** comprise of the two T-arms **30** and the T-body **31**. The two T-arms **30** serve the function of situating the compressible elastomeric seal ring **23** at the middle of the overall Thermoplastic Liner System Assembly, as they would be partially housed in the recessed groove **17** in the middle of the inner diameter of the box coupling **13**. The T-body **31** is designed to be narrower than the T-arms **30**, as the T-body **31** would undergo regular and constant compression forces acted upon it during final make-up by the pin connectors **12**. This narrower T-body **31** would also prevent the seal ring from being displaced from its intended position, as any movement of the T-arms **30** would be restricted by the pin connectors **12** and the recessed groove **17**. This effectively prevents the entire compressible elastomeric seal ring **23** from being dislodged or pulled into the fluid flow within the tubular piping system. **Figure 26** illustrates the position of the compressible

elastomeric seal ring **23** relative to the cross-section of the overall Thermoplastic Liner System Assembly.

[0051] The features which are believed to be novel in the disclosed inventive design are set forth in the appended claims below. Any modifications, variations, or changes made to the embodiments described above would be apparent to those familiar with liner systems for tubular systems conveying corrosive oil and gas fluids under elevated temperature and pressure, and the Thermoplastic Liner System Design described herein thus encompasses such modifications, variations, or changes and are not limited to the specific embodiments described herein.

Claims

1. A carbon steel connection assembly to house the Thermoplastic Liner System Assembly, comprising the following features:

    a. two specially designed carbon steel pin connectors, which are both configured to have compatible thread profiles with the carbon steel box coupling and able to be fully made up to make a solid integral carbon steel connection assembly;

    b. a specially designed carbon steel box coupling configured to have compatible thread profiles with the carbon steel pin connectors;

    c. some degree of thread interference between the pin connectors and box coupling to ensure appropriate connection gas-tightness and leak integrity upon final make-up which would be optional for tubular piping systems with low internal pressure.

2. The carbon steel pipe connection assembly of claim **1**, wherein a metal-to-metal seal profile interaction between the individual carbon steel pin connector and the carbon steel box coupling would achieve gas-tightness of the connection due to seal interference between both the pin connector and the box coupling, achieving full seal interference upon final make-up and would be an optional feature for tubular piping systems with low internal pressure.

3. The carbon steel pipe connection assembly of claim **1**, wherein both pin connectors respectively have an intermediate and/or external shoulder as a torque stop and stop limit for the box coupling end once the maximum number of turns to make-up is achieved, to ensure precise make-up position and prevent over- or under-compression of the seal ring from occurring so that the seal ring can achieve its insulation purpose.

4. The carbon steel pipe connection assembly of claim **1**, wherein a recessed groove at the centre of the carbon steel box coupling can partially house a T-shaped compressible elastomeric seal ring.

5. A chemically inert and impermeable layer of thermoplastic able to withstand elevated temperatures within the tubular piping system, with a higher coefficient of expansion as carbon steel; lined along the inner diameter of the carbon steel pipe by running a pre-rolled, pre-shaped thermoplastic tube into the pipe and sealing the annulus between the thermoplastic tube and the pipe with a filler material.

6. The thermoplastic liner layer of claim **5**, wherein the thickness of the layer should be thick enough to provide an impermeable insulation for the carbon steel pipe body against corrosive oil and gas fluids; while being thin enough to ensure the fluid flow rate is not significantly decreased by the reduced inner diameter due to the addition of the thermoplastic liner.

7. The thermoplastic liner layer of claim **5**, wherein an internal upset taper of the thermoplastic liner would reduce the outer diameter of the liner free end at end B to allow it to fit into the end flare of the thermoplastic liner at end A.

8. The thermoplastic liner layer of claim **5**, wherein at end B, the thermoplastic liner is designed as a free end with excess liner tube material extending beyond the carbon steel pin connector allowing for longitudinal thermal expansion or contraction of the thermoplastic liner and prevent inward buckling or collapse of the liner along the pipe body.

9. The thermoplastic liner layer of claim **5**, wherein at end A, the thermoplastic liner utilizes an end flare design to hold it in place relative to the carbon steel pin connector; and has an inner diameter large enough to encompass the outer diameter of the internal upset thermoplastic liner free end at end B.

10. A stiff elastomeric end cap, placed at the pin connector at end B.

11. The end cap of claim **10**, wherein the shape of the cross-section profile of the end cap is in a L-shaped geometry, extending a short distance inward along the longitudinal axis and would hold the above-mentioned thermoplastic liner in place relative to the inner diameter of the carbon steel pipe.

12. The end cap of claim **10**, wherein the end cap is made with an elastomeric material stiff enough to hold the thermoplastic liner and resist against the thermoplastic liner system collapsing radially inwards at the pin connectors.

13. The end cap of claim **10**, wherein the end cap would not be fixed or attached to the carbon steel pin connectors to provide some free allowance for the fibreglass-reinforced epoxy liner to expand longitudinally along the pipe axis during elevated temperature conditions.

14. The end cap of claim **10**, wherein the end flare would insulate the carbon steel pin connector end from corrosive fluids within the tubular piping system, serving as the contact surface between the pin connector assembly and the compressible elastomeric seal ring in the final make-up position.

15. A compressible elastomeric seal ring placed between both carbon steel pin connectors, sealing the gap between both pin connectors to prevent corrosive fluid flow into the carbon steel connection through the connection thread.

16. The compressible elastomeric seal ring of claim **15**, wherein the location of the seal ring between both carbon steel pin connectors is designed to a precise position in the middle of both pin connectors of claim **1(a)**; aided by the presence of the recessed groove in the middle of the carbon steel box coupling which would partially house the T-arms of the seal ring.

17. The compressible elastomeric seal ring of claim **15**, wherein the shape of the cross-section profile of the seal ring is in a T-shaped geometry; with the T-arms of the

elastomeric seal ring fitting snugly into the machined groove at the centre of the carbon steel coupling and the T-body held in place by both carbon steel pin connectors upon achieving final make-up position.

18. The compressible elastomeric seal ring of claim **15**, wherein the T-arms of the elastomeric seal ring are held in place by both carbon steel pin connectors, blocking the seal ring from moving towards the centre of the tubular piping system.

19. The compressible elastomeric seal ring of claim **15**, wherein the elastic nature of the elastomeric seal ring material allows for compression of the T-body of the seal ring by both carbon steel pin connectors in the final make-up position; filling up all available gaps between both pin connectors, insulating the centre of the connection from corrosive fluids within the tubular piping system.