A water hammer mitigating flow control structure for a downhole completion including a tubular member configured for the downhole environment. A valve member in operable communication with the tubular member and positionable with respect to the tubular member to allow or prevent fluid movement through the tubular member. An absorber in operable communication with the valve member and configured to allow movement of the valve member the movement absorbing a pressure rise against the valve member in use. Also included is a method for mitigating water hammer in a flow control structure for a downhole completion.
WATER HAMMER MITIGATING FLOW CONTROL STRUCTURE AND METHOD

BACKGROUND

[0001] For many industries where fluids are managed in pipelines of various sorts and with actuable valves to permit and prevent fluid flow, water hammer is a problem. The commonly termed water hammer is a tube wave created when a flow of fluid is suddenly stopped by a structure such as a valve. Upstream of the valve, fluid continues to move into the closed valve, increasing pressure in a local volume of fluid, which pressure propagates as a wave back in the upstream direction potentially causing damage as it propagates and when it reflects off other structures. Downstream of the valve the fluid also continues to move thereby creating a localized low-pressure in the fluid, which also can propagate as a wave in the downstream direction. In extreme cases, cavitation can occur at the downstream side of the valve with all of the intrinsic problems that are known to practitioners.

[0002] In the drilling and completion arts, water hammer can be a significant problem for a number of different components of downhole systems such as safety valves for example. Means to address water hammer would be well received by the art.

SUMMARY

[0003] A water hammer mitigating flow control structure for a downhole completion including a tubular member configured for the downhole environment; a valve member in operable communication with the tubular member and positioned with respect to the tubular member to allow or prevent fluid movement through the tubular member; and an absorber in operable communication with the valve member and configured to allow movement of the valve member the movement absorbing a pressure rise against the valve member in use.

[0004] A method for mitigating water hammer in a flow control structure for a downhole completion including allowing a valve member to move relative to a tubular member with which the valve member is operable to allow or prevent fluid movement through the tubular member; absorbing a pressure rise against the valve member with the movement.

BRIEF DESCRIPTION OF THE DRAWINGS

[0005] Referring now to the drawings wherein like elements are numbered alike in the several Figures:

[0006] FIG. 1 is a schematic view of one embodiment of a flow control valve configured to mitigate water hammer in a position open to flow;

[0007] FIG. 2 is a schematic view of the embodiment of FIG. 1 in a reactive position following closure of the valve;

[0008] FIG. 3 is a schematic view of another embodiment of a flow control valve configured to mitigate water hammer;

[0009] FIG. 4 is a schematic view of another embodiment of a flow control valve configured to mitigate water hammer.

DETAILED DESCRIPTION

[0010] In each of the following embodiments it is to be noted that the “ringing” of the water hammer effect is mitigated. In some applications the most important place to mitigate that ringing is where the formation is directly exposed thereto. For example, in an injection system, a ringing downhole of the injection valve is detrimental to the formation. Mitigation of the ringing downhole of the valve would accordingly be of paramount importance. Ringing in other parts of the system may also however be of detrimental effect and might advantageously be mitigated as well. Some of the embodiments below will mitigate water hammer in either or both directions.

[0011] Referring to FIG. 1, a first embodiment of a flow control structure 10 configured to mitigate water hammer is schematically illustrated. The structure 10 includes a tubular member 12, a valve member 14 and an absorber 16 that together allow for a mitigation in the origination of a tube wave upon closure of the valve or a mitigation of the reflection of a tube wave originated at the valve member 14 earlier in time or originated elsewhere in a system in which the structure 10 is installed. The above noted components may be disposed within a housing 18. The tubular member is, in the embodiment illustrated in FIGS. 1 and 2, sealed to an inside surface 20 of housing 18 with one or more seals 22 such as o-rings, or other similar configurations capable of providing a sliding seal against a surface such as surface 20. As illustrated there are three seals 22 but it will be understood that more or fewer could be employed without departing from the invention. Disposed in operable communication with the tubular member 12 is valve 14, which as illustrated is a ball valve but could be of other structure including but not limited to a flapper, illustrated in conjunction with the embodiment of FIG. 4, discussed hereunder. In FIG. 1 the absorber 16 is shown both upstream and downstream of the valve member 14 but it will be understood that it is contemplated that only upstream or only downstream locations of the absorber will not depart from the invention. Further it is to be noted that the absorber may operate in compression, extension or both depending upon application. It is also to be appreciated that it is the valve member that need be movable and that this can occur with the tubular member as illustrated in FIGS. 1 and 2 or can occur within the tubular member where that member is fixed and the absorber is in contact with the valve member.

[0012] Returning to discussion of FIG. 1 directly, it will be noted that a means for actuating the valve member is provided in the form of a hydraulic line 24. This is but one embodiment of means to actuate the valve member and others are contemplated such as electromagnetic means, pneumatic means, mechanical shifting means, etc. The particular means of actuating the valve member does not impact the operation of the invention.

[0013] It will be appreciated from the view of FIG. 1 that with the valve member open, fluid will flow (see arrows 26) through the device substantially unimpeded. When the valve member 14 is actuated to the closed position (FIG. 2) however, the force of fluid 26 causes a pressure thereof to build against the closed valve member 14. It is this pressure buildup that originates a tube wave that will reflect from the valve member 14 back along a tubing 28 in the upstream direction to potentially do damage to components therealong. Because of the construction of the embodiment of FIGS. 1 and 2, the tube wave originated by the actuation of the valve member 14 to the closed position will be substantially mitigated due to the ability of the valve member 14 to move in the downstream direction. Since the energy of the tube wave comes from the pressure buildup against a member and the reflection of that energy back in the direction from which it came, the movement of the member against which pressure would naturally build will mitigate the ultimate energy buildup and reflection.
Accordingly the resulting wave is in fact mitigated. Further, the same thing will happen if the valve member 14 is impacted by a tube wave generated somewhere else in the tubing. This then results in mitigation of that tube wave also hence positively affecting the entire system. Because in one embodiment the absorber exists on both upstream and downstream positions relative to the valve member 14, the device will operate on tube waves originating or propagating in or from either direction. This also can be the case however if the absorber is only on one side of the valve member 14 depending upon how the absorber is set up, i.e. with compressive capability, extensive capability or both and the position of the absorber at rest relative to the housing 18.

[0014] Although the absorber 16 is illustrated as a coil spring, it is contemplated that the absorber 16 may comprise other configurations such as a gas spring, a rubber spring, capillary spring or other resilient configurations. It is further noted that the spring rate may be constant or variable in embodiments. In each iteration, the valve member 14 will be allowed to move in at least one direction and in some embodiments will be allowed to move in both directions, and in either case, will be decelerated to a stop gradually after movement begins pursuant to a valve closure.

[0015] It is noted that most of the discussion herein is related to the pressure rise on the upstream side of the valve member 14. It will be appreciated however that the same action that mitigated that rise on the upstream side of the valve member will mitigate the low-pressure event caused at the downstream side of the valve member in a prior art system. This is because the valve member is following the fluid in the downstream direction and therefore not allowing the fluid to pull the pressure down in the local area immediately downstream of the valve member 14, as it would do in a fixed valve member prior art system.

[0016] In another embodiment, referring to FIG. 3, the resilient member is not needed and rather friction alone is relied upon to cause a controlled deceleration of the movement of the valve member 14. Since it is the reduction in the speed of deceleration of the fluid flowing through the tubular that acts to reduce the origination of or reflection of a tube wave, this can be accomplished with a bore in housing 18 in which the valve member may slide providing that the valve member 14 will slide more rapidly upon closure of the valve member and then progressively slow down to a stop. Such an embodiment may be configured as a frustoconical polished bore with the smaller dimensioned end of the bore being downstream of the valve member 14. Upon closure of the valve member, the member 14 will move in the downstream direction (arrow) under the influence of the flowing fluid. As the valve member 14 is entering a smaller and smaller dimension range of the frustocone, friction on the valve member is progressively higher. The valve will hence slow to a stop smoothly and generate and or reflect little or no tube wave. In this embodiment, the valve member 14 will not reset itself as it does in the embodiments that use a resilient member.

[0017] In another embodiment, referring to FIG. 4, the foregoing embodiments are modified to include one or more openings 30 in the housing 18. In this embodiment the tubular member 12 and seal(s) 22 cover the one or more openings that extend to a chambers that allow for pressure diffusion such as atmospheric chambers, or "bags" of fluid impermeable material. Upon the actuation of the valve member 14 (actuated in any of the known ways to actuate a flow control valve, in the illustrated case a flapper or a ball valve), the valve member 14 will move in the downstream direction as did the embodiment of FIG. 1 but in this case, the tubular member 12, moving with the valve member 14 will uncover the one or more openings 30 thereby providing a pressure diffusion pathway for the building pressure of the fluid flow due to the closure of the valve member 14. This action in combination with the movement of the valve member 14, will act to mitigate the origination and/or reflection of a tube wave. Depending upon the application, if there is no prohibition to fluid flow into an annulus of the configuration, the openings 30 may open to that annulus. In other configurations, such as a safety valve for example, a fluid pathway to the annulus would be prohibited and hence this embodiment could not be used for such an application.

[0018] It is further noted that each embodiment where there is a resilient absorber, a dashpot, and particularly a single acting dashpot that allows rapid initial movement but slows the return movement of the valve member, could be added to damp the resilience particularly upon the rebound stroke after compression of the absorber due to valve closure.

[0019] While one or more embodiments have been shown and described, modifications and substitutions may be made thereto without departing from the spirit and scope of the invention. Accordingly, it is to be understood that the present invention has been described by way of illustrations and not limitation.

1. A water hammer mitigating flow control structure for a downhole completion comprising:
   a) a tubular member configured for the downhole environment;
   b) a valve member in operable communication with the tubular member and positionable with respect to the tubular member to allow or prevent fluid movement through the tubular member, and an absorber in operable communication with the valve member and configured to allow movement of the valve member the movement absorbing a pressure rise against the valve member in use.

2. A water hammer mitigating flow control structure as claimed in claim 1 wherein the valve member is a flapper valve.

3. A water hammer mitigating flow control structure as claimed in claim 1 wherein the valve member is a ball valve.

4. A water hammer mitigating flow control structure as claimed in claim 1 wherein the absorber is of constant rate.

5. A water hammer mitigating flow control structure as claimed in claim 1 wherein the absorber is of variable rate.

6. A water hammer mitigating flow control structure as claimed in claim 1 wherein the absorber is positioned downstream of fluid flow relative to the valve member.

7. A water hammer mitigating flow control structure as claimed in claim 1 wherein the absorber is positioned both upstream and downstream of the valve member.

8. A water hammer mitigating flow control structure as claimed in claim 7 wherein the absorber is two absorbers with one positioned upstream and one positioned downstream of the valve member.

9. A water hammer mitigating flow control structure as claimed in claim 1 wherein the absorber is a spring.

10. A water hammer mitigating flow control structure as claimed in claim 9 wherein the spring is a coil spring.

11. A water hammer mitigating flow control structure as claimed in claim 1 wherein the absorber is a gas charged chamber.
12. A water hammer mitigating flow control structure as claimed in claim 1 wherein the absorber further includes a dash pot.

13. A water hammer mitigating flow control structure as claimed in claim 12 wherein the dash pot is single acting.

14. A water hammer mitigating flow control structure as claimed in claim 1 wherein the structure further includes a housing radially adjacent the tubular member having one or more openings therein that are covered until the tubular member is moved following a pressure rise against the valve member in use.

15. A water hammer mitigating flow control structure as claimed in claim 14 wherein the one or more openings absorb pressure when exposed to fluid pressure subsequent to the valve member experiencing a pressure rise in use.

16. A water hammer mitigating flow control structure as claimed in claim 1 wherein the pressure rise is an origination or a reflection of a tube wave.

17. A method for mitigating water hammer in a flow control structure for a downhole completion comprising: allowing a valve member to move relative to a tubular member with which the valve member is operable to allow or prevent fluid movement through the tubular member; absorbing a pressure rise against the valve member with the movement.

18. A method for mitigating water hammer in a flow control structure as claimed in claim 17 wherein the absorbing includes deforming a spring.

19. A method for mitigating water hammer in a flow control structure as claimed in claim 17 wherein the deforming includes deforming a spring at a downstream position relative to the valve member.

20. A method for mitigating water hammer in a flow control structure as claimed in claim 17 wherein the deforming includes deforming a spring at both downstream and upstream positions relative to the valve member.

21. A method for mitigating water hammer in a flow control structure as claimed in claim 17 wherein upon deforming the spring in the downstream position, one or more openings in a housing of the structure are uncovered.

22. A method for mitigating water hammer in a flow control structure as claimed in claim 17 wherein the absorbing includes a rebound and the rebound is slowed.