WELL CASING SEALS

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This invention relates to cementing casing in wells and more particularly to a method and apparatus for preventing fluid communication between the casing and the cement.

In cementing a casing in a bore hole, cement slurry is pumped into the annular space between the casing and the wall of the bore hole. When the cement hardens, it forms a seal blocking the flow of fluids through the annular space above and below the cemented portion of the wall. During normal producing operations, a substantial pressure differential may exist between the cemented zones. If the pressure becomes too great, leakage of fluid may occur due to a failure of the bond between the casing and the cement, failure of the bond between the cement and the bore hole wall, or failure of the cement itself. Usually, the weakest bond occurs between the casing and cement.

When the casing cement bond fails, well fluid is pumped by the pressure differential and surface of the casing, between the cement and the casing from the high pressure zone to the low pressure zone. This condition may make it impossible to carry out the producing operations.

Accordingly, it is an object of this invention to provide a method and apparatus for preventing fluid communication between the casing and cement.

It is a further object of this invention to provide a casing seal capable of withstand high pressure differentials.

It is a still further object of this invention to provide cementing seals for preventing fluid communication which are readily applied.

These objects are accomplished in accordance with a preferred embodiment of the invention by a band that is applied to the casing pipe when it is being made up in a string. The band extends around the circumference of the casing. After the band is applied, it is tightly pressed against the surface of the casing to form a seal. Preferably, the band is formed of a heat shrinkable plastic material, and after the ring is applied over the casing, the band is heated to cause it to shrink and tightly grip the surface of the casing. As an alternative, the band may be formed of an elastomeric material and a ring of heat shrinkable plastic material may be applied concentrically over the band. Heat is then applied to the outer ring to cause it to contract, thereby pressing the inner ring firmly against the surface of the casing. As a further modification, the band may be compressed against the casing by a rigid clamping ring. The outer surface of the heat shrinkable band or the clamping ring may be roughened or coated with hard particles, such as sand, to increase the strength of the bond between the band or ring and the cement.

These preferred embodiments are illustrated in the accompanying drawings in which:

FIG. 1 is a cross sectional view of a casing cemented in a bore hole having the seal rings of this invention applied thereto;

FIG. 1A is a cross sectional view of a seal ring coated with particulate material;

FIG. 2 is a cross sectional view of a cemented casing having a modified seal ring thereon;

FIG. 3 is a cross sectional view of a casing having a second modified seal device applied thereto;

FIG. 4 is a cross sectional view along the line 4—4 in FIG. 3;

FIG. 5 is a cross sectional view of a casing having a third modified seal device applied thereto;

FIG. 6 is a cross sectional view along the line 6—6 in FIG. 5;

FIG. 7 is a side elevational view of the third modified seal device;

FIG. 8 is a cross sectional view of a casing having a fourth modified seal device applied thereto;

FIG. 9 is a cross sectional view along the line 9—9 in FIG. 8;

FIG. 10 is a cross sectional view as in FIG. 9, but showing the position of the clamping ring prior to compression of the sealing ring; and

FIG. 11 is an enlarged cross sectional view of a clamping ring coated with particulate material.

After a bore hole has been drilled, it is customary to set casing pipe in the hole by pumping cement down through the casing and out the bottom of the casing. The cement flows upwardly through the annular space between the exterior of the casing and the wall of the bore hole. When the cement hardens, the casing is anchored in the bore hole, and the cement acts as a barrier to the flow of fluid upwardly or downwardly through the annular space. A casing pipe 2 is shown schematically in FIG. 1. The casing 2 extends through a bore hole 4, with cement 6 filling the space between the casing and the wall of the bore hole 4.

In order to carry out normal well operations, it may be necessary to perforate the casing and the cement to reach a producing formation behind the cement. When this is done, fluid pressure may become very high at the perforations and tend to cause failure of the bond between the casing 2 and the cement 6. The casing-cement bond may also fail as a result of a high pressure differential above and below the cemented zone. Usually, it is very important for the perforated zones to remain isolated. If there is fluid leakage, either through the cement or along the wall of the casing, it may interfere with successfully carrying out the operation.

In accordance with this invention, an elastomeric ring 8 is applied to the external surface of the casing, as shown in FIG. 1. In its free state, the internal diameter of the ring 8 is slightly larger than the external diameter of the casing. Accordingly, the ring 8 may easily be applied when the casing string is being made up by slipping the ring over the end of the casing pipe and moving the ring along the casing to the desired location. A secondary ring 10 is mounted over the primary ring 8 and is substantially concentric with the primary ring. The secondary ring would usually be assembled together with the primary ring 8 before the rings are applied to the casing, but the rings also may be assembled together after they are applied to the casing. The primary ring 8 is formed of a resilient, elastomeric material which is capable of circumferential and radial compression, without excessive deformation. The secondary ring 10 preferably is formed...
of a plastic resin that shrinks when heated. An example of such a heat shrinkable plastic material is irradiated, biaxially oriented polyethylene. When heat is applied to the secondary ring 10, the ring 10 shrinks and tightly draws the primary ring 8 against the surface of the casing 2. The advantage in using a heat shrinkable plastic for the ring 10 is that there are external obstructions on the ring which might interfere with the flow of cement through the annular space. However, devices such as metal bands or clamps, which are mechanically tightened to compress the ring 8, may be utilized in place of the ring 10.

In carrying out the method of this invention, the rings 8 and 10 are applied to the surface of the casing and positioned to correspond to the desired elevation. Heat is then applied to the secondary ring 10 to shrink the secondary ring and to press the primary ring 8 tightly against the surface of the casing 8. The casing string is then run in the bore hole and conventional cementing operations are carried out. Since the rings 8 and 10 tightly grip the surface of the casing, they are not displaced by the flow of cement through the annular space between the casing and the bore hole wall. When the cement hardens 30 effect to prevent the flow of fluid between perforated zones, or between cemented zones. The rings 8 and 10 prevent the flow of fluid along the surface of the casing and form an effective seal.

The secondary ring 10 may be omitted and the primary ring 8 may be formed of a heat shrinkable plastic. Further, to the bend between the ring and the cement may be strengthened by coating the exposed surfaces of the ring with particulate material, as shown in an enlarged cross sectional view in FIG. 1A. The ring 8 has a bonding layer which includes a resin matrix 9 and partially embedded particulate material 11, such as sand particles. The bonding layer preferably has essentially a single layer of sand particles, the majority of which are arranged so that adjacent particles are in contiguous or edge-touching relation. The particles preferably are sized in relation to the thickness of the matrix layer 9 so as to be embedded between 1/4 and 3/4 of their overall thickness in the resin layer.

The resin for the matrix 9 must be compatible with the plastic forming the heat shrinkable ring 8. The matrix may be formed of a resin that cures at room temperature and has favorable bonding characteristics with the plastic in the ring 8 and the particulate material 11. An example of such a matrix resin is an epoxy resin which cures without heating, such as described in U.S. Patent No. 3,017,487. The particulate material may also be embedded directly in the exposed surfaces of the ring 8 after softening the surface with a suitable solvent.

A modified form of the invention is shown in FIG. 2. A circular ring 12 is mounted on the casing 2', as shown in FIG. 2. The ring 12 has a greater internal diameter than the external diameter of the casing 2' and therefore, it is free to slide along the casing to the position corresponding to the desired elevation in the bore hole. Preferably, the entire ring 12 is formed of a heat shrinkable plastic. The ring is secured to the casing by applying heat to the ring to cause it to shrink tightly against the surface of the casing.

The ring 12 has a central groove in each of the four sides of the ring and the corners of the ring are rounded. The upper and lower portions of the ring are thicker radially than the central portion between the inner and outer grooves. Consequently, the upper and lower portions experience a greater amount of radial shrinkage than the center portion and tightly grip the casing surface, while leaving a hollow space 14 between the casing and the ring. Also, when fluid pressure is exerted upwardly, for example, between the surface of the casing and the cement, the lower corner of the ring 12, which normally engages the casing, is displaced radially outward by the fluid pressure. Since the ring 12 is confined by the hardened cement in the bore hole, the radial displacement of the lower corner of the ring causes the upper corner to expand into the hollow space 14, thereby effectively blocking the flow of fluid past the ring 12.

Although it is preferred to form the ring 12 out of a heat shrinkable plastic material, the ring may be formed of an elastomeric material. The internal diameter of the ring 12 then is smaller than the outside diameter of the casing 2' and it is necessary to stretch the ring in order to mount it on the casing. When the ring 2' is in place on the casing there is sufficient hoop tension in the ring to maintain the ring tightly against the casing and thereby resist displacement of the ring by fluid pressure. The ring 12 also may have a coating of particulate material applied to the exterior surface as described with respect to the ring 8'.

The particle coated elastomeric rings 8' and 12 may have the coating applied away from the well site and then assembled on the casing. Since the rings 8' and 12 are formed of a resin material, the matrix may be bonded to the ring by a solvent. As a result, the matrix would become integral with the ring. The sand or other particulate material is securely bonded in the matrix and the entire composite ring forms a strong integral unit which may be readily applied to the casing.

A second form of the seal device is shown in FIGS. 3 and 4. The seal device includes an elastomeric ring 16 and a clamp ring 18 which are applied to the external surface of a casing 20. The clamp ring 18 is in the form of two semi-circular hollow segments 22 and 24. The rings 22 and 24 are joined together at one end by a tab portion 26 on the ring segment 24 and a hook portion 28 on the segment 22. The hook portion 28 projects through an opening in the tab 26 to form a hinge. The opposite end of the ring segments 22 and 24 are releasably secured together by a latch including a pin 30 that is pivotally mounted on the end of the segment 22, and a link 32 that is fastened to the lever 30. The link 32 is in the form of a loop with its opposite ends secured to opposite sides of the lever 30. The link is received in a slot 34 in the ring segment 24 to draw the ends of the segments together as the lever 30 swings from the substantially radial of the ring 18 to the position shown in FIG. 3. The seal ring 16 preferably has a greater radial thickness than the depth of the interior recess in the ring 18.

The sealing device shown in FIGS. 3 and 4 is applied to a casing 20 by passing the ring 16 over the end of the casing until it is positioned at a desired elevation. Preferably, the ring 16 has a slightly smaller internal diameter than the external diameter of the casing, so that it fits snugly against the wall of the casing. The clamp ring 18 is opened by swinging the lever 30 toward the segment 24 to release the link 32 from the slot 34, thereby allowing the segments 22 and 24 to swing apart about the hinge formed by the tab portion 26 and hook portion 28. The ring 18 is then applied over the seal ring 16 and the link 32 is positioned in the slot 34. Then, by swinging the lever 32 against the ring 22, as shown in FIG. 3, the ring is tightened against the outer surface of the ring 16 to compress the ring against the surface of the casing 20. The clamp ring 18 overlaps on opposite sides of the ring 16 when it is applied to the casing. Thus, the clamp ring 18 protects the seal ring 16 from abrasion or displacement as the casing is lowered into the well bore.

A third form of the sealing device is illustrated in FIGS. 5, 6 and 7. In this form of the invention, a pair of seal rings 30 are applied to the external surface of a casing 38. A band 40 is applied over the rings 36 for clamping the rings tightly against the surface of the casing. The band 40 has channel portions 42 at each end which are joined together by a web portion 44. The band 40 is split longitudinally to allow circumferential size
adjustment. This adjustment is accomplished by means of a screw clamp 46, as shown in FIG. 7. The clamp 46 includes a screw 48. A strip 50 is positioned between the screw 48 and the web portion 44 and the screw threads engage corresponding slots in the strip 50. The clamp 46 is secured to the web 44 at one end of the band 40 and the strip 50 is secured by welding or other means to the opposite end of the band. As the screw 48 is turned, the screw threads progressively engage the slots in the strip to draw the ends of the band together. Consequently, the diameter of the band decreases and the strip 50 may be compressed against the casing 38. As an alternative, the clamp 46 and the strip 50 may be separate from the band 40, with the clamp 46 secured on one end of the strip 50 and the opposite end of the strip engaging the screw 48. By encircling the band 40 with the strip 50, it may be used for drawing tightly together the ends of the band and compressing the rings 35.

The third modified form of the seal device is applied to the casing 38 by passing the rings 36 over the end of the casing and positioning them at a desired location, and spaced in a distance corresponding to the spacing between the channel portions 42 on the band. The band 40 may be applied by passing it over the end of the casing in the same manner as the ring 36, or the band may be spread apart sufficiently to permit the band to be assembled over the casing. The strip 50 is then inserted between the screw 48 and the web portion 44, and by turning the screw 48, the ends of the band are drawn together to compress tightly the seal rings against the surface of the casing. When the band 40 is secured over the seal rings 36, the casing may be lowered into the well bore and the band protects the seal rings from abrasion or displacement.

As shown in FIGS. 4 and 6, the sealing rings 16 and 36 may be grooved circumferentially in the same manner as the ring 12 in FIG. 2.

A fourth modified form of the seal device of this invention is illustrated in FIGS. 8 to 10. The seal device includes an elastomeric sealing ring 52 which encircles a casing 54. The ring 52 is compressed against the casing 54 by a pair of clamping rings 56. The rings 56 have outwardly sloping flanges 58 adjacent the casing which cooperate to form a channel for receiving the sealing ring 52. The rings are joined together by bolts 60 which are spaced around the circumference of the casing 54. As shown in FIG. 9, the elastomeric ring 52 may have a square cross section prior to deformation by the flanges 58.

The sealing ring 52 is first applied to the casing 54 by slipping the sealing ring over the end of the casing and positioning the ring at the desired elevation. The clamping rings 56 are positioned on opposite sides of the sealing rings, and the clamping rings are loosely joined together by bolts 60, as shown in FIG. 10. When the bolts are tightened, the sealing ring 52 is compressed radially and axially until it conforms approximately to the shape shown in FIG. 9. In this manner a tight fluid seal is formed between the casing and the ring 52. Also, when the casing is lowered in the well, the rings 56 prevent abrasion or displacement of the sealing ring 52.

The outer surfaces of the rigid rings 18, 40 and 56 are exposed to the cement in the annular space between the casing and the bore hole wall. It is necessary to obtain a strong bond between the outer surfaces of the rigid rings and the well fluid and to prevent the rings from bypassing the seal rings by flowing around the outside of the rigid rings. The strength of the ring to cement bond can be increased by roughening the outer surface of the ring. This may be accomplished by abrading the outer surface of the ring, or by coating the surface with hard solid particulate material, such as sand. One method of coating a ring with particulate material is to apply first a coating of matrix material such as liquid, thermosetting resin material to the outer surface of the ring. The particulate material is then embedded in the matrix material while the resin material is still in a viscous state. When the matrix material hardens, the particulate material is securely bonded to the ring.

A portion of a sand coated ring 62, which is representative of the rigid rings 18, 40 and 56, is shown in FIG. 11. The ring 62, which may be formed of metal, has a coating 64 of thermosetting resin material on its outer surface. The outer surface of the ring 62 may be roughened by abrasion to improve the bond between the resin material and the ring. The thermosetting resin material may be selected from commercially available mixtures of a thermosetting resin and an appropriate resin hardener or catalyst. Suitable epoxy resins and hardening agents are described in U.S. Patent No. 2,602,785, issued July 8, 1952. The epoxy resins should be thickened by the addition of material such as titanium dioxide to obtain a viscous or thick syrup-like consistency. A satisfactory, commercially available resin is Hydol 4343 and a hardener or catalyst suitable for use with this product is Hydol 3520. The resin coating is sufficiently thick to form a matrix for securely bonding sand or other particulate material to the surface of the ring 62. In essentially a liquid or a particulate material. The particulate material 66 is embedded in the resin material 64 to a sufficient depth to ensure strong bonding between the particulate material and the resin material. Preferably, the particulate material is sand which falls within the range of 20 and 20 mesh as measured on the United States sieve standard. To ensure a strong bond between the sand and the matrix, the matrix layer should be sufficiently thick for the sand to be embedded between 1/4 and 3/4 of the overall thickness of the said grains. The sand may be applied by hand or by suitable implements.

The coatings on the rings 18, 40 and 56, as shown in FIG. 11, are preferably applied away from the well site. The rings form a rigid base to resist flexing the matrix layer which might cause some of the sand particles to become dislodged. Furthermore, since the seal rings are inserted in the rigid rings after they are assembled, a high temperature thermosetting resin may be used for the matrix without damaging the seal rings.

In each of the embodiments shown in FIGS. 3 to 10, additional hoop tension may be achieved by forming the elastomeric rings of a heat shrinkable plastic material in accordance with this invention. The clamping rings not only protect the rings from abrasion from the cement, but also provide additional localized deformation to supplement the sealing action caused by the shrinkage of the seal member. The combination of a heat shrinkable sealing ring and a clamping ring around the sealing ring provides a seal which is capable of withstanding very high hydraulic pressures between the casing and the cement.

The seals of this invention have been found to be effective in preventing fluid communication along the surface of the casing, without interfering with the flow of cement through the annulus. When cementing, if sand grains are provided on the surface of the seal or clamping rings, a particularly strong bond is formed with the cement because of the natural affinity between the sand grains and the cement. Furthermore, the seal rings are easily applied and positioned on the casing when the casing is being made up. The rings grip the surface of the casing so tightly that they are not displaced when the casing is being run in the well. The clamping rings also form a housing separating the upper and lower portions of the cement in the bore hole. When the pressure is applied above or below the sealing rings, the sealing rings bear against the clamping rings rather than directly against the cement.

While this invention has been illustrated and described in several embodiments, it is recognized that variations and changes may be made therein without departing from the invention as set forth in the claims.

We claim:

1. A casing seal comprising a circular ring, said ring...
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having a radial groove in the inner axial surface thereof, said ring having a coating of hard solid particulate material on the exterior surface of the ring, whereby the groove permits deflection of the ring to resist fluid pressure.

2. In a bore hole having a casing cemented therein, a casing seal comprising a seal ring extending circumferentially around said casing and projecting radially outward from the casing, said ring being tensioned circumferentially, said ring having a radial groove adjacent said casing and spaced from opposite ends of said ring, said cement being solidified into a monolithic mass extending around said ring, said groove being substantially void of solid material, whereby the groove allows displacement of a portion of the ring toward the groove in response to a fluid pressure differential across the ring.

3. A cemented casing seal according to claim 2 including a rigid ring extending around the circumference of said seal ring, said rigid ring having means for contracting said rigid ring.

4. A casing seal comprising an elastomeric ring and means for compressing said ring radially, said compressing means includes a substantially rigid ring, said elastomeric ring having a gripping surface along the internal circumference thereof, said rigid ring having substantially radially extending flanges, said elastomeric ring being received in said rigid ring between said flanges, said flanges terminating in substantially circular edges, said edges having a substantially greater diameter than said ring internal circumference, said ring gripping surface having a radial groove therein to allow limited displacement of portions of said elastomeric ring in response to fluid pressure, and means for adjusting the diameter of said rigid ring.

5. A casing seal according to claim 4 wherein said compressing means includes arcuate segments, and latch means for drawing said segments together circumferentially to compress said elastomeric ring.

6. A casing seal according to claim 4 wherein said compressing means includes a band extending around said ring, and screw means for adjusting the diameter of said band.

7. A casing seal according to claim 6 wherein said band includes a pair of channel portions, said channel portions being in substantially parallel planes, said elastomeric ring being inserted in one of said channel portions, and another elastomeric ring being inserted in the other of said channel portions.

8. A casing seal according to claim 4 wherein said rigid ring has an outer surface, said surface being roughened.

9. A casing seal according to claim 8 wherein said rigid ring surface has solid particulate material bonded thereon.

10. A casing seal according to claim 8 wherein said rigid ring surface has a coating of adhesive material forming a matrix and solid particulate material bonded to said matrix.

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