METHODOLOGY AND COMPOSITIONS FOR CONSOLIDATING PROPPANT IN FRACTURES

Inventors: Philip D. Nguyen, Duncan, OK (US); Johnny A. Barton, Marlow, OK (US); O. Marlene Isenberg, Duncan, OK (US)

Correspondence Address:
Robert A. Kent
Halliburton Energy Services
2600 South 2nd Street
Duncan, OK 73525 (US)

Appl. No.: 10/383,184
Filed: Mar. 6, 2003

Publication Classification

ABSTRACT

Improved methods and compositions for consolidating proppant in subterranean fractures are provided. In accordance with the methods of the invention, proppant particles coated with a hardenable bisphenol A-epichlorohydrin resin composition are mixed with a gelled liquid fracturing fluid and the fracturing fluid is pumped into a subterranean zone. The fracturing fluid forms one or more fractures in the subterranean zone and deposits the proppant particles coated with the resin composition therein. Thereafter, the hardenable resin composition on the proppant particles is allowed to harden by heat and consolidate the proppant particles into degradation resistant permeable packs. The hardenable bisphenol A-epichlorohydrin resin compositions of the invention are storable for long periods of time before use.
METHODS AND COMPOSITIONS FOR CONSOLIDATING PROPPANT IN FRACTURES

BACKGROUND OF THE INVENTION

[0001] 1. Field of the Invention

[0002] The present invention relates to methods and storable hardenable resin compositions for forming one or more fractures in high temperature subterranean zones and consolidating proppant particles therein.

[0003] 2. Description of the Prior Art

[0004] Hydrocarbon producing wells are often stimulated by hydraulic fracturing treatments. In hydraulic fracturing, a viscous fracturing fluid which also functions as a carrier fluid is pumped into a subterranean zone to be fractured at a rate and pressure such that one or more fractures are formed in the zone. Proppant particles, e.g., graded sand, for propping the fractures open are suspended in the fracturing fluid so that the proppant particles are deposited in the fractures when the fracturing fluid is broken. That is, a viscosity breaker is included in the fracturing fluid whereby the fracturing fluid reverts to a thin fluid which is returned to the surface. The proppant particles deposited in the fractures function to prevent the fractures from closing so that conductive channels are formed through which produced hydrocarbons can readily flow.

[0005] In order to prevent the subsequent flow-back of the proppant particles as well as loose or incomplete fines with fluids produced from the subterranean zone, the proppant particles have heretofore been coated with a hardenable resin composition which is caused to harden and consolidate the proppant particles in the zone into permeable packs. However, when the subterranean zone has a temperature above about 200°F, and it produces hydrocarbons at exceptionally high rates or undergoes reoccurring stresses due to frequent well shutoffs and openings, the hardened resin composition and the permeable proppant particle packs consolidated therewith rapidly deteriorate which allows proppant particles and formation fines to flow-back with produced formation fluids. The flow-back of the proppant particles and formation fines is very detrimental in that it erodes metal goods, plugs piping and vessels and causes damage to valves, instruments and other production equipment.

[0006] Another problem encountered in the use of prior hardenable resin compositions for coating proppant particles is that the hardenable resin composition or components thereof have had short shelf lives. In addition, the hardenable resin composition components have heretofore had low flash points making them dangerous to use. Also, when the prior hardenable resin compositions or components thereof have been stored at high ambient temperatures, the compositions or components have quickly hardened making them unsuitable for use.

[0007] Thus, there are needs for improved methods and storable hardenable resin compositions for consolidating proppant particles in subterranean fractures whereby the permeable packs of consolidated proppant particles formed are resistant to degradation by high production rates, stress cycling and/or thermal degradation. Further, there are needs for improved hardenable resin compositions that are premixed and have long shelf lives and high flash points.

SUMMARY OF THE INVENTION

[0008] The present invention provides improved methods and compositions for consolidating proppant in fractures formed in high production rate, high stress and/or high temperature subterranean zones which meet the needs described above and overcome the deficiencies of the prior art. The hardenable resin compositions of this invention are hardened by heat and consolidate resin coated proppant particles at temperatures above about 200°F into degradation resistant permeable packs which do not allow proppant flow-back and the production of formation fines with formation fluids.

[0009] An improved method of the present invention for forming one or more fractures in a subterranean zone having a temperature above about 200°F penetrated by a well bore and consolidating proppant particles therein is comprised of the following steps. Proppant particles coated with a hardenable resin composition are provided. The hardenable resin composition is comprised of a liquid bisphenol A-epichlorohydrin resin, a 4,4'-diaminodiphenyl sulfone hardening agent dissolved in a dimethyl sulfoxide or dimethyl formamide solvent, a silane coupling agent and a surfactant for facilitating the coating of the resin on the proppant particles and for causing the resin composition to flow to the contact points between adjacent coated proppant particles. Optionally, a hydrolyzable ester for breaking gelled fracturing fluid films on the proppant particles can be included in the hardenable resin composition. A high flash point diluent such as dipropylene glycol methyl ether can also optionally be included in the hardenable resin composition to reduce its viscosity to a desirable level for ease of pumping during use. A gelled liquid fracturing fluid is also provided which is pumped into the subterranean zone to form one or more fractures and to deposit the proppant particles therein. The proppant particles coated with the hardenable resin composition are mixed with the fracturing fluid being pumped whereby the proppant particles coated with the hardenable resin composition are suspended therein. When the proppant particles coated with the hardenable resin composition have been deposited in the one or more fractures formed, the pumping of the fracturing fluid and the mixing of the proppant particles coated with the hardenable resin composition with the fracturing fluid are terminated. Thereafter, the hardenable resin composition on the resin composition coated proppant particles is allowed to harden by heat and consolidate the proppant particles into one or more degradation resistant permeable packs.

[0010] Another improved method of this invention for forming one or more fractures in a subterranean zone penetrated by a well bore and consolidating proppant particles therein, the subterranean zone having a temperature above about 200°F is comprised of the following steps. A liquid hardenable resin composition is provided comprised of a liquid bisphenol A-epichlorohydrin resin, a 4,4'-diaminodiphenyl sulfone hardening agent dissolved in a dimethyl sulfoxide solvent, an n-beta-(aminomethyl)-gamma-amino-propyltrimethoxysilane coupling agent, a C12-C22 alkyl phosphate surfactant, a mixture of dimethylglutarate, dimethyldipate and dimethylsuccinate esters, and a dipropylene glycol methyl ether diluent. A source of dry proppant particles and a gelled liquid fracturing fluid comprised of water and a gelling agent selected from the group consisting of guar gum, guar gum derivatives and cellulose derivatives.
are also provided. The gelled liquid fracturing fluid is pumped into the subterranean zone to form the one or more fractures therein and to place the proppant particles therein. The hardenable resin composition is coated onto the dry proppant particles conveyed from the source thereof to form hardenable resin composition coated proppant particles. The hardenable resin composition coated proppant particles are mixed with the fracturing fluid pumped into the subterranean zone whereby the hardenable resin composition coated proppant particles are suspended therein. When the hardenable resin composition coated proppant particles have been placed in the one or more fractures formed in the subterranean zone, the pumping of the gelled fracturing fluid, the coating of the hardenable resin composition onto the dry proppant particles and the mixing of the hardenable resin composition coated proppant particles formed with the fracturing fluid are terminated. Thereafter, the hardenable resin composition on the hardenable resin composition coated proppant particles is allowed to harden by heat and consolidate the proppant particles into one or more degradation resistant permeable packs.

[0013] The proppant particles utilized in accordance with the present invention are generally of a size such that formation particulate solids that migrate with produced fluids are prevented from being produced from the subterranean zone. Various kinds of proppant particles can be utilized including graded sand, bauxite, ceramic materials, glass materials, walnut hulls, polymer beads and the like. Generally, the proppant particles have a size in the range of from about 2 to about 400 mesh, U.S. Sieve Series. The preferred proppant is graded sand having a particle size in the range of from about 10 to about 70 mesh, U.S. Sieve Series. Preferred sand particle size distribution ranges are one or more of 10-20 mesh, 20-40 mesh, 40-60 mesh or 50-70 mesh, depending on the particular size and distribution of formation solids to be screened out by the consolidated proppant particles.

[0014] Liquid bisphenol A-epichlorohydrin resin is readily available from a number of commercial sources. For example, a suitable such resin is commercially available from the Resin Resolution Corporation of Houston, Tex. Upon curing by heat in a subterranean zone, the bisphenol A-epichlorohydrin resin forms an insoluble mass that is highly resistant to high production rate, high stress and/or high temperature degradation, e.g., the cured resin resists thermal degradation at temperatures up to 400°F. The bisphenol A-epichlorohydrin resin is generally present in the hardenable resin composition in an amount in the range of from about 40% to about 65% by weight of the hardenable resin composition, and more preferably in an amount of about 50%.

[0015] The liquid hardening agent for hardening the bisphenol A-epichlorohydrin resin at temperatures above about 200°F is comprised of 4,4'-diaminodiphenyl sulfone dissolved in dimethyl sulfoxide or dimethyl formamide solvent and is present in the hardenable resin composition in an amount in the range of from about 15% to about 50% by weight of the composition, and more preferably in an amount of about 25%. The solvent contains the 4,4'-diaminodiphenyl sulfone in an amount of about 40% by weight of the solvent.

[0016] Examples of silane coupling agents which can be utilized in the hardenable resin composition include, but are not limited to, N,N-2-(aminoethyl)-3-aminopropltrimethoxysilane, 3-glycidoxypropyltrimethoxysilane and n-beta-(aminoethyl)-gamma-aminopropylmethoxysilane. Of these, n-beta-(aminoethyl)-gamma-aminopropylmethoxysilane is preferred. The silane coupling agent is included in the hardenable resin composition in an amount in the range of from about 0.1% to about 3% by weight of the composition and more preferably in an amount of about 1%.

[0017] Various surfactants for facilitating the coating of the resin on the proppant particles and for causing the resin to flow to the contact points between adjacent resin coated proppant particles can be utilized in the hardenable resin composition. Examples of the surfactants include, but are not limited to, ethoxylated nonyl phenol phosphate ester surfactants, mixtures of one or more cationic surfactants and one or more non-ionic surfactants and a C12-C18 alkyl phosphonate surfactant. Of these, a C12-C18 alkyl phosphonate surfactant is preferred. The surfactant is included in the hardenable resin composition in an amount in the range of from about 0.1% to about 10% by weight of the composition and more preferably in an amount of about 5%.

DESCRIPTION OF PREFERRED EMBODIMENTS

[0012] The present invention provides improved methods of forming one or more fractures in a subterranean zone penetrated by a well bore and consolidating proppant particles therein, the subterranean zone having a temperature above about 200°F. comprising the following steps. Proppant particles coated with a hardenable resin composition comprised of a liquid bisphenol A-epichlorohydrin resin, a 4,4'-diaminodiphenyl sulfone hardening agent dissolved in a dimethyl sulfoxide or dimethyl formamide solvent, a silane coupling agent and a surfactant for facilitating the coating of the resin on the proppant particles and for causing the resin to flow to the contact points between adjacent resin coated proppant particles are provided. Optionally, a hydrolyzable ester for breaking gelled fracturing fluid films on the proppant particles can be included in the hardenable resin composition. A high flash point diluent such as dipropylene glycol methyl ether can also optionally be included in the hardenable resin composition to reduce its viscosity to a desirable level for ease of pumping during operation. A gelled liquid fracturing fluid is also provided which is pumped into the subterranean zone to form the one or more fractures and to deposit the proppant particles therein. The proppant particles coated with the hardenable resin composition are mixed with the fracturing fluid being pumped into the subterranean zone whereby the proppant particles coated with the hardenable resin composition are suspended therein. When the proppant particles coated with the hardenable resin composition have been deposited in the one or more fractures, the pumping of the gelled liquid fracturing fluid and the mixing of the proppant particles coated with the hardenable resin composition with the fracturing fluid are terminated. Thereafter, the hardenable resin composition on the resin composition coated proppant particles are allowed to harden by heat and consolidate the proppant particles into one or more high production rate, high stress and/or high temperature degradation resistant permeable packs.
Examples of hydrolyzable esters which can optionally be included in the hardenable resin composition include, but are not limited to, a mixture of dimethylglutarate, dimethyladipate and dimethylsuccinate, sorbitol, catechol, dimethylthiolate, methyl salicylate, dimethylsuccinate and tert-butylhydroperoxide. Of these, a mixture of dimethylglutarate, dimethyladipate and dimethylsuccinate are preferred. When utilized, the hydrolyzable ester is included in the liquid hardenable resin composition in an amount in the range of from about 0.1% to about 53% by weight of the composition and more preferably in an amount of about 2%.

A high flash point diluent that can optionally be included in the hardenable resin composition is dipropylene glycol methyl ether. When used, the diluent is present in an amount of about 1% to about 40% by weight of the composition.

The liquid hardenable resin composition of this invention can be premixed and stored at atmospheric conditions, e.g., temperatures up to 120°F. without significant viscosity increase or deterioration. As mentioned above, the liquid hardenable resin composition hardens at temperatures above about 200°F. and can be utilized in wells having temperatures in the range of from about 200°F. to about 350°F. and higher. The liquid hardenable resin composition has a safe high flash point above 170°F.

Another improved method of forming one or more fractures in a subterranean zone penetrated by a well bore and consolidating proppant particles therein, the subterranean zone having a temperature above about 200°F. is comprised of the following steps. A liquid hardenable resin composition is provided comprised of a liquid bisphenol A-epichlorohydrin resin, a 4,4'-diaminodiphenyl sulfone dissolved in a dimethyl sulfoxide solvent, an n-beta-(aminoethyl)-gamma-aminopropyltrimethoxysilane coupling agent, a C12-C22 alkyl phosphate surfactant, a mixture of dimethylglutarate, dimethyladipate and dimethylsuccinate hydrolyzable esters and a dipropylene glycol methyl ether diluent. A source of dry proppant particles and a gelled liquid fracturing fluid are also provided. The gelled liquid fracturing fluid is comprised of water and a gelling agent selected from the group consisting of guar gum, guar gum derivatives and cellulose derivatives. The gelled liquid fracturing fluid is pumped into the subterranean formation to form the one or more fractures therein and to place the proppant particles therein. The hardenable resin composition is coated onto the dry proppant particles conveyed from the source thereof to form hardenable resin composition coated proppant particles. The hardenable resin composition coated proppant particles are mixed with the fracturing fluid being pumped whereby the hardenable resin composition coated proppant particles are suspended therein. When the hardenable resin composition coated proppant particles have been placed in the one or more fractures by the fracturing fluid, the pumping of the fracturing fluid, the coating of the hardenable resin composition onto the dry proppant particles and the mixing of the hardenable resin composition coated proppant particles formed with the fracturing fluid are terminated. Thereafter, the hardenable resin composition on the hardenable resin composition coated proppant particles is allowed to harden by heat and consolidate the proppant particles into one or more high production rate, high stress and/or high temperature degradation resistant permeable packs.

The bisphenol A-epichlorohydrin resin, the 4,4'-diaminodiphenyl sulfone hardening agent dissolved in a dimethyl sulfoxide solvent, the silane coupling agent, the surfactant, the hydrolyzable esters and the dipropylene glycol methyl ether diluent are present in the hardenable resin composition in the same amounts as described above.

The water in the gelled liquid fracturing fluid is selected from the group consisting of fresh water and salt water. The term “salt water” is used herein to mean unsaturated salt solutions and saturated salt solutions including brines and seawater.

The gelling agent in the fracturing fluid is generally present in an amount in the range of from about 0.01% to about 3% by weight of water therein and more preferably in an amount of about 0.1% to about 1%.

The gelled liquid fracturing fluid can include a cross-linking agent for increasing the viscosity of the fracturing fluid. Examples of suitable cross-linking agents include, but are not limited to, alkali metal borates, borax, boric acid and compounds capable of releasing multivalent metal ions in aqueous solutions. When used, the cross-linking agent is included in the fracturing fluid in an amount in the range of from about 0.001% to about 5% by weight of water therein and more preferably in an amount of about 0.01% to about 1%.

The fracturing fluid generally also includes a delayed viscosity breaker which functions to reduce the viscosity of the fracturing fluid and cause the resin composition coated proppant particles suspended in the fracturing fluid to be deposited in the fractures. Examples of delayed viscosity breakers which can be utilized include, but are not limited to, alkali metal and ammonium persulfates which are delayed by being encapsulated in a material which slowly releases the breaker, alkali metal chlorides, alkali metal hypochlorites and calcium hypochlorite. When used, the delayed viscosity breaker is included in the fracturing fluid in an amount in the range of from about 1% to about 5% by weight of water therein.

A preferred method of this invention for forming one or more fractures in a subterranean zone penetrated by a well bore and consolidating proppant particles therein, the subterranean zone having a temperature above about 225°F. comprises the steps of: (a) providing proppant particles coated with a hardenable resin composition comprised of a liquid bisphenol A-epichlorohydrin resin, a 4,4'-diaminodiphenyl sulfone hardening agent dissolved in a solvent selected from the group consisting of dimethyl sulfoxide and dimethyl formamide, a silane coupling agent and a surfactant for facilitating the coating of the resin on the proppant particles and for causing the resin to flow to the contact points between adjacent resin coated proppant particles; (b) providing a gelled liquid fracturing fluid; (c) pumping the gelled liquid fracturing fluid into the subterranean zone to form the one or more fractures and to deposit the proppant particles therein; (d) mixing the proppant particles coated with the hardenable resin composition with the fracturing fluid pumped in accordance with step (c) whereby the proppant particles coated with the hardenable resin composition are suspended therein; (e) terminating steps (c) and (d) when the proppant particles coated with the hardenable resin composition have been deposited in the one or more fractures; and, (f) allowing the hardenable resin composition on
the resin composition coated proppant particles to harden by heat and consolidate the proppant particles into one or more degradation resistant permeable packs.

[0028] Another improved method of the present invention for forming one or more fractures in a subterranean zone penetrated by a well bore and consolidating proppant particles therein, the subterranean zone having a temperature above about 225° F. comprises the steps of: (a) providing a liquid hardenable resin composition comprised of a liquid bisphenol A-epichlorohydrin resin, a 4,4'-diaminodiphenylsulfone hardening agent dissolved in a solvent selected from the group consisting of dimethyl sulfoxide and dimethyl formamide, an n-beta-(aminoethy1)-gamma-aminopropyltrimethoxysilane coupling agent, a C₁₂-C₃₂ alkyl phosphate surfactant, a mixture of dimethyladipate and dimethylsuccinate hydrolyzable esters and a dipropylene glycol methyl ether diluent; (b) providing a source of dry proppant particles; (c) providing a gelled liquid fracturing fluid comprised of water and a gelling agent selected from the group consisting of guar gum, guar gum derivatives and cellulose derivatives; (d) pumping the gelled liquid fracturing fluid into the subterranean zone to form the one or more fractures therein and to place the proppant particles therein; (e) coating the hardenable resin composition onto the dry proppant particles conveyed from the source thereof to form hardenable resin composition coated proppant particles; (f) mixing the hardenable resin composition coated proppant particles formed in step (e) with the fracturing fluid pumped in accordance with step (d) whereby the hardenable resin composition coated proppant particles are suspended therein; (g) terminating steps (d), (e) and (f) when the hardenable resin composition coated proppant particles have been placed in the one or more fractures and (h) allowing the hardenable resin composition coated proppant particles to harden by heat and consolidate the proppant particles into one or more degradation resistant permeable packs.

[0029] A hardenable resin composition of this invention for coating proppant particles comprises: a hardenable resin comprised of a liquid bisphenol A-epichlorohydrin resin; a 4,4'-diaminodiphénylsulfone hardening agent dissolved in a solvent selected from the group consisting of dimethyl sulfoxide and dimethyl formamide; a silane coupling agent; and a surfactant for facilitating the coating of the resin on the proppant particles and for causing the resin to flow to the contact points between adjacent resin coated proppant particles.

[0030] In order to further illustrate the methods and compositions of this invention, the following examples are given.

EXEMPLARY

EXAMPLE 1

[0031] The effect of time and temperature on the viscosity of a hardenable resin composition of this invention was determined. A hardenable resin composition was prepared comprised of a liquid bisphenol A-epichlorohydrin resin present in an amount of 49% by weight of the composition, a 4,4'-diaminodiphenylsulfone hardening agent dissolved in a dimethyl sulfoxide solvent present in an amount of about 35% by weight of the composition, an n-beta-(aminoethyl)-gamma-aminopropyltrimethoxysilane coupling agent present in an amount of about 1% by weight of the composition, a C₁₂-C₃₂ alkyl phosphate surfactant present in an amount of about 4% by weight of the composition and a mixture of dimethylglutarate, dimethyladipate and dimethylsuccinate esters present in an amount of about 1% by weight of the composition, and a diluent of dipropylene glycol methyl ether in an amount of about 10% by weight of the composition.

[0032] Samples of the hardenable resin composition were exposed to room temperature for eleven days and were maintained in a water bath at a temperature of 120° F. for eleven days. The samples had viscosities between 1, 100 and 1300 centipoises which is a desirable viscosity level for coating the resin onto proppant particles.

EXAMPLE 2

[0033] One of the hardenable resin composition samples described in Example 1 above was coated onto dry 20/40 mesh bauxite proppant particles in an amount of 3% by weight of the proppant. The resin coated proppant was mixed with water gelled with carboxymethylhydroxypropyl guar and cross-linked with a zirconium cross-linker. Two portions of the resulting viscous fluid containing hardenable resin composition coated proppant particles were stirred for 1 hour at 175° F. to simulate the effect of pumping and fluid suspension during a fracturing treatment. The fluids were then transferred and packed into brass flow cells without stress stimulating fracture closure pressure. One of the resulting proppant particle packs was cured at a temperature of 325° F. for 3 hours and the other was cured at the same temperature for 72 hours. Consolidated cores were obtained from the proppant packs formed and the cores were tested for unconfined compressive strengths.

[0034] The consolidated core that was cured for 3 hours had an unconfined compressive strength of 130±108 psi and the consolidated core that was cured for 72 hours had an unconfined compressive strength of 1230±47 psi.

[0035] Thus, the results of the tests described in Examples 1 and 2 above clearly show that the methods and hardenable resin compositions of the present invention meet the needs described above and overcome the deficiencies of the prior art.

[0036] Thus, the present invention is well adapted to attain the objects and advantages mentioned as well as those which are inherent therein. While numerous changes may be made by those skilled in the art, such changes are encompassed within the spirit of this invention as defined by the appended claims.

What is claimed is:

1. An improved method of forming one or more fractures in a subterranean zone penetrated by a well bore and consolidating proppant particles therein, the subterranean zone having a temperature above about 225° F., comprising the steps of:

(a) providing proppant particles coated with a hardenable resin composition comprised of a liquid bisphenol A-epichlorohydrin resin, a 4,4'-diaminodiphenylsulfone hardening agent dissolved in a solvent selected from the group consisting of dimethyl sulfoxide and dimethyl formamide, a silane coupling agent and a surfactant for facilitating the coating of the resin on the
proppant particles and for causing the resin to flow to the contact points between adjacent resin coated proppant particles;
(b) providing a gelled liquid fracturing fluid;
(c) pumping said gelled liquid fracturing fluid into said subterranean zone to form said one or more fractures and to deposit said proppant particles therein;
(d) mixing said proppant particles coated with said hardenable resin composition with said fracturing fluid pumped in accordance with step (c) whereby said proppant particles coated with said hardenable resin composition are suspended therein;
(e) terminating steps (c) and (d) when said proppant particles coated with said hardenable resin composition have been deposited in said one or more fractures; and
(f) allowing said hardenable resin composition on said resin composition coated proppant particles to harden by heat and consolidate said proppant particles into one or more degradation resistant permeable packs.
2. The method of claim 1 wherein said liquid bisphenol A-epichlorohydrin resin is present in said hardenable resin composition in an amount in the range of from about 40% to about 65% by weight of said composition.
3. The method of claim 1 wherein said 4,4'-diaminodiphenyl sulphone hardening agent is dissolved in said dimethyl sulfoxide or dimethyl formamide solvent in an amount of about 40% by weight of said solvent.
4. The method of claim 1 wherein said 4,4'-diaminodiphenyl sulphone hardening agent dissolved in said dimethyl sulfoxide or dimethyl formamide solvent is present in said hardenable resin composition in an amount in the range of from about 15% to about 50% by weight of said composition.
5. The method of claim 1 wherein said silane coupling agent in said hardenable resin composition is selected from the group consisting of N-2(aminomethyl)-3-aminopropyltrimethoxysilane, 3-glycidoxypropyltrimethoxysilane and N-beta-(aminomethyl)-gamma-aminopropyltrimethoxysilane.
6. The method of claim 1 wherein said silane coupling agent in said hardenable resin composition is N-beta-(aminomethyl)-gamma-aminopropyltrimethoxysilane.
7. The method of claim 1 wherein said silane coupling agent is present in said hardenable resin composition in an amount in the range of from about 0.1% to about 3% by weight of said composition.
8. The method of claim 1 wherein said surfactant for facilitating the coating of said resin on said proppant particles and for causing said resin to flow to the contact points between adjacent resin coated proppant particles is selected from the group consisting of an ethoxylated nonyl phenol phosphate ester, mixtures of one or more cationic surfactants and one or more non-ionic surfactants and a C12-C18 alkyl phosphonate surfactant.
9. The method of claim 1 wherein said surfactant is a C12-C18 alkyl phosphonate surfactant.
10. The method of claim 1 wherein said surfactant is present in said hardenable resin composition in an amount in the range of from about 0.1% to about 10% by weight of said composition.
11. The method of claim 1 which further comprises a hydrolyzable ester for breaking gelled fracturing fluid films on said proppant particles.
12. The method of claim 11 wherein said hydrolyzable ester is selected from the group consisting of a mixture of dimethyladipate, dimethyladipate and dimethylsuccinate, sorbitol, catechol, dimethylthiolate, methyl salicylate, dimethylsuccinate and terbutylhydroperoxide.
13. The method of claim 11 wherein said hydrolyzable ester is present in said hardenable resin composition in an amount in the range of from about 0.1% to about 5%.
14. The method of claim 1 wherein said hydrolyzable ester is present in said hardenable resin composition in an amount in the range of from about 1% to about 40% by weight of said composition.
15. An improved method of forming one or more fractures in a subterranean zone penetrated by a wellbore and consolidating proppant particles therein, the subterranean zone having a temperature about about 225° F comprising the steps of:
(a) providing a liquid hardenable resin composition comprised of a liquid bisphenol A-epichlorohydrin resin, a 4,4'-diaminodiphenyl sulphone hardening agent dissolved in a solvent selected from the group consisting of dimethyl sulfoxide and dimethyl formamide, an n-beta-(aminomethyl)-gamma-aminopropyltrimethoxysilane coupling agent, a C12-C18 alkyl phosphate surfactant, a mixture of dimethyladipate, dimethyladipate and dimethylsuccinate hydrolyzable esters and a dipropylene glycol methyl ether diluent;
(b) providing a source of dry proppant particles;
(c) providing a gelled liquid fracturing fluid comprised of water and a gelling agent selected from the group consisting of guar gum, guar gum derivatives and cellulose derivatives;
(d) pumping said gelled liquid fracturing fluid into said subterranean zone to form said one or more fractures therein to place said proppant particles therein;
(e) coating said hardenable resin composition on said dry proppant particles conveyed from said source thereof to form hardenable resin composition coated proppant particles;
(f) mixing said hardenable resin composition coated proppant particles formed in step (e) with said fracturing fluid pumped in accordance with step (d) whereby said hardenable resin composition coated proppant particles are suspended therein;
(g) terminating steps (d), (e) and (f) when said hardenable resin composition coated proppant particles have been placed in said one or more fractures; and
(h) allowing said hardenable resin composition on said hardenable resin composition coated proppant particles to harden by heat and consolidate said proppant particles into one or more degradation resistant permeable packs.
19. The method of claim 18 wherein said liquid bisphenol A-epichlorohydrin resin is present in said hardenable resin composition in an amount of about 50% by weight of said composition.

20. The method of claim 18 wherein said 4,4’-diaminodiphenyl sulfone hardening agent is dissolved in said dimethyl sulfoxide solvent in an amount of about 25% by weight of said solvent.

21. The method of claim 18 wherein said 4,4’-diaminodiphenyl sulfone hardening agent dissolved in said dimethyl sulfoxide solvent is present in said hardenable resin composition in an amount of about 25% by weight of said composition.

22. The method of claim 18 wherein said silane coupling agent is present in said hardenable resin composition in an amount of about 1% by weight of said composition.

23. The method of claim 18 wherein said surfactant is present in said hardenable resin composition in an amount of about 5% by weight of said composition.

24. The method of claim 18 wherein said hydrolyzable ester mixture is present in said hardenable resin composition in an amount in the range of from about 2% by weight of said composition

25. The method of claim 18 wherein said propellant particles are graded sand.

26. The method of claim 18 wherein said water in said gelled liquid fracturing fluid is selected from the group consisting of fresh water and salt water.

27. The method of claim 18 wherein said gelling agent is present in said fracturing fluid in an amount in the range of from about 0.1% to about 1% by weight of water therein.

28. The method of claim 18 wherein said gelled liquid fracturing fluid further comprises a cross-linking agent selected from the group consisting of alkali metal borates, borax, boric acid and compounds capable of releasing multivalent metal ions in aqueous solutions.

29. The method of claim 28 wherein said cross-linking agent is present in said fracturing fluid in an amount in the range of from about 0.01% to about 1% by weight of water therein.

30. The method of claim 28 wherein said gelled liquid fracturing fluid further comprises a delayed viscosity breaker selected from the group consisting of alkali metal and ammonium persulfates which are delayed by being encapsulated in a material which slowly releases said breaker, alkali metal chlorides, alkali metal hypochlorites and calcium hypochlorites.

31. The method of claim 30 wherein said delayed viscosity breaker is present in said fracturing fluid in an amount in the range of from about 1% to about 5% by weight of water therein.

32. A hardenable resin composition for coating propellant particles comprising:

- a hardenable resin comprised of a liquid bisphenol A-epichlorohydrin resin;
- a 4,4’-diaminodiphenyl sulfone hardening agent dissolved in a solvent selected from the group consisting of dimethyl sulfoxide and dimethyl formamide;
- a silane coupling agent; and
- a surfactant for facilitating the coating of the resin on the proppant particles and for causing the resin to flow to the contact points between adjacent resin coated proppant particles.

33. The composition of claim 32 wherein said liquid bisphenol A-epichlorohydrin resin is present in an amount in the range of from about 40% to about 65% by weight of said composition.

34. The composition of claim 32 wherein said 4,4’-diaminodiphenyl sulfone hardening agent is dissolved in said dimethyl sulfoxide or dimethyl formamide solvent in an amount of about 40% by weight of said solvent.

35. The composition of claim 32 wherein said 4,4’-diaminodiphenyl sulfone hardening agent dissolved in said dimethyl sulfoxide or dimethyl formamide solvent is present in an amount in the range of from about 15% to about 50% by weight of said composition.

36. The composition of claim 32 wherein said silane coupling agent is selected from the group consisting of N-2-(aminoethyl)-3-aminopropyltrimethoxysilane, 3-glycidoxypropyltrimethoxysilane and n-beta-(aminoethyl)-gamma-aminopropyl-trimethoxysilane.

37. The composition of claim 32 wherein said silane coupling agent is n-beta-(aminoethyl)-gamma-aminopropyltrimethoxysilane.

38. The composition of claim 32 wherein said silane coupling agent is present in an amount in the range of from about 0.1% to about 3% by weight of said composition.

39. The composition of claim 32 wherein said surfactant for facilitating the coating of said resin on said propellant particles and for causing said resin to flow to the contact points between adjacent resin coated propellant particles is selected from the group consisting of an ethoxylated nonyl phenol phosphate ester, mixtures of one or more cationic surfactants and one or more non-ionic surfactants and a C12-C22 alkyl phosphonate surfactant.

40. The composition of claim 32 wherein said surfactant is comprised of a C12-C22 alkyl phosphate surfactant.

41. The composition of claim 32 wherein said surfactant is present in an amount in the range of from about 0.1% to about 10% by weight of said composition.

42. The composition of claim 32 which further comprises a hydrolyzable ester for breaking gelled fracturing fluid films on said propellant particles.

43. The composition of claim 42 wherein said hydrolyzable ester is selected from the group consisting of a mixture of dimethylglutarate, dimethyladipate and dimethylsuccinate, sorbitol, catechol, dimethyltioate, methyl salicylate, dimethylsuccinate and tertbutylhyperperoxide.

44. The composition of claim 42 wherein said hydrolyzable ester is a mixture of dimethylglutarate, dimethyladipate and dimethylsuccinate.

45. The composition of claim 42 wherein said hydrolyzable ester is present in said hardenable resin composition in an amount in the range of from about 0.1% to about 5%.