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(54) **MODULAR HYDROJETTING TOOL**

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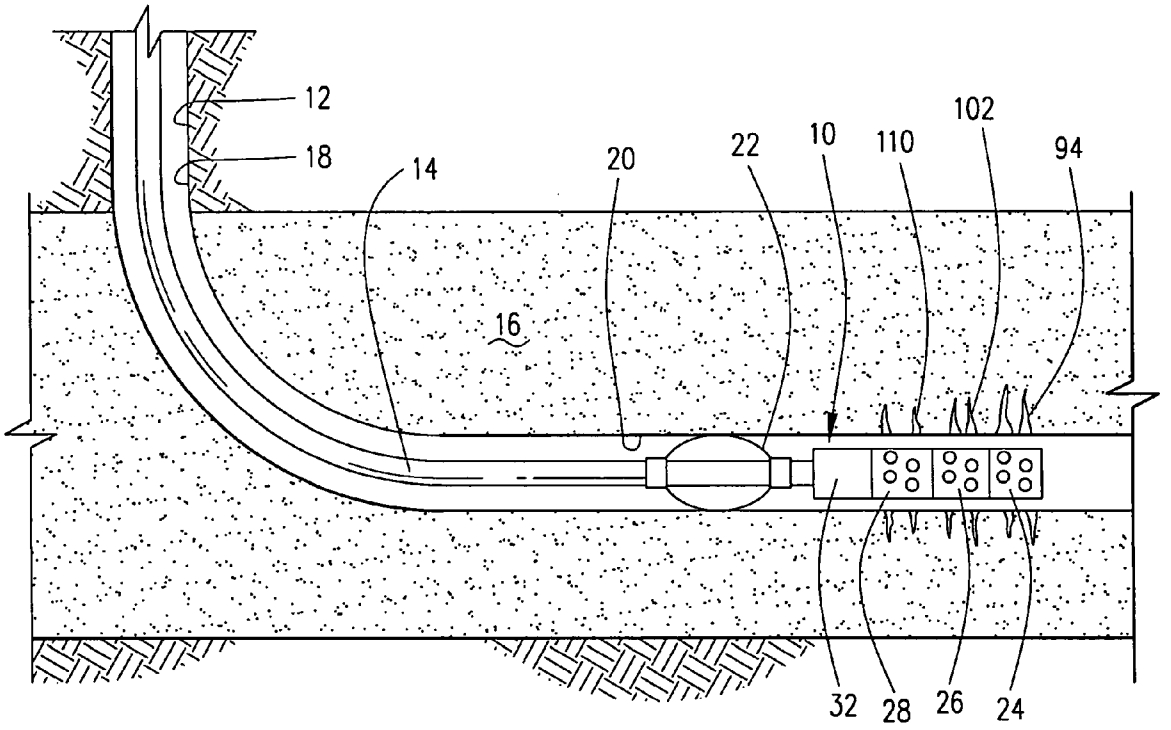
(57) **ABSTRACT**

A modular hydrojetting tool for fracturing well formations. The tool has a plurality of jetting modules. Each jetting module has a plurality of jetting nozzles therein. A sleeve is disposed in each jetting module except the lowermost module, and each sleeve is moveable from a first position covering the jetting nozzles in the corresponding module to a second position covering the jetting nozzles in an adjacent module. Plugs may be pumped into the tool to move each sleeve sequentially, thereby operating the jetting modules sequentially.



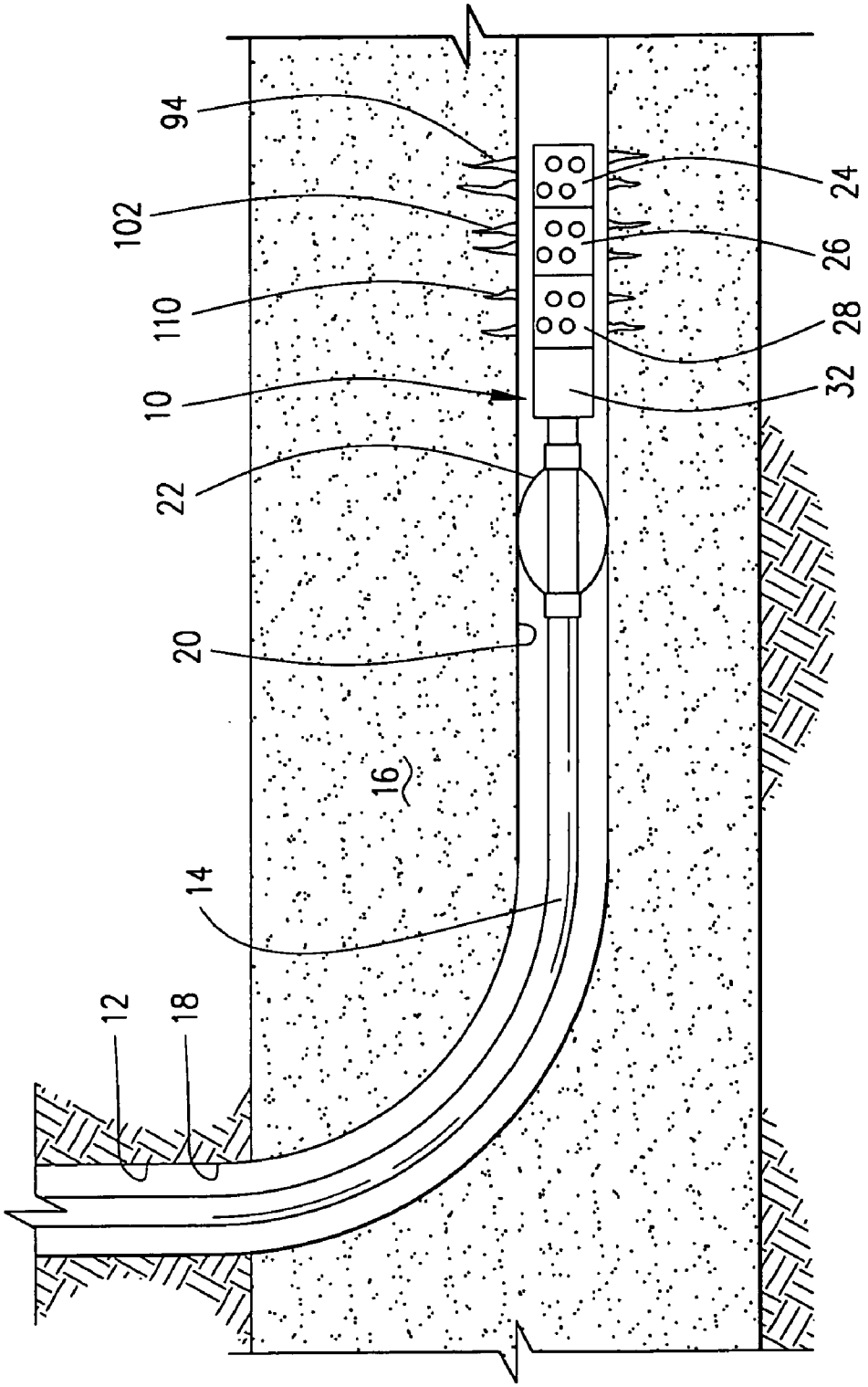


FIG. 1

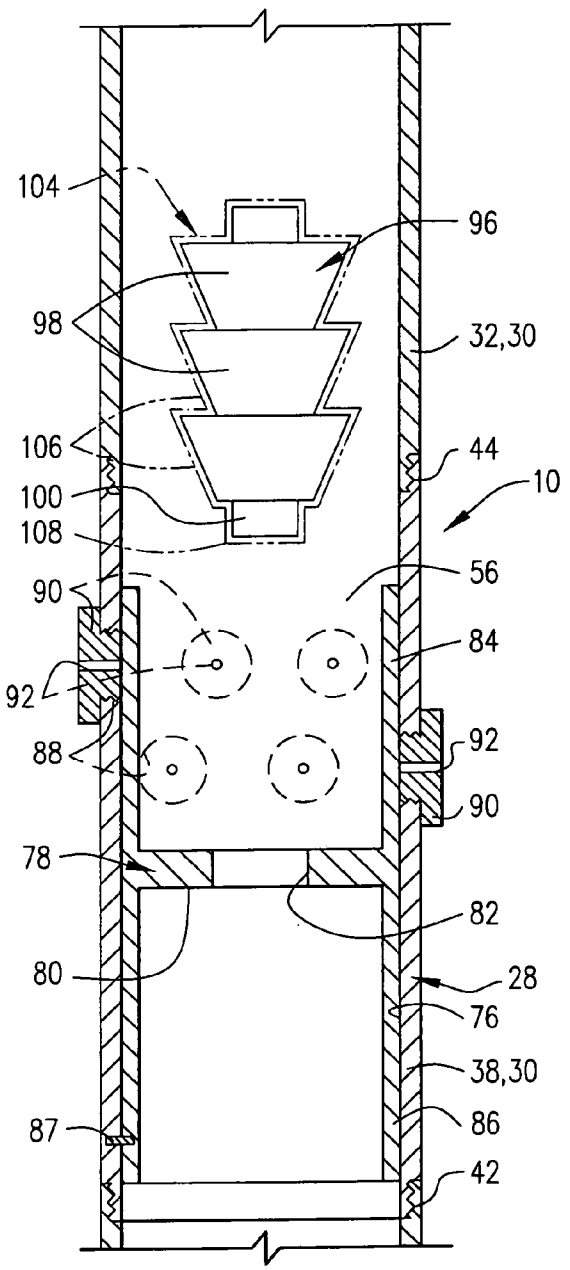

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FIG. 2A

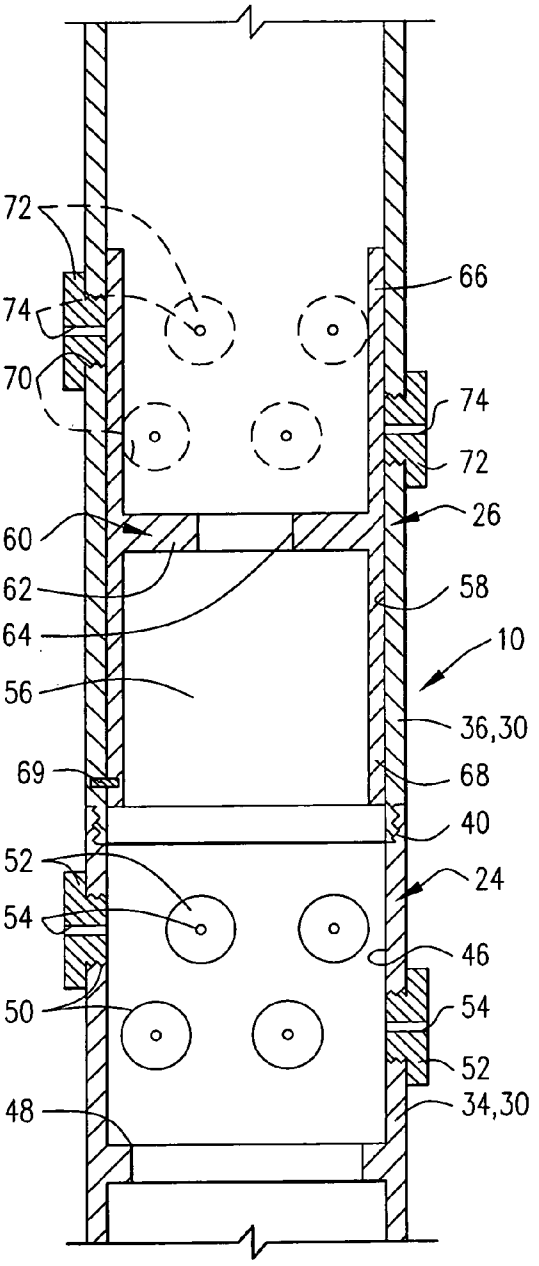
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FIG. 2B

MODULAR HYDROJETTING TOOL

BACKGROUND

[0001] The present invention relates to hydrojetting tools for fracturing oil and gas wells, and more particularly, to a hydrojetting tool with jetting openings which may be sequentially opened during a jetting operation.

[0002] Hydraulic fracturing is often utilized to stimulate the production of hydrocarbons from subterranean formations penetrated by wellbores. In performing hydraulic fracturing treatments, a portion of the formation to be fractured is isolated using conventional packers or the like, and a fracturing fluid is pumped through the wellbore and perforations into the isolated portion of the formation to be stimulated at a rate and pressure such that fractures are formed and extended in the formation. Propping agent is suspended in the fracturing fluid to keep the fractures from closing and thereby provide conductive channels in the formation through which produced fluids can readily flow to the wellbore.

[0003] One method that has been developed for such fracturing is to use a hydrojetting tool having at least one fluid jet forming nozzle. The hydrojetting tool is positioned adjacent to a formation to be fractured, and fluid is then jetted through the nozzle against the formation at a pressure sufficient to form a cavity therein. The high pressure exerted on the formation causes a microfracture to occur. Hydrojetting has been used in cased wellbores as well as uncased ones.

[0004] Hydrojetting has worked well to create a controlled fracture. However, the process is limited in that the method uses a tool that inherently is limited in its ability to deliver large volumes of proppant through the orifices.

[0005] A problem that can arise with hydrojetting is that the jetting nozzles can erode to an extent that they can no longer jet the fluid at a sufficient pressure to cut into the formation. With present hydrojetting tools, the tool must be retrieved from the well and refitted with new jetting nozzles. Obviously, this is a costly and time-consuming procedure. The present invention solves this problem by providing a hydrojetting tool with a series of modules, each module having at least one jetting nozzle therein. The jetting nozzles may be sequentially opened so that a new jetting nozzle is available when it is determined that the previous jetting nozzle has had too much erosion. The tool may be run into the wellbore with as many modules as necessary.

SUMMARY

[0006] The modular hydrojetting tool of the present invention comprises a plurality of jetting modules that can be opened sequentially from the surface when desired. Each module has at least one jetting nozzle therein.

[0007] The invention may be described as a hydrojetting tool for use in a well adjacent to a formation of interest, wherein the tool comprises a plurality of jetting modules, each jetting module having jetting nozzles therein adapted for jetting fluid into the formation The jetting modules may be operated sequentially.

[0008] At least one of the modules has a sleeve therein moveable from a first position covering the jetting nozzles in the one module to a second position covering the jetting nozzles in an adjacent module. A plug may be pumped into engagement with the sleeve for moving it from the first position to the second position. The sleeve preferably comprises an inwardly extending mandrel adapted for engagement by the plug. The plug may be further pumped through the sleeve after moving it from the first position to the second position thereof.

[0009] Stated in another way, the apparatus is a hydrojetting tool comprising a plurality of jetting modules with jetting nozzles therein adapted for jetting fluid into a well formation, and a sleeve slidably disposed in all but one of the jetting modules. Each sleeve has a first position covering the jetting nozzles in the corresponding jetting module and is moveable to a second position uncovering the jetting nozzles in the corresponding jetting module and covering the jetting nozzles in an adjacent jetting module. The sleeves may be moved sequentially such that the jetting modules may be operated sequentially.

[0010] The apparatus may further comprise a plurality of plugs, wherein each plug may be pumped into engagement with a corresponding one of the sleeves for moving the corresponding sleeve from its first position to its second position.

[0011] In the preferred embodiment, each sleeve comprises an upper sleeve portion which covers the jetting nozzles in the corresponding jetting module when the sleeve is in the first position, a lower sleeve portion which covers the jetting nozzles in the adjacent jetting module when the sleeve is in the second position, and an inwardly extending mandrel disposed between the upper and lower sleeve portions and adapted for engagement by the corresponding plug. The mandrels define holes therein, and the holes are progressively larger from a lowermost sleeve to an uppermost sleeve.

[0012] The jetting module not having a sleeve therein is the lowermost jetting module. The lowermost jetting module may have a shoulder therein for limiting movement of the sleeve in the adjacent jetting module.

[0013] Numerous objects and advantages of the present invention will become apparent to those skilled in the art when the following detailed description of the invention is read in conjunction with the drawings illustrating such embodiment.

BRIEF DESCRIPTION OF THE DRAWINGS

[0014] **FIG. 1** illustrates a modular hydrojetting tool of the present invention in position in a tool string in a deviated portion of a well.

[0015] **FIGS. 2A and 2B** show a cross-sectional view of the modular hydrojetting tool.

DESCRIPTION

[0016] Referring now to the drawings, and particularly to **FIG. 1**, a modular hydrojetting tool of the present invention is shown and generally designated by the numeral **10**. Hydrojetting tool **10** is positioned in a wellbore **12** on a tubing string **14**. Wellbore **12** is shown as a deviated wellbore that penetrates a subterranean formation **16**. Wellbore **12** includes a substantially vertical portion **18** which

extends to the surface and a substantially horizontal portion **20** which extends into formation **16**. It will be understood by those skilled in the art that hydrojetting tool **10** may be used in virtually any type of wellbore and is not intended to be limited to use in deviated wells.

[**0017**] Additional tools may be run with hydrojetting tool **10** as desired. For example, but not by way of limitation, a centralizer **22** may be run to keep hydrojetting tool **10** in a central position within wellbore **12**. Other tools could also be run with hydrojetting tool **10** but are not shown for simplicity.

[**0018**] Referring now to **FIGS. 2A and 2B**, the details of hydrojetting tool **10** will be discussed. Hydrojetting tool **10** comprises a plurality of jetting modules. In the illustrated embodiment, there are a first module **24**, a second module **26** and a third module **28**. First module **24** is the lowermost module. Second module **26** is above first module **24**, and third module **28** is above second module **26**. As will be further described herein, any number of modules can be included in hydrojetting tool **10**, and the invention is not intended to be limited to the three shown.

[**0019**] Hydrojetting tool **10** has a housing **30** which includes an upper adapter **32** connected to tubing string **14** in a known manner. Housing **30** also includes a first module housing **34** which is the outer portion of first module **24**, a second module housing **36** which is the outer portion of second module **26**, and a third module housing **38** which is the outer portion of third module **28**. First module housing **34** is attached to second module housing **36** by a threaded connection **40**. Second module housing **36** is attached to third module housing **38** by a threaded connection **42**. Third module housing **38** is attached to upper adapter **32** by threaded connection **44**.

[**0020**] First module housing **34** of first module **24** defines a bore **46** therein with an inwardly extending shoulder **48** at the lower end thereof. Above shoulder **48**, a plurality of openings **50** are defined in first module housing **34**. A first jetting nozzle **52** is disposed in each opening **50**. Each of first jetting nozzles **52** defines an orifice **54** therein. First jetting nozzles **52** may be replaceable.

[**0021**] Hydrojetting tool **10** has a central opening **56** therethrough. In the configuration of hydrojetting tool **10** as it is run into wellbore **12**, first jetting nozzles **52** are in communication with central opening **56**.

[**0022**] Second module housing **36** of second module **26** defines a bore **58** therein. A second module sleeve **60** is slidably disposed in bore **58**. Second module sleeve **60** has an inwardly extending mandrel **62** therein with a hole **64** therethrough. Extending upwardly from mandrel **62** is an upper sleeve portion **66**, and extending downwardly from mandrel **62** is a lower sleeve portion **68**. Second module sleeve **60** is initially held in second module housing **36** by a shear pin **69**.

[**0023**] Above mandrel **62** a plurality of openings **70** are defined in second module housing **36**. A second jetting nozzle **72** is disposed in each opening **70**. Each of second jetting nozzles **72** defines an orifice **74** therein. Second jetting nozzles **72** may be replaceable. In the configuration of hydrojetting tool **10** as it is run into wellbore **12**, second jetting nozzles **72** are covered by upper sleeve portion **66** of second module sleeve **60** so that second jetting nozzles **72** are not in communication with central opening **56**. This is a first position of second module sleeve **60**.

[**0024**] Third module **28** is substantially identical to second module **26**. Third module housing **38** of third module **28** defines a bore **76** therein. A third module sleeve **78** is slidably disposed in bore **76**. Third module sleeve **78** has an inwardly extending mandrel **80** therein with a hole **82** therethrough. Hole **82** in third module sleeve **78** is larger than hole **64** in second module sleeve **60**. Extending upwardly from mandrel **80** is an upper sleeve portion **84**, and extending downwardly from the mandrel **80** is a lower sleeve portion **86**. Third module sleeve **78** is initially held in third module housing **38** by a shear pin **87**.

[**0025**] Above mandrel **80**, a plurality of openings **88** are defined in third module housing **38**. A third jetting nozzle **90** is disposed in each opening **88**. Each of third jetting nozzles **90** defines an orifice **92** therein. Third jetting nozzles **90** may be replaceable. In the configuration of hydrojetting tool **10** as it is run into wellbore **12**, third jetting nozzles **90** are covered by upper sleeve portion **84** of third module sleeve **78** so that third jetting nozzles **90** are not in communication with central opening **56**. This is a first position of third module sleeve **78**.

[**0026**] First, second and third jetting nozzles **52**, **72** and **90** are illustrated as being oriented substantially perpendicular to a central axis of hydrojetting tool **10** and wellbore **12**. However, if so desired, any or all of the first, second and third jetting nozzles **52**, **72** and **90** could be positioned at a different angle so that fractures may be initiated at such angles.

Operation of the Invention

[**0027**] In operation, modular hydrojetting tool **10** is run into wellbore **12** on tubing string **14** in a conventional manner. As already indicated, other tools, such as centralizer **22** may also be run on tubing string **14** as needed. Hydrojetting tool **10** is positioned at the desired location within formation **16**.

[**0028**] As previously discussed herein, hydrojetting tool **10** is initially in a configuration in which first jetting nozzles **52** are open and in communication with central opening **56**, and second and third jetting nozzles **72** and **90** are closed and covered by second and third module sleeves **60** and **78**, respectively, which are in the first positions thereof.

[**0029**] Jetting fluid is pumped down tubing string **14** and jetted out first jetting nozzles **52** to begin initiation of fractures **94** in formation **16** and then propagation of propped fractures. As the fracture propagates, fluid rate is increased and injection via the annulus between tubing string **14** and wellbore **12** is initiated and established. Bemouli's principle allows the hydraulic fracture to remain isolated at the point of the jetting, and proppant fluid is pumped in the flow via tubing string **14** and through first jetting nozzles **52**. This proppant increases the erosion process of first jetting nozzles **52**, and the pressure due to the nozzle diameter starts to decrease and can be detected at the surface.

[**0030**] When the operator determines when or if first jetting nozzles **52** have eroded or "washed" out too much for effective further jetting, a plug **96** is dropped into tubing string **14** and pumped down into hydrojetting tool **10**. Plug

96 has a plurality of wipers 98 to engage the inner surface of tubing string 14 and has a nose 100 on a lower end. Plug 96 is adapted to pass through hole 82 in third module sleeve 78 and to engage mandrel 62 on second module sleeve 60. Nose 100 is adapted to fit in hole 64 in second module sleeve 60. After plug 96 thus engages second module sleeve 60, further pressure applied will force plug 96 to shear shear pin 69 and move second module sleeve 60 downwardly until it contacts shoulder 48 in first module housing 34. This is a second position of second module sleeve 60. When second module sleeve 60 moves to this second position, it covers and closes first jetting nozzles 52 and uncovers and thus opens second jetting nozzles 72 to communication with central opening 56.

[0031] Further jetting with second jetting nozzles 72 may then be carried out to form additional fractures 102.

[0032] When or if it is determined that second jetting nozzles 72 have incurred too much erosion, then another trip plug 104 is dropped into tubing string 14 and pumped down into hydrojetting tool 10. Plug 104 has a plurality of wipers 106 to engage the inner surface of tubing string 14 and has a nose 108 on a lower end. Plug 104 is adapted to engage mandrel 80 on third module sleeve 78. Nose 108 is adapted to fit in hole 82 in third module sleeve 78. After plug 104 thus engages third module sleeve 78, further pressure applied will force plug 104 to shear shear pin 87 and move third module sleeve 78 downwardly until it contacts the upper end of second module sleeve 60. This is a second position of third module sleeve 78. When third module sleeve 78 moves to this second position, it covers and recloses second jetting nozzles 72 and uncovers and thus opens third jetting nozzles 90 to communication with central opening 56.

[0033] Further jetting with third jetting nozzles 90 may then be carried out to form additional fractures 110.

[0034] While three modules have been shown herein for hydrojetting tool 10, those skilled in the art will see that additional modules could also be used as necessary to carry on jetting of formation 16 until the desired amount of fluid is flowed out formation 16. The above-described procedure would simply be repeated for each module. It is important to note that each succeeding trip plug must be larger than the previous one so that the plug and mandrel systems match and the next series of jetting nozzles are opened and used as desired.

[0035] First module housing 34 has been illustrated herein as having central opening 56 continue below shoulder 48 so that fluid can be flowed through hydrojetting tool 10 to any other tools therebelow and also to allow full circulation of fluid through tubing string 14 and hydrojetting tool 10 as required. Plugs 96 and 104 may be configured so that they can be pumped on through hydrojetting tool 10 by the application of additional pressure thereon to provide for such further fluid flow or circulation. If this flow is not necessary, a lower end of first module housing 34 is simply closed.

[0036] It will be seen, therefore, that the modular hydrojetting tool of the present invention is well adapted to carry out the ends and advantages mentioned as well as those inherent therein. While a presently preferred embodiment has been shown for the purposes of this disclosure, numerous changes in the arrangement and construction of the parts and steps in the method of use may be made by those skilled in the art. All such changes are encompassed within the scope and spirit of the appended claims.

What is claimed is:

1. A hydrojetting tool for use in a wellbore, comprising a plurality of jetting modules, wherein:

each jetting module has jetting nozzles therein adapted for jetting fluid into a formation adjacent the wellbore; and

the jetting modules may be operated sequentially.

2. The tool of claim 1 wherein at least one of the jetting modules has a sleeve therein moveable from a first position covering the jetting nozzles in the one jetting module to a second position covering the jetting nozzles in an adjacent jetting module.

3. The tool of claim 2 further comprising a plug which may be pumped into engagement with the sleeve for moving it from the first position to the second position.

4. The tool of claim 3 wherein the sleeve comprises an inwardly extending mandrel adapted for engagement by the plug.

5. The tool of claim 3 wherein the plug may be further pumped through the sleeve after moving the sleeve from the first position to the second position.

6. The tool of claim 1 wherein:

there are at least three jetting modules;

each of the jetting modules except one has a sleeve therein; and

each sleeve is moveable from a first position covering the jetting nozzles in the corresponding jetting module to a second position covering the jetting nozzles in an adjacent jetting module.

7. The tool of claim 6 further comprising a plurality of plugs, wherein each plug is adapted for engagement with a corresponding one of the sleeves for moving the sleeve from its first position to its second position.

8. The tool of claim 7 wherein the plugs may be further pumped through the corresponding sleeve after moving the sleeve from the first position to the second position.

9. The tool of claim 6 wherein the jetting module without a sleeve therein is a lowermost jetting module.

10. The tool of claim 1 wherein the jetting nozzles are replaceable.

11. A hydrojetting tool for use in a wellbore, comprising:

a plurality of jetting modules, wherein each jetting module has jetting nozzles therein adapted for jetting fluid into a formation adjacent the wellbore; and

a sleeve slidably disposed in all but one of the jetting modules, wherein each sleeve has a first position covering the jetting nozzles in the corresponding jetting module and is moveable to a second position uncovering the jetting nozzles in the corresponding jetting module and covering the jetting nozzles in an adjacent jetting module.

12. The tool of claim 11 wherein the sleeves may be moved sequentially such that the jetting modules may be operated sequentially.

13. The tool of claim 11 wherein the sleeves are moved downwardly from the first to second positions thereof.

14. The tool of claim 13 further comprising a plurality of plugs, wherein each plug may be pumped into engagement with a corresponding one of the sleeves for moving the corresponding sleeve from its first position to its second position.

15. The tool of claim 14 wherein each sleeve comprises:

an upper sleeve portion which covers the jetting nozzles in the corresponding jetting module when the sleeve is in the first position;

a lower sleeve portion which covers the jetting nozzles in the adjacent jetting module when the sleeve is in the second position; and

an inwardly extending mandrel disposed between the upper and lower sleeve portions and adapted for engagement by the corresponding plug.

16. The tool of claim 15 wherein the mandrels define holes therein, the holes being progressively larger from a lowermost sleeve to an uppermost sleeve.

17. The tool of claim 14 wherein the plugs may be further pumped through the tool after moving the corresponding sleeve from its first position to its second position.

18. The tool of claim 11 wherein the jetting module not having a sleeve therein is a lowermost jetting module.

19. The tool of claim 18 wherein the lowermost jetting module has a shoulder therein for limiting movement of the sleeve in the adjacent jetting module.

20. The tool of claim 11 wherein the jetting nozzles are replaceable.

21. A hydrojetting tool for use in a wellbore, comprising:

a plurality of jetting modules, wherein each jetting module has jetting nozzles therein adapted for jetting fluid into a formation adjacent the wellbore;

a sleeve slidably disposed in all but one of the jetting modules, wherein each sleeve has a first position covering the jetting nozzles in the corresponding jetting module and is moveable to a second position uncovering the jetting nozzles in the corresponding jetting module and covering the jetting nozzles in an adjacent jetting module; and

a plurality of plugs, wherein each plug is adapted for being pumped into engagement with a corresponding one of the sleeves and thereby moving the corresponding sleeve from its first position to its second position.

22. The tool of claim 21 wherein the sleeves may be engaged and moved sequentially such that the jetting modules may be operated sequentially.

23. The tool of claim 21 wherein the sleeves are moved downwardly from the first to second positions thereof.

24. The tool of claim 21 wherein each sleeve comprises:

an upper sleeve portion which covers the jetting nozzles in the corresponding jetting module when the sleeve is in the first position;

a lower sleeve portion which covers the jetting nozzles in the adjacent jetting module when the sleeve is in the second position; and

an inwardly extending mandrel disposed between the upper and lower sleeve portions and adapted for engagement by the corresponding plug.

25. The tool of claim 24 wherein the mandrels define holes therethrough, the holes being progressively larger from a lowermost sleeve to an uppermost sleeve.

26. The tool of claim 21 wherein the plugs may be further pumped through the tool after moving the corresponding sleeve from the first position to the second position.

27. The tool of claim 21 wherein the jetting module not having a sleeve therein is a lowermost jetting module.

28. The tool of claim 21 wherein the jetting nozzles are replaceable.

29. A method of treating a formation located adjacent a wellbore, comprising the steps of:

providing a tool comprising first and second jetting modules, wherein each jetting module has at least one jetting nozzle therein adapted for jetting fluid into the formation;

positioning the tool adjacent the formation;

pumping fluid to the tool, wherein the fluid is jetted out the at least one jetting nozzle in the first jetting module but not out the at least one jetting nozzle in the second jetting module; and

pumping a plug to the tool, wherein fluid stops being jetted out the at least one jetting nozzle in the first jetting module and starts being jetted out the at least one jetting nozzle in the second jetting module.

* * * * *