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Artificial Comminution as a Substitute for Hydro-Fracking of Shales

Hanish C. Sharma, Kunal Sharma and Mrinal Anand

College of Engineering Studies, University of Petroleum and Energy Studies, Dehradun-248007, Uttarakhand, India

Presenting Author Email Id: *mrinal.anand@stu.upes.ac.in*

Abstract

Shale gas has eme0rged as the power player of the twenty-first century. But like other energy resources, it has its pros and cons as well. Its potentiality to show a boom in energy sector in the coming future has mesmerized the big players, while its environmental impacts are an eye opener for the international authorities. The fundamentals of the shale drilling remain conventional, but the difference is made in its recovery. As for now, the well is drilled vertically and then horizontally till the required distance of shale is reached. All conventional methods of casing and cementing are applied. Then arises the difference that perforations are made as small fissures using mechanical methods. This is sequential to highly pressurized mixture of millions of gallons of water, sand and chemicals that are injected into the target fissures to crack the fissures, open them up through sands and the gas is hence flowed to recover. However on a different note, the same procedure of gas recovery can be carried out using non-conventional method. The energy used from water pressure in hydraulic fracking can be replaced by kinetic energy of high-rate shearing generated by underground explosions that would reduce the rock into fragments and release the gas trapped in it. The process of comminution is seen in faulting zones under the earth as well as humans take advantage of this method to great extent on a daily basis. Shales under high pressure and temperature of actual origin can be tested under laboratory conditions to test the high-rate shearing and its consequences for investigative approach. Hence the application of the explosion method would not see a far future in Shale Industry if worked upon guaranteeing another environment friendly boom in the sector.

Introduction

The extent of porosity in shale rocks range from 5% to 15%, however the permeability hardly ranges from 250 nD to 1000 nD. The extreme low values of permeability restrict the flow of shale gas confining it to the pores. A completely revolutionary method confining to mechanical techniques involving comminution, i.e. fracturing the heavy masses to smaller particles, can be introduced to increase the permeability extent in the shales permitting free flow of gas. A mechanical device with yield strength greater than the Ultimate Compressive Strength (UCS) of shales, ideally cylindrical in shape with its diameter less than the borehole diameter, stretched within the length of the horizontal borehole laid through the reservoir, filled with explosives throughout such that its detonation creates impact pressure greater than the UCS of shales creating fissures through the fractures already mechanically created. This is how the static and dynamic elastic parameters can be mechanically manipulated to play with the anisotropy of shales to fulfill our cause of permeability generation. The above mentioned method can completely overtake the hydraulic fracturing to overcome its limitations.

Experimental Details

As per the requirements of our procedure we need to carry out experiments in laboratory condition to check for the different mechanical properties of the shale formation. The Young's modulus as well as P wave modulus of the shale rock can be inferred which would suggest the compliance of materials to be used for the establishment of our method. Another interesting property called anisotropy of the shales can be exploited to check its dependency on the clay, organic content, shale fabric and maturity of the shales. The rock can be tested for its brittleness or viscoplastic creep ductility to see its dependence on pore space, volume etc. The degree of deformation and the extent to which the impact can propagate with respect to time can be mathematically modeled to reach to the relations that could imply the design of impact along with its intensity. However, the explosives as mentioned in Table No. 1 can be tested under laboratory conditions to inscribe the essentiality of the impact pressure to be generated on the rock. The material for the synthetic sheath used between parts of cylinder for strength has to be checked. Different materials such as steel and alloys can be tested for the formation of a mechanical device (as shown in Figure 1 and Figure 2) to be used for the explosion purposes.

Results and Discussion

The high end anisotropy can be well exploited to create fissures in the shale rock with the help of mechanical tool with the proposed design. The review of different literatures suggests the correlation pertaining to dependency of the degree of anisotropy of shales with directly proportional relation with the clay and kerogen content, shale fabric and maturity. The static and dynamic elastic parameters generally lower down monotonically with the increase in clay and kerogen content. The Young's modulus and Poisson's ratio of the shales that is found to be greater than 0.3 give ultimate analysis of the major elastic properties to be exploited. Viscoplastic creep ductility is the property of the rocks to deform permanently in time bound situations like impact (in our case), refers to its inverse proportionality with the pore space and volume. This derives to the situation of deformation of the rock which shows different characteristics at different angles. If the impact is perpendicular to the bedding plane, the deformation is maximum, however it is minimum in the case of parallel and in the same regard at different angles between the two extremities. This suggests for the impact to be generated nearly perpendicular to the bedding plane in order to get maximum deformations or ruptures in this case of shale rocks, with minimum impact pressure to be applied. Another interesting observation can be made if we consider the formation in the form of stiff and soft alternates, applying pressure perpendicular to the formation gives an isostress curve, parallel to the formation gives an isostrain curve, however irregular pressurization gives intermediate deformation with stress and strain both variable. All the above three conditions are well plotted in the graph shown in Figure 3. This plot builds a relation between elastic properties versus deformational properties.

Pertaining to the physical properties of shale rock we find the following: hardness on Mohr's scale as 3, specific gravity varying between 2.4 to 2.8, and generally grey to black in colour with increasing organic content respectively. Shales are basically composed of clay (60%) in the form of illite, montmorilonite, kaolinite, etc., quartz (30%) as amorphous silica and crystobalite, feldspar (5%), calcite and dolomite (5%), iron oxide (0.5%), organic matter (1%), etc. The formation of shales basically are a result of compaction of mud, silt etc. in environments of low water movement over a geological period of time.

The shales are basically found at a depth of around 7000 to 12000 ft below the earth surface at a high pressure of around 300-500 bars. The temperature of the formation remains around 250-350 ^{o}F. These extreme conditions imply to the extreme techniques to fracture the shales. Generating above conditions in the laboratory we can check the Uniaxial Compressive Strength and apply Point Load Test on the shales to confirm the kind of material to be used as for the fracturing host. The yield strength of the host material should be greater than the UCS of the shales (i.e. around 200 MPa) in order to make proper fractures. List of such materials as mentioned in Table 2 can be tested for the same.

The instrument namely KMH Fracture Host basically consists of a cylindrical outer covering made up of a material like high carbon steel or some other (as per laboratory testing of materials) with yield strength greater than 200 MPa that can also persist the impact of the explosives. The diameter of the cylinder is less than the borehole diameter. This cylinder is horizontally split into two halves and connected through an expandable synthetic sheath with its Ultimate Strength greater than the strength generated through the explosives. The hollow part of the cylinder is filled with explosives (as per Table 1) pertaining to laboratory testing of the same. The explosives are connected to a detonation chamber with cable wire at its center for the operation of the host. Piercers are attached to the external body of the cylinder as shown in Figure 1 and Figure 2.

The host basically works on the principle of impact pressure created by the explosives laid throughout the length of the cylinder. The entire instrument is controlled through the cable wire extending from the instrument to the surface. After the drilled borehole reaches the shale reservoir, the explosives inside the host are detonated which causes sudden impact on the steel covering marking its stretch on both the sides controlled by the synthetic sheath. Thus, the created impact pressure causes the piercers on the outer surface to strike the shales and create fractures in accordance to the parameters that we need to control. These parameters of control like the length of fracture, width of fracture, intensity of impact on the formation etc. can be tested in laboratory before the application of the above mentioned phenomenon.

As per our conventional method of drilling for shale gas reservoirs, we initially go vertical and after certain depth we go horizontal through the shale reservoirs. The borehole diameter basically varies between 8-12 inches All the early phenomena of drilling is applied before the introduction of water in the hole. The water and its pressurized nature are substituted by the introduction of KMH fracture host, i.e. made to travel to the end of the length of the reservoir rock varying subsequently for different reservoirs. The host is made to withstand at the center with the help of strands through the length of the reservoir. Now, the detonation is done and fractures are created as per the above mentioned working procedure of the host.

Now, after the fractures are created, issue lies in maintaining them. A pressurized introduction of solid particles mixed with gases (colloidal to particulate) in which the solid particles are made to carry zeta potential with them to avoid coagulation in the path. As and when these fractures are created by the host, these solid particles carrying zeta potential get settled into the opening of the fractures, substituting the sand and propend in case of hydraulic fracturing. Once we are done with the above mentioned procedure, we can withdraw the entire arrangement of host as well as pressurized gases. Consequently we can proceed to well activation and all other conventional methods of flow of gas to the surface and its collection.

For developing nations like Indian subcontinent where shale can be a power player but due to its conventional method of extraction, it does not comply to intrude into its economy. The amount of water used and its condition after the use, harasses the environment leading to global problems, even for the shale power players. So a substitute mechanical method of extraction as discussed above, can be quite worthy in compliance to global shale future.

Conclusion

The viability of the KMH fracture host as per the static and dynamic elastic parameters and high degree of anisotropy of shales can be visualized to be quite surgent for global shale future. The depth pressure and temperature of the shale gas formation conveniently complies with the technique of extraction that we propose. However all the mechanical and physical parameters of shale as well as that of the materials used in the host have to be tested in laboratory and mathematically modelled before its application in industry.

References

1. Bažant, Zdeněk P. and Ferhun C. Caner. "*Comminution of solids caused by kinetic energy of high shear strain rate, with implications for impact, shock, and shale fracturing*". 2013.
2. Cooper, Paul W. (1996). *Explosives Engineering*, New York: Wiley-VCH.
3. Sone, Hiroki and Mark D. Zoback. *Mechanical properties of shale-gas reservoir rocks. Geophysics. Vol.78, No.5.* 2013.
4. Anikoh, G. A. and B. M. Olaleye. *Estimation of Strength properties of Shales From some of its Physical Properties using Developed Mathematical Models.* IJES. Vol 2. Issue 4. Pages 1-5.
5. Walls, Jole D. and Elizabeth Diaz. *Relationship to shale prorsity-permeability trends to pore type and organic content.* Denver, CO. October 2011.
6. Material Data Book. Cambridge University Engineering Department. Ed. 2003.

List of Tables

Table 1. List of Explosives with specifications

Explosive class	Explosive class	Explosive class	Explosive class velocity (m/s)	Explosive class(g/cm^3)
Aromatic	1,3,5-trinitrobenzene	TNB	7,450	1.6
Aromatic	4,4'-Dinitro-3,3'-diazenofuroxan	DDF	10,000	2.02
Aromatic	Trinitrotoluene	TNT	6,900	1.6
Aromatic	Triaminotrinitrobenzene	TATB	7,350	1.8
Aliphatic	Methyl nitrate		6,300	1.21
Aliphatic	Nitroglycol	EGDN	7,300	1.48
Aliphatic	Nitroglycerine	NG	7,700	1.59
Aliphatic	Mannitol hexanitrate	MHN	8,260	1.73
Aliphatic	Tetranitroglycoluril	Sorguyl	9,150	1.95
Aliphatic	Octanitrocubane	ONC	10,100	2
Aliphatic	Urea nitrate	UN	4,700	1.59
Aliphatic	Acetone peroxide	AP or TATP	5,300	1.18
Aliphatic	Hexamethylene triperoxide diamine	HMTD	4,500	0.88
Inorganic	Ammonium nitrate	AN	5,270	1.3

Table 2. Yield Stress of different materials

		σ_y (MPa)	σ_{ts} (MPa)
Metals			
Ferrous	Cast Irons	215 - 790	350 - 1000
	High Carbon Steels	400 - 1155	550 - 1640
	Medium Carbon Steels	305 - 900	410 - 1200
	Low Carbon Steels	250 - 395	345 - 580
	Low Alloy Steels	400 - 1100	460 - 1200
	Stainless Steels	170 - 1000	480 - 2240
Non-ferrous	Aluminium Alloys	30 - 500	58 - 550
	Copper Alloys	30 - 500	100 - 550
	Lead Alloys	8 - 14	12 - 20
	Magnesium Alloys	70 - 400	185 - 475
	Nickel Alloys	70 - 1100	345 - 1200
	Titanium Alloys	250 - 1245	300 - 1625
	Zinc Alloys	80 - 450	135 - 520

Figure 1. <u>Labelled Diagram for suggested KMH Fracture Host</u>

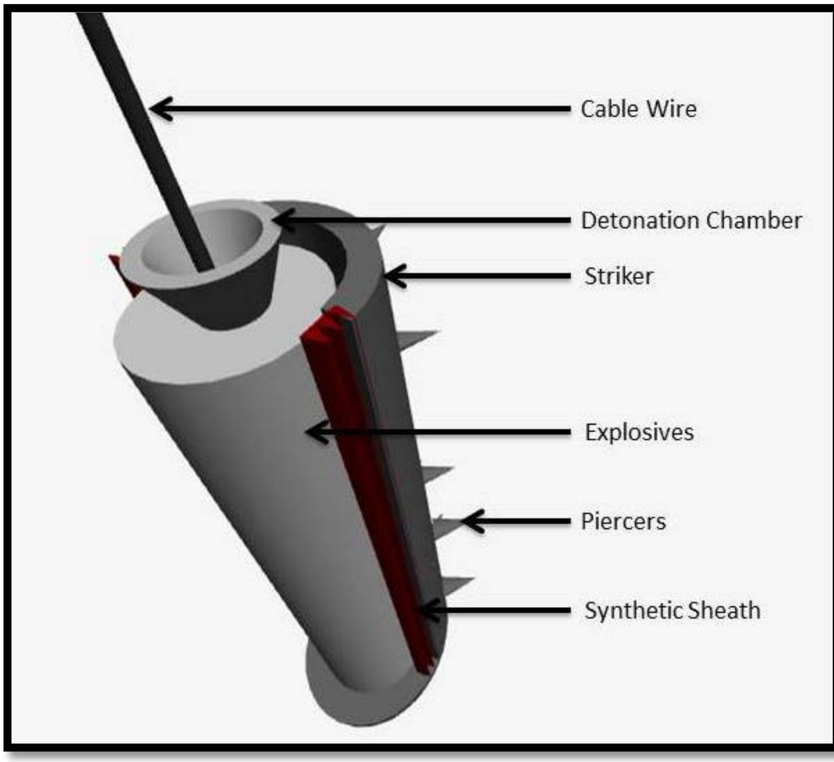

Figure 2. <u>Diagrams depicting KMH Fracture Host in different views</u>

Figure 3. <u>Relation between Young's Modulus and Kerogen Volume of Shales</u>

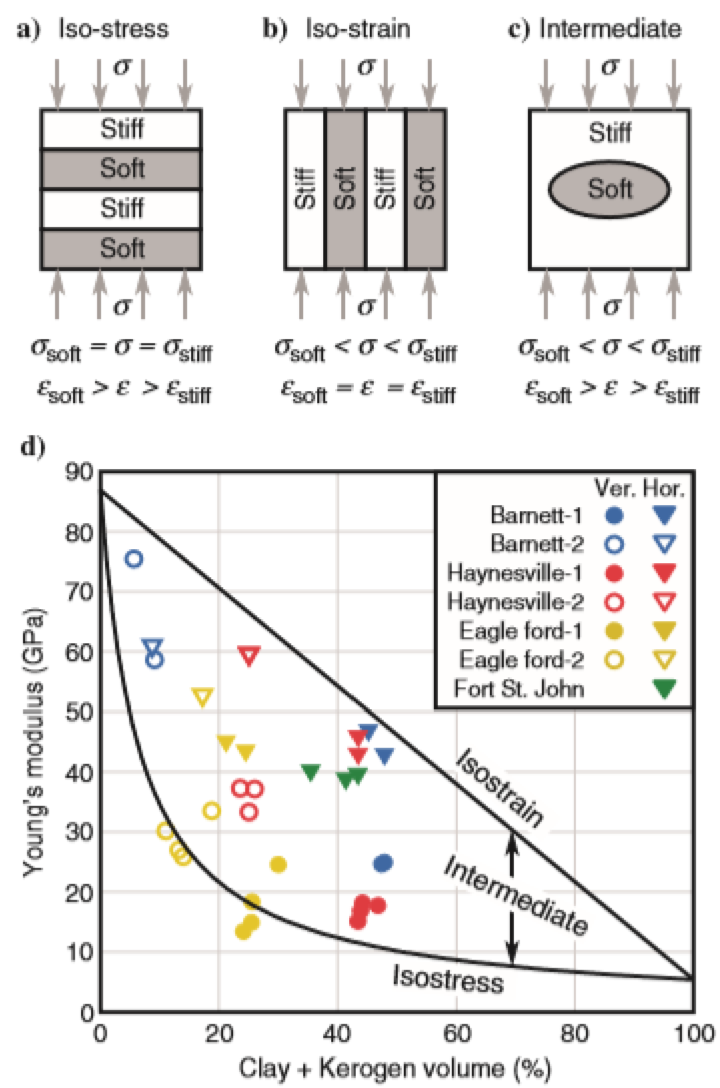

Figure 8. (a) Schematic of a layered shale model loaded perpendicular to the bedding, representing the isostress condition. (b) Schematic of a layered shale models loaded parallel to the bedding, representing the isostrain condition. (c) One example of shale models that could result in an intermediate state between isostress and isostrain conditions. (d) Laboratory Young's modulus data plotted against the sum of clay and kerogen volume, together with the Voigt and Reuss bounds calculated assuming $E_{soft} = 5.4$ GPa, $E_{stiff} = 86.9$ GPa.