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Influences of proppant on fracture making ability and fracture conductivity in coalbed methane

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Abstract: The fracture conductivity is one of the most important factors affecting coalbed methane production. The size of proppant, the number of proppant placement layers and the embedment all affect the permeability, thus affecting the fracture conductivity. However, exist research ignored the influence of fracture width. Therefore, according to the formula for calculating the fracture width of acid fracturing, the formula for calculating the fracture width is deduced. According to Carman-Kozeny formula, the fracture conductivity calculation models with and without embedment are respectively established. Through conducting the flow experiment on the coal core, the influence of the number of placement layers and embedment degree on the fracture conductivity is analyzed. The results show that the larger the particle size of proppant is, the more layers are laid, and the wider the fracture width is, thus the greater the fracture conductivity is. The smaller the embedment degree of proppant, the greater the fracture conductivity.

1. Introduction

The hydraulic fracturing technology is to form fractures with strong fracture conductivity, which is a stimulation technology in oil and gas reservoirs. In the fracturing process, the choice of proppant has great influence on the fracture conductivity. Through experimental researches, Guo^[1] believes that compared with sandstone formation fractures, proppant embedment is more harmful to the conductivity of coal seam fractures. Zou^[2] tested the long-term fracture conductivity of hydraulic fractures in middle and high rank coal and rock through experiments, and considered the damage of coal powder to the fracture conductivity. Through experimental researches, Dong^[3] believes that proppant with lower crushing rate has higher conductivity, and higher concentration rate of particle size distribution can obtain higher fracture conductivity. However, the influence of the fracture width is neglected in these researches. Therefore, according to the average fracture width formula, the authors derive the relationship between fracture width and proppant performance. The fracture width is affected by proppant performance, and the two have a certain linear relationship. According to Carman-Kozeny formula, diversion calculation models with and without embedment are established respectively.



2. Establishment of model

The proppants are laid layer by layer, and the number of proppants laid on each layer is equal ^[4]. Therefore, the total number of proppant placements can be obtained by following equation:

$$N = \left[n \left(\frac{H - 2R}{2R\sqrt{3}/2} + 1 \right)_{int} - A \right] \left(\frac{L}{2R} \right)_{int}$$

2.1. The calculation model without considering embedment

According to the calculation formula of average fracture width ^[5]

$$w = \frac{xV}{2(1 - \varphi)HL}$$

According to Blake-Kozeny equation ^[6] the permeability is

$$K_f = \frac{2R^2 \left(LHw - N \frac{4\pi R^3}{3} \right)^3}{75LHw \left(N \frac{4\pi R^3}{3} \right)^2}$$

According to Carman-Kozeny formula ^[7] the fracture conductivity is

$$K_f w = \frac{2R^2 (N\pi R^3 8/3) \left(LHw - N \frac{4\pi R^3}{3} \right)^3}{75w \left[LHN \frac{4\pi R^3}{3} \right]^2}$$

2.2. The calculation model with considering embedment

In the early stage of fracturing in coalbed methane reservoir, after proppant is injected, proppant has certain propping effect on the fracture, forming sand-filled fracture ^[8] in the formation. According to Carman-Kozeny formula, the fracture conductivity is

$$K_f w_{h0} = \frac{2R^2 (N\pi R^3 8/3 - 2LHh) \left(LHw_{h0} - N \frac{4\pi R^3}{3} + V_E \right)^3}{75w_{h0} \left[LH \left(N \frac{4\pi R^3}{3} - V_E \right) \right]^2}$$

3. The factors affecting fracture width and fracture conductivity

In the experiment, the national invention patent equipment was used for Lanzhou quartz sand to do flow experiment. Firstly, a coal core was drilled from the coal sample in block A of Xinjiang which is shown in Figure 1. Then, the conductivity is tested with quartz sand of 2 particle sizes (20/40 mesh, 30/50 mesh) and 10 kinds of layers.



Figure 1. Core (cylinder) drilled from coal seam in block A of Xinjiang

3.1. The influence of fracture width and conductivity without considering embedment

Without considering embedment, the model selects proppants with different sizes of particle, calculates the fracture width, porosity and fracture conductivity under different layers. Then, the relationship between the number of proppant placement layers, particle sizes and fracture width under the same closure pressure (17.25MPa) is shown in Figure 2.

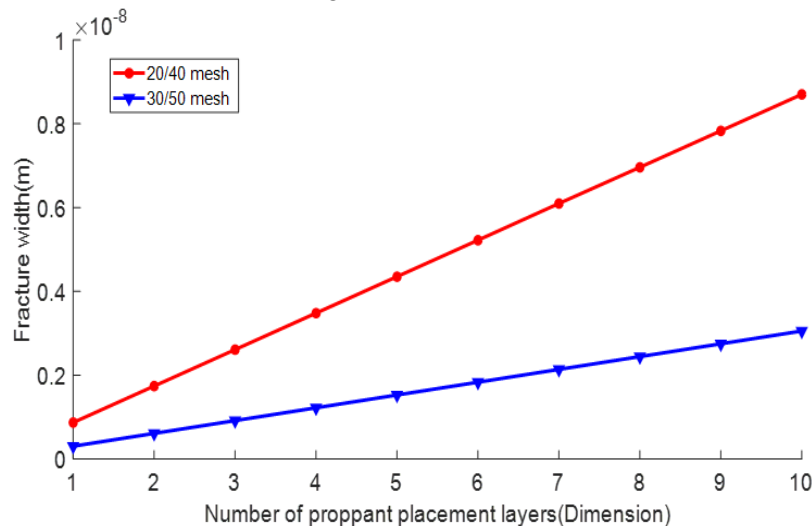


Figure 2. Relationship between number of proppant placement layers and fracture width

Without considering embedment, it can be seen from Fig. 3 that under the condition that the particle size of proppant is not changed. With the increase of proppant concentration, the conductivity is correspondingly enhanced. Therefore, under the condition of the same number of proppant layers, with the increase of proppant particle sizes, the fracture conductivity will be enhanced accordingly. Therefore, in the process of CBM development, it is possible to increase the fracture conductivity of fractures by appropriately increasing the number of proppant layers and proppant particle size, so as to improve the CBM production.

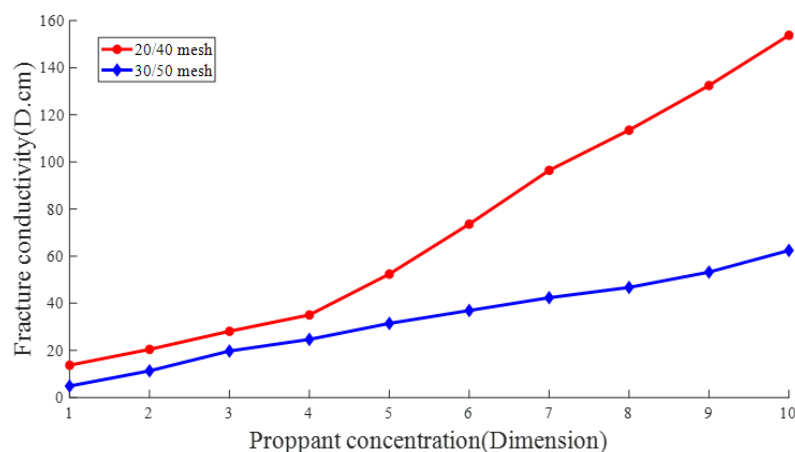


Figure 3. Effects of proppant concentration on fracture conductivity

3.2. Considering the influence of embedment on fracture conductivity

Considering the embedment of proppant, it can be seen from fig. 4 that when the particle size of proppant is unchanged, the fracture conductivity is decreased with the increase of embedment degree. When the embedment depth of proppant is constant, the fracture conductivity increases with the increase of proppant particle size.

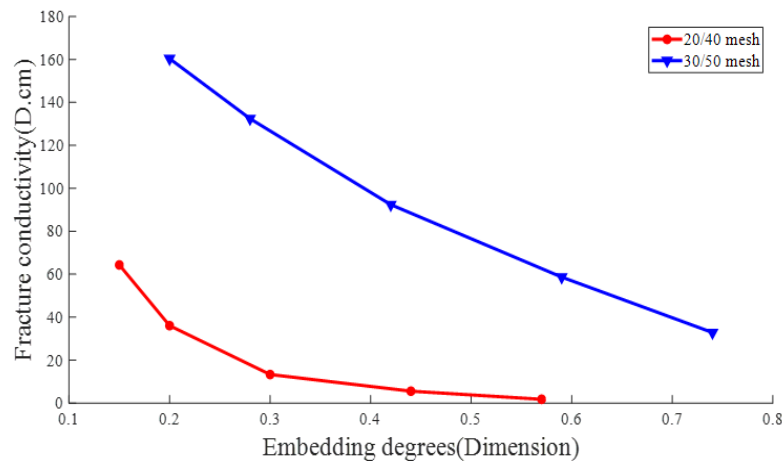


Figure 4. Influences of embedment degrees on fracture conductivity

4. Conclusions

(1) With the number of proppant layers unchanged, the fracture width increases with the increase of proppant particle size.

(2) Increasing the particle size and the number of layers of proppant can appropriately increase the width of the fracture, thus improve the fracture conductivity.

(3) When the particle size of proppant is constant, the fracture width becomes narrower with the increase of embedment degree, thus the fracture conductivity is decreased.

Nomenclature

N	The total number of proppant placement, dimensionless
H	Coal seam height, m
L	Coal seam length, m
R	The radius of proppant, m
n	The number of proppant placement layers, dimensionless
ϕ	Porosity, dimensionless
w_o	Original fracture width, m
h	Embedment depth, m
w_{h0}	The fracture width of embedment depth, m
X	Acid solubility, dimensionless
V	The volume of acid consumed in acid fracturing, m^3
V_E	The volume of proppant embedded in h, m^3
ϕ_h	The porosity of proppant embedded in h, dimensionless
K_f	The permeability of proppant embedded in h, D

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