# ALGORITHM FOR GEOMETRY CALCULATION OF HYDRAULIC FRACTURES USING PROGRAMMING LANGUAGE PYTHON

**P. Baffuor, V.V. Soloviev**
Scientific advisor - professor P.N. Zyatikov
***National Research Tomsk Polytechnic University Tomsk, Russia***

Currently, among the effective methods for increasing the productivity of both injection and producing oil and gas wells, the most important role is played by hydraulic fracturing. To increase the flow rate of the oil reservoirs, the technology of crack formation is applied. There are many different models that describe the characteristics and behavior of a hydraulic fractures.

Hydraulic Fractures are created when hydraulic fluids (pressurized) which are mostly viscous are pumped into the wellbore creating cracks which are characterized by their width, length and height. Hydraulic fractures are a class of tensile fracture propagating in rocks under pre-existing compressive stress in response to the injection or release of pressurized fluid [1]

**Purpose of the work**-Write an algorithm using programming language Python that will help calculate the width of hydraulic fractures using formulas of 2D models PKN and KGB.

Knowing the target length of the fracture and assuming that the half-length ($h_f$), plain strain modulus (E′), rate of injection ($q_i$), viscosity (μ) of injected fluid. The pumping time, $t_e$, can then be determined using the combination of a width equation and material balance. The injection rate however, refers to the slurry (not clean fluid) injected into one wing.[2]

**Tasks of this research**- The Algorithm tackles the following areas:

- Calculation of the wellbore width at the end of pumping from the PKN width equation
- Conversion of wellbore width into average width
- Calculation of injected volume:
- Calculation of Injected volume $V_i$ and fluid efficiency $\eta_e$.

**Basic Types of Fracture Geometry -** There are many analytical and numerical models in literature for estimating fracture sizes and propagation. These models were developed to calculate the fracture geometry, especially the width, for a specified length and flow rate. They ensure that fracture width is sufficient for proppant entry.[3] These include two-dimensional, three-dimensional and pseudo-three-dimensional (Yang 2011). For design purposes, an approximate description of the geometry of the cracks should be simple models that predict the length and average width of the crack at the end of the fluid injection, such as the 2D models of PKN and KGD. The fracture geometry is actually more complex than the simple one described in these models and is determined by many parameters related to rock mechanics, internal stresses, and used fluids (Warpinski 1989). However, these models are widely used in industry and are widely accepted as an acceptable approximation for estimating fracture sizes.

The KGD and PKN models, apply to only fully confined fractures, and only differ in the assumption: their conversions from three-dimensional (3D) solids and fracture mechanics problem into a two-dimensional (2D) (i.e., plane strain) problems.

**KGD MODEL FRACTURE PROPAGATION**

**Assumptions:**

i. The formation is an infinite, homogeneous, isotropic, linear elastic medium characterized by Young's modulus E, Poisson's ratio ν and toughen $K_{Ic}$
ii. Fracture height significantly exceeds its total length 2L ($2X_f$) and the influence of the upper and lower boundaries can be neglected.
iii. The horizontal sections of the crack are the same and to use the two-dimensional statement of the problem of elasticity when describing rock deformation and its destruction.

Fracture width according to KGD is calculated by the formula below

$$w_w = \left(\frac{336}{\pi}\right)^{1/4} \left(\frac{\mu q_i x_f^2}{E' h_f}\right)^{1/4} = 3,22\left(\frac{\mu q_i x_f^2}{E' h_f}\right)^{1/4} \quad (1)$$

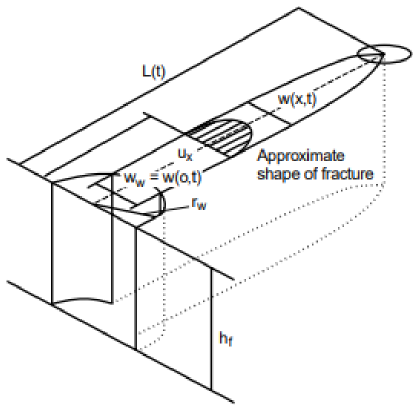


***Fig. 1- KGD geometry for 2D fracture [6]***

### PKN MODEL FRACTURE PROPAGATION

**Assumptions:**

The PKN model takes the shape of an elliptical fracture where its height is constant and the fracture length $(x)$ is much larger than the fracture width $(w_0\,(x))$.Perkins and Kern developed their model for non-Newtonian fluids and included turbulent flow, however the fluid flow rate is assumed to be governed by the basic equation for flow of a Newtonian fluid in an elliptical section (Lamb, 1932):

$$\frac{dp}{dx} = \frac{-64q\mu}{\pi h_f w^3} \quad (2); \quad w(x) = 3\left[\frac{\mu q_i (L-x)}{E'}\right]^{1/4} \quad (3); \; w_{w,o} = 3.27\left(\frac{\mu q_i x_f}{E'}\right)^{1/4} \quad (4)$$

Perkins-Kern width equation (4) shows the influence of the rate of injection, viscosity and the plain strain modulus, if length is known. Average width (5) and injected volume (6) are calculated as

$$\overline{w_e} =, \gamma w_{w,o} = 0.628 w_{w,o}. \quad (5); \quad V_i = q_i t_e \quad (6)$$

Fluid efficiency however is calculated using formula: $\eta_e = \frac{h_f x_f \overline{w_e}}{V_i}$ (7)

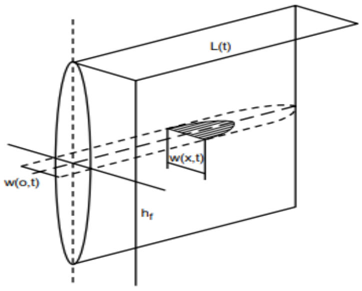


***Fig. 2- PKN geometry for 2D fracture [4]***

### PKN WIDTH ALGORITHMS

1. Wellbore width at the end of pumping

```
def main():
    viscosity = get_user_value("what is the viscosity? ")
    injectionrate = get_user_value("what is the one wing injection rate? ")
    halflength = get_user_value("what is the half length of the fracture? ")
    psm = get_user_value("what is the Plane strain modulus? ")
    top_part = viscosity * injectionrate * halflength
    bracket = top_part / psm
    results = 3.27 * (bracket ** 0.25)
    roundup = str(round(results,2))
    print(">>>>>>>>>>")
    print("The wellbore width at the end of pumping from PKN is " + roundup)



def get_user_value(question):
    value_state=False
    while not value_state:
        try:
            value=input(question)
            result=float(value)
            value_state=True
        except:
            print("Enter number or decimal")
            print(".......")
    return result


if __name__ == "__main__":
```

```
def main():
    fracture_width = get_user_value("What is the fracture width? ")
    average_width = 0.628*fracture_width
    result = round(average_width,2)

    print("")
    print("The average width is " + str(result))

def get_user_value(question):
    value_state=False
    while not value_state:
        try:
            value=input(question)
            result=float(value)
            value_state=True
        except:
            print("Enter number or decimal")
            print(".......")
    return result

if __name__ == '__main__':
    main()
```

2. Average width
3. Calculate the pumped volume and the Efficiency (utilization factor) of the liquid (when using $V_i$ from (6) or when $V_i$ is already known)**.**

```
from os import system, name


def main():
    # Start screen
    start()


def start():...


def check_quit(option):...


def clear_screen():...


# Option is a required parameter, old_result is optional
def do_chosen_calculation(option, old_result=0):...


def get_continuity(old_result=0):...


def get_user_option(question):...


def get_user_value(question):...
```

References


1. Detournay E. Mechanics of hydraulic fractures //Annual Review of Fluid Mechanics. – 2016. – Т. 48. – С. 311-339.
2. Economides M., Oligney R., Valkó P. Unified fracture design: bridging the gap between theory and practice. – Orsa Press, 2002.
3. Economides M. J. et al. Reservoir stimulation. – Englewood Cliffs, NJ : Prentice Hall, 1989. – Т. 2.