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# Estimation of Fracture Length as a Mechanical Property in Hydrofraturing Technique using an Experimental Setup

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## ABSTRACT

A hydro-mechanical approach is developed to investigate progressive fracture damage study with flow behavior in PMMA sample. A series of experiments are conducted to replicate the field work of hydrofraturing process. The PMMA (poly methyl methacrylate) specimens have been performed to simulate to fracture developments that are similar to hydrofraturing process. These Fractures are mechanical breaks in rocks involving discontinuities in displacement across surfaces or narrow zones. The Micro mechanical factor which influences the new crack and porosity generation is heavily influenced by the high pressure, temperature and injection hole diameter on the PMMA sample. This combined technique of Pressure (N/mm$^2$), Temperature (ºC) and Injection hole diameter (mm) are robust and yields consistent in fracture length (mm) development during all the series of experiments are conducted. The fracture propagation can be easily visualized through the PMMA samples. The maximum fracture length observed as 580mm.

**Keywords:** *Hydro mechanical; Hydro fracturing; Fracture length*

## 1. INTRODUCTION

The hydro fracturing technique has been widely used for the stimulation of petroleum and geothermal reservoirs and also acts to increase bore hole yield by injecting high pressure water into a bore hole to create and enlarge fractures in the surrounding rock. It does not increase the storativity of the aquifer but effectively widen the influence of the bore hole so that it draws water from a greater area of storage. This technique involves pumping a fluid under pressure into a borehole. This pressurized fluid introduced into the borehole produces stress concentration in the surrounding rock causing the development of fractures [1]. Other applications of hydraulic fracturing have been recently found in geotechnical engineering for ground reinforcement and in environmental engineering for solid waste disposal. Hydraulic fractures induced by fluid pressurized inside a solid host material also occur in nature as joints [2]. Because of the heterogeneity of the material properties, rock structure and in situ stress state, the hydraulic fracturing process is highly complex [3]. A common difficulty in the hydraulic fracturing process in the real time is in observation and measurement of the fractures that develop beneath the earth. Generally, the induced fracture geometry is measured by cutting the sample after the test [4] [5] [6] or by using an acoustic monitoring system [7] [8]. This method gives valuable results but limitations are there. The final results are observed by cutting the samples after the test. The resolution of the acoustic method is currently insufficient to capture details of the fracture propagation process. As a result, laboratory experiments on hydraulic fracturing in transparent materials have also been performed. These studies allowed the visualization in real time of the developing geometry of the fracture [9] [10] and the direction of fracture propagation [11] [12] [13]. Commonly used transparent geomaterial analogues for fracturing are poly methyl methacrylate (PMMA, acrylic) [14] [15]. In this Research paper, a laboratory technique is introduced to produce hydraulic fractures as like as the field applications. The Fracture behavior is hard to predict because the relationship between stress and permeability is complex and highly dependent on pressure, temperature and injection hole diameter. The resulting fractures can be used to analysis the basis of hydraulic fracture propagation, the fracture occurred during the compression, flow of fluids in fractures and fracture networks are depends on the mechanical effects.

## 2. EXPERIMENTAL WORK

### 2.1 Fabricating the Experimental Set Up

The experimental set up [Fig. 1] consists of a container for storing the fluid, a commercially available feed pump to feed pressurized fluid to the inner casing pipe provided in the PMMA test sample. The 20 nos. of PMMA test samples were prepared for the test. The PMMA test sample has a length of 300mm and outside diameter of 150mm. The inner casing pipe made up of stain less steel and inner diameter was 6 to 10 mm. The applied pressure can be varied manually by adjusting the two control valves provided in the experimental setup in the range of 4 to 8 N/mm$^{2}$. Before starting the experiment, the required pressure applied in to casing pipe is to be ensured by adjusting the flow control valves. A separate by pass line is provided in the experimental setup for achieving the required pressure for the same. A 555 timer IC is provided for feed pump to control the pressurized fluid rate with respect to the time, say 5 sec to 15 mins. The PMMA test sample is placed over the heater for heating purpose in the range of 40 to 60ºC. The heater control unit is made up of Nichrome heater having a capacity of 400W. The Dimmersat is 0 - 2A, Single phase, open type and it is provided for varying the input to the heater and measurement of input is carried out by a voltmeter and ammeter. The Voltmeter – Digital range is 0 to 200V AC. The Ammeter digital range is 0 to 2A AC, The temperature indicator is digital with range of 0 to 199.9ºC. The electrical supply for the experimental setup is AC single phase, 230V earthed stabilized current. By varying the Dimmerstat, adjust the heat input at desired value for desired temperature on the PMMA sample. The commercially available chromium, aluminum thermocouples are embedded to the PMMA test sample for temperature measurement through a temperature gauge. The experimental table and Stand were made up of MS square hollow pipe and angle. The pressure applied in the range of 4 to 8 N/mm$^{2}$ to the casing pipe, the temperature range for the study is 40ºC to 60ºC and the casing pipe diameter vary from 6 mm to 10mm.

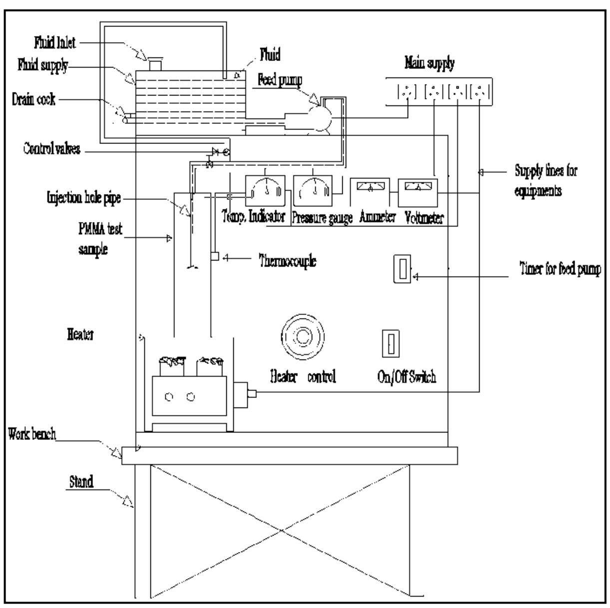


**Fig.1. Experimental set up for Hydrofraturing process**

## 2.2 Finding the Limits of the Experiments Test Parameters

From the literature, the predominant factors that have a greater influence on the Fracture rate of Hydro fracturing process had been identified. They were: (i) Pressure applied in N/mm$^{2}$ (ii) Temperature in ºC (iii) Injection hole diameter in mm. Large numbers of trial experiments were conducted to identify the feasible testing conditions for obtaining the Fracture length of Hydro fracturing process. The following inferences were obtained [Table-1]:

a. Based on the field trials the pressure applied is limited to 4 to 8 N/mm$^{2}$.

b. From the literature survey, the temperature and the injection hole diameter is limited to the range of 40ºC to 60ºC and 6 to 10 mm respectively.

c. Further the Maximum with stand temperature of the PMMA samples is to be Less than 100ºC, hence the temperature range is fixed to 40 to 60 ºC only.

**Table 1. Range for the experiments**

| S. No | Factors | Unit | Range for the experiments | | | | |
|---|---|---|---|---|---|---|---|
| 1 | Pressure applied | N/mm$^{2}$ | 4 | 5 | 6 | 7 | 8 |
| 2 | Temperature | ºC | 40 | 45 | 50 | 55 | 60 |
| 3 | Injection hole diameter | mm | 6 | 7 | 8 | 9 | 10 |

## 3. RESULTS AND DISCUSSION

The table [2] shows the 20 experimental results in which the results shows the Fracture length in mm obtained from at different Pressure in N/mm$^{2}$, Temperature in ºC, Injection hole diameter in mm. At every Pressure and Temperature, Injection hole diameter the PMMA test sample usually exhibited a Fracture length in the range of minimum of 210mm to 580 mm. The highest Fracture length was observed at a pressure 7 N/mm$^{2}$, Temperature of 55ºC and Injection hole diameter of 9 mm [Fig.2]. The Fracture length was remained constant approximately and comparatively low fracture length was observed at low pressure of 5 N/mm$^{2}$, temperature of 45ºC and injection hole diameter of 7mm.

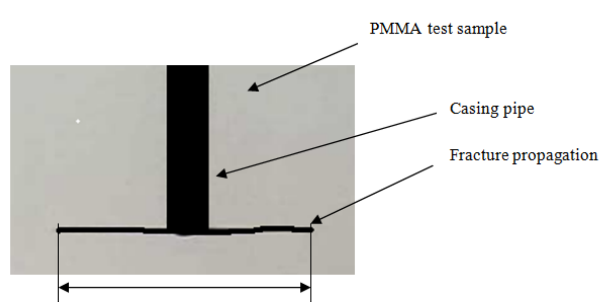


 

**Fig-2 shows the highest Fracture length of 580mm was observed at a pressure 7 N/mm$^2$, Temperature of 55ºC and Injection hole diameter of 9 mm**

**Table 2 Experimental test result**

| Expt.. No | Important parameters | | | Fracture length (mm) |
|---|---|---|---|---|
| | Pressure applied (N/mm$^2$) | Temperature (ºC) | Injection hole diameter (mm) | |
| 1 | 5.00 | 45.00 | 7.00 | 210 |
| 2 | 7.00 | 45.00 | 7.00 | 250 |
| 3 | 5.00 | 55.00 | 7.00 | 200 |
| 4 | 7.00 | 55.00 | 7.00 | 400 |
| 5 | 5.00 | 45.00 | 9.00 | 240 |
| 6 | 7.00 | 45.00 | 9.00 | 350 |
| 7 | 5.00 | 55.00 | 9.00 | 360 |
| 8 | 7.00 | 55.00 | 9.00 | 580 |
| 9 | 4.32 | 50.00 | 8.00 | 220 |
| 10 | 7.68 | 50.00 | 8.00 | 460 |
| 11 | 6.00 | 41.59 | 8.00 | 210 |
| 12 | 6.00 | 58.41 | 8.00 | 410 |
| 13 | 6.00 | 50.00 | 6.32 | 260 |
| 14 | 6.00 | 50.00 | 9.68 | 420 |
| 15 | 6.00 | 50.00 | 8.00 | 390 |
| 16 | 6.00 | 50.00 | 8.00 | 420 |
| 17 | 6.00 | 50.00 | 8.00 | 420 |
| 18 | 6.00 | 50.00 | 8.00 | 350 |
| 19 | 6.00 | 50.00 | 8.00 | 430 |
| 20 | 6.00 | 50.00 | 8.00 | 330 |

## 3.1 Effect of Pressure (N/mm$^2$) on Fracture Length (mm)

The Fluid is pressurized because of feed pump in the range of 4 to 8 N/mm$^2$. This high pressure fluid is compressed between the casing pipe and surface of the test sample and this energy can be stored in or released from the test medium to the surrounding area subjected to internal pressure which induces the elastic strain energy before the fracture occurs at the peak pressure. If the internal energy exceeds the limit that the material can withstand, the energy release will occur to re-establish the internal energy level within a tolerable limit. The excess of energy is dissipated with the growth of micro cracks during process. The Micro mechanical factor which influences the new crack and porosity generation is heavily influenced by the high pressure. The fracture propagation stops when the elastic strain energy releases over the surface of the test sample. The fracture length is visualized as a collection of coplanar flat cracks. Under low pressure applied the fracture is represented by large, closely spaced cracks, hence the fracture length decreases and measured as 210 mm. As the applied pressure increases, cracks with the smallest thickness with crack spacing increases. Hence highest fracture length of 580mm was observed when the applied pressure was maximum.

## 3.2 Effect of Temperature (ºC) on Fracture Length (mm)

Because of heating the test sample, the deformation resulting from thermal expansion or contraction is non uniform along the radial and axial directions. This induces the thermal stresses in the sample. For example, under heating condition, the material close to the periphery tends to expand more than the material closer to the axis. Consequently, this produces an outer ring of compression and an inner core of tension. Since fractures in tensile stress fields tend to grow in a plane that is perpendicular to the maximum principle stress, it is expected that loading the sample hydraulically would create a fracture that is oriented perpendicular to the sample axis [Fig-3].[16]. Hence highest fracture length of 580 mm was observed when the temperature was at its maximum.

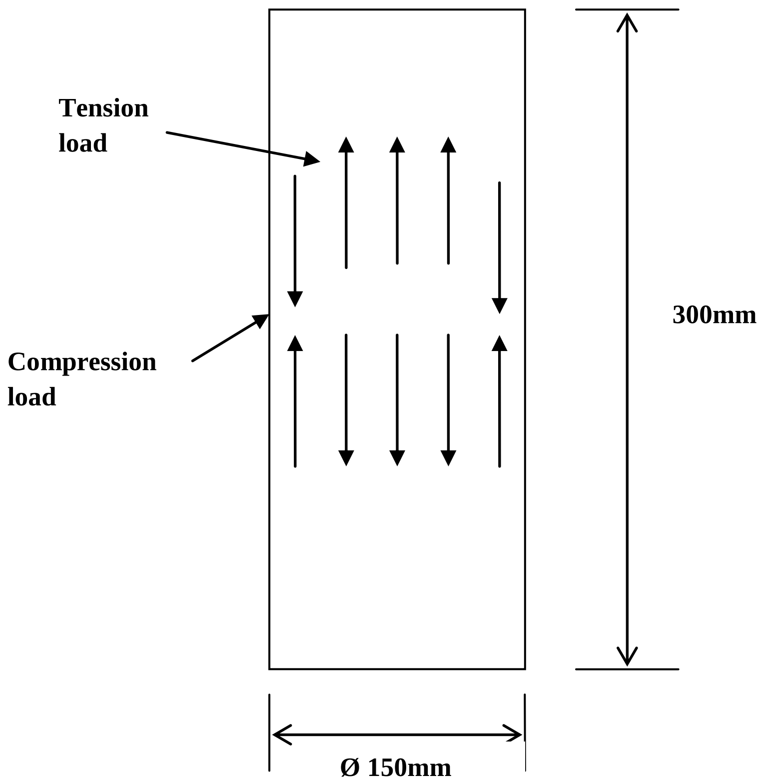


**Fig-3 shows the PMMA sample with dimensions and load acting due to temperature effect**

### 3.3 Effect of Injection Hole Diameter On Fracture Length (mm)

As the injection hole diameter is increases from 6 to 10mm, the area of the contact between the injection hole diameter and surface is gradually increased. The fluid which is being impinges on the test sample exert a large internal pressures on the perimeters of underground structures of the test sample and this pressure develops an internal fractures with in the sample. The sample with fractures with large apertures is susceptible to deformation enabling to produce large stresses that induces a further cracking through hydraulic fracturing. Further, the mechanical deformation of fractures being opened by asperities in contact with the varying diameter of the injection hole. Because of the applied pressure, these asperities deform and additional asperities come into contact. Due to this change in the geometry of test sample structure, changes were observed in the geometry of the fluid flow path. The geometry of the void space affects both the flow properties and the physical properties of the test specimen hence highest fracture length of 580 mm was observed at injection hole diameter of 9 mm. This combined technique of Pressure (N/mm$^2$), Temperature (ºC) and Injection hole diameter (mm) is robust and has consistent role in fracture length (mm) development during all the 20 experimental trials

## 4. CONCLUSIONS

- The Micro mechanical factor which influences the new crack and porosity generation is heavily influenced by the following factors of applied pressure, Temperature and Injection hole diameter on the PMMA test sample.
- The fracture propagation can be easily visualized through the PMMA test sample.
- The highest Fracture length of 580mm was observed at a pressure of 7 N/mm$^2$, Temperature of 55ºC and Injection hole diameter of 9 mm.
- The lowest Fracture length of 2.1mm was observed with all the factors were at their lowest level in the range considered in the study

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