# Experimental and Numerical Modeling of Hydraulic Fracturing in Loshan Sandstone

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## Extended Abstract

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### Introduction

Hydraulic fracturing is used in the oil industry in order to increase the index of production and processing in wells whose efficiency has been dropped due to long-term harvest or the rocks around the well are low permeable. Since the hydraulic fracturing operation is costly, it is of special importance to determine the pressure required for hydraulic fracturing and the suitable pump for this operation to the project managers.

The hydraulic fracturing technique refers to the process of initiation and extension of fractures in rocks caused by the hydraulic pressure applied by a fluid. This technique was developed by Clark (19). Haimson and Fairhorst (20) continued the research on the initiation and extension of fracture. Hubbert and Willis conducted comprehensive studies on the mechanics of hydraulic fracturing to determine the direction and condition of principal stresses using the hydraulic fracturing process. Since then, numerous studies and modellings have been conducted to investigate the factors effecting the hydraulic fracturing.

The present research is important because experimental and numerical modeling were used to calculate the hydraulic fracturing pressure for different conditions and to select the suitable pump for the operation.

These simulations are aimed to investigate the fracture pressure in Loshan sandstone to determine a relationship between the pressure needed for fracturing and the confining pressure.

## Material and methods

The specimen examined in this study is the Loshan sandstone. Sandstone is a sedimentary rock which is formed in all geological periods and is mainly consisted of fine sand particles, different minerals and has various colors. This rock is mainly formed in the shallow seas, deltas, along the coasts, and in hot deserts. Moreover, materials such as clay and silicon oxide contributed to the cementation of its particles.

The rock sample of Loshan sandstone is a calcareous sandstone with a limestone-silica structure whose cement is calcareous (Figure 1). The main and secondary minerals in this rock include calcite, feldspar alkaline, quartz, and opaque minerals. The diagenesis of this rock includes sericitization, chertization, and calcification. The main shapers of this rock are shaped and semi-shaped quartzes with calcite.

The physical and mechanical properties of the specimens are presented in Table 1.

**Table 1. Physical and mechanical properties of the Loshan sandstone**

| Elastic modulus (GPa) | Uniaxial compressive strength (MPa) | Poisson's ratio | Tensile strength (MPa) | Dry unit weight ( $KN/m^3$) | Effective Porosity (%) |
|---|---|---|---|---|---|
| 12..22 | 54.62 | 0.21 | 6 | 21.60 | 7.5 |

**Figure 1. Loshan sandstone**

## Results and discussion

Fracture pressures in the developed models are listed in table 2. The Fracture pressures obtained from numerical modeling had a 10% difference with the experimental modeling results.

**Table 2. Experimental ant numerical modeling results**

| Model number | Axial stress (MPa) | Confining pressure (MPa) | Fracture pressures obtained from numerical modeling | Fracture pressures obtained from experimental modeling |
|---|---|---|---|---|
| 1 | 2.26 | 2 | 13.8 | 14.58 |
| 2 | 2.5 | 2.5 | 15 | 15.7 |
| 3 | 5 | 0 | 9.9 | 11.16 |
| 4 | 7 | 0 | 9.9 | 11.39 |

Figure 2 shows the relationship between the pressure required to initiate hydraulic fracturing and confining pressure for Loshan sandstone. There was a linear relationship between fracture pressure and confining pressure. Thus, with an increase of the confining pressure, the pressure required to initiate hydraulic fracturing increased. The relationship between the fracture pressure and the confining pressure for Loshan sandstone is in the form of Equation (1).

$$P_f = 1.7386\ \sigma_3 + 11.242 \quad (1)$$

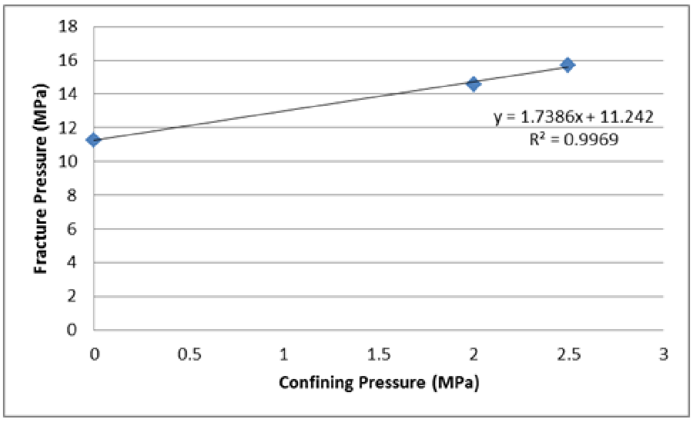


**Figure 2. Relationship between fracture pressure and confining pressure**

## Conclusion

The following conclusions were drawn from this research.

1. The increase of lateral stress led to an increase in the fracture pressure.
2. Changes in the axial stress did not significantly change the fracture pressure.
3. The results of numerical mode~~l~~lings were well consistent with those of the experimental mode~~l~~lings.
4. Unlike other studies conducted in this field, the numerical model~~l~~ings in this study were performed without any initial pre-determinations for the crack-less models. Results show that in most cases, cracks initiate from the center and are extended toward both ends of the sample. The crack extension direction was parallel to the borehole axis inside the sample and perpendicular to the lateral stress. This is fully consistent with the observations in the experimental models.

**Keywords:** Hydraulic fracturing, experimental modeling, numerical modeling, Loshan sandstone.

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