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EFFECTS OF WELLBORE STABILITY TO SAND PRODUCTION

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ABSTRACT

The paper describe a series of laboratory experiment to observe the effects wellbore stability to sand production. The wellbore stability is the most important of aspect that should be considered during and production activities. The paper will presented only the effect of wellbore stability due the structure design at production zone i.e perforated cased wellbore. The physical model has been design as wellbore where different borehole angle and perforation parameter (shot density and perforation pattern) has been impose to see the effect on the stability and sand production. Generally all models fail and sand particles were produced and found that stable perforated wellbore produce less sand particles.

INTRODUCTION

Sand production and wellbore instability is interrelated phenomenon which must be considered carefully during the designing period of a petroleum well. In practice, the sandstone formation will be cased and cemented since it is friable consolidated, then perforated. This is to allow communication between the oil bearing of the reservoir rock and wellbore. Thus planning the perforation and its pattern will be most important factor to avoid potential problem such as total casing collapse and wellbore failure. Fail to do so, will also lead to sand particles influx in the wellbore or sand production. The wellbore instabilities occurs due to several aspects such as shape and direction of borehole, shot density, perforation pattern, production rates, overburden and confining pressure

Since, we are dealing with rocks, therefore, understanding the rock mechanics aspect is primarily important before the drilling, completion and production activities to avoid loss of reserves, added expenses in combating equipment erosion, reduced

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productivity and consequent handling and disposal of the produced sand. The reservoir rock is in equilibrium stage between overburden and pore pressure. It also triaxially stressed state. Thus, when borehole and perforations are created in the formation and production zone respectively, rearrangement of the stress takes place. Hence, the stresses must be redistributed and the surrounding rock must be able to carry it. The carried stress might exceed the peak strength of the rock and if the rock structure is not strong enough to carry the stress, then the surrounding rock may fail and causing failure within the rock. This phenomenon will lead to production of crushed material on the perforation face and the perforated wellbore may collapse. The amount of sand production is fully depends on the wellbore stability or the structure stability.

A study has been conducted in the laboratory scale in order to study the effects of wellbore stability to the sand production depending on the wellbore angle, shot density and perforation pattern (spiral, inplane and inline).

LABORATORY WORKS

Since sandstone were used in designing the wellbore model, the mechanical properties of the particular rock have to be understand. Therefore the standard test has been carried out using ASTM standard method.

2.1 Rock Standard Tests

Six standard tests have been carried out, i.e. porosity, permeability, density, compressive strength, tensile strength and triaxial test. From the compressive strength test the Young Modulus, E were determined. As for the shear strength and angle of internal friction were determined by using the triaxial test data. Table 1 shows the dimension of the specimen used for the standard tests. All specimen were cored from sandstone mass, cut into desired length and lapped at the both ends to reduce the flaws during experiments. The rate of loading of 0.7 $MN/m^2/sec$ was used for uniaxial compressive strength test and the Brazillian test were adopted for the tensile test where the disc specimen was loaded at rate of 0.2 $MN/m^2/sec$. The triaxial test was conducted with five different confining pressure and loaded with 0.7 $MN/m^2/sec$ until the specimen fails. After the test, the Mohr diagram was plotted in order to obtain triaxial shear strength and the angle of internal friction.

Table 1 - Specimen dimension for standard test

Parameter	Length (inch)	Diameter (inch)	Equipment used
Porosity	2	1	Helium Porosimeter
Permeability	2	1	Gas Permeameter
Density	1	1	Weighing Machine
Uniaxial Compressive Strength	5	2	Servo Machine
Tensile Strength	1	2	Servo Machine
Triaxial Test	5	2	Servo Machine

2.2 Wellbore model preparation

Two type of models have been prepared for the studies, they are block and cylindrical models. The sandstone rock mass were cut into block by using cutting machine with water flush as coolent where the heigth, width and length was 6 inch. As for the cylindrical model the sandstone rock mass were cored using 6 inch internal diameter coring bit and cut into 6 inch length.

The block model then cored at the center with 2 inch borehole and angle of 0°, 10°, 20° and 30°. Whereby the cylindrical were cored at the center without any inclination angle. Then the 1 inch steel pipes were cut correspondance to the boreholes cored in the models to represent the casing. The cement slurry (class G cement) were then prepared with respect to API Spec. 10 and 2 to 1 cement-water ratio. The steel pipe or casing was then placed in the middle of the borehole and the cement slurry was squeezed into the annulus as the bonding agent between casing and the formation. The entire systems were then left over for 24 hours in order to allow the cement to set. After which, followed by the saturation procedure where the wellbore model were saturated with gylcerol to represent formation fluid. As the saturation procedure completed the wellbore model then perforated with different shot density and perforation pattern. Table 2 shows the wellbore design used in the study.

Table 2 - The wellbore models designed details

Wellbore Model	Dimension (inch)	Borehole Angle (degree)	Shot Density (SPF)	Perforation Pattern
Block Model	6 x 6 x 6	0, 10, 20, 30	8	Spiral, inplane inline
Cylindrical Model	6 x 6	0	6,8,16	Spiral, inplane inline

2.3 Wellbore stability test

The stability test was conducted using the Servo Controller Compression Machine. The machine is fully computerized and need to be programmed before testing since this is customized testing method. The machine software will communicate with the machine and be able to detect the failure.

Few special platens have been fabricated earlier in accordance to the wellbore model types. There were two platens for each model i.e. top and bottom platens. The top and bottom platens were put at the top and bottom of the wellbore model respectively. The assemblies then carefully put into the servo machine and placed at the center of the compression machine. The rate of loading programmed was 0.7 MN/m2/sec. The computer will exhibit online plotting of the load versus displacement. Once the wellbore model failed the machine stopped and unloaded automatically. The sand particles produced after the failure were then collected carefully for the sieve analysis.

2.4 Sieve analysis method

The particles which produced by the failed wellbore model were weighted before being sieved. This weight will be recorded as recovered weight. Then the laboratory disc was carefully emptied on the nested sieves. To avoid contamination by dust and sand particle loss, the sieve column was closed off with cover. Electric sieve shaker then used to shake the nested sieve for 10 minutes (Vicker (1978), Craigh (1978) and Wills (1979)). Then the contents of each sieve was carefully brushed off and weighted

Consequently, the weighed for each particle size range as defined by the mesh size range of successive sieves was calculated. The amount of oversized and undersized sand particles were then calculated. Cumulative percentage oversized is defined as cumulative percentage of particle retained on the sieves. The cumulative percentage undersized is the cumulative percentage of particle passing through all the sieves and collected at bottom of the sieve shaker.

RESULTS AND DISCUSSION

Table 3 shows the average value of the basic mechanical properties of the sandstone used as the wellbore model.

Table 3 - Average value for basic mechanical properties of sandstone

PARAMETER	AVERAGE VALUE
Density, ρ	2.03 g/cc
Porosity, ϕ	11 %
Permeability, K	3.63 mD
Uniaxial Compressive Strength, C_o	32 MN/m^2
Tensile Strength, T_o	1.82 MN/m^2
Young Modulus, E	9.95 GN/m^2
Poisson Ratio, ν	0.3
Triaxial Shear Strength, S_o	12.90 MN/m^2
Angle of Internal Friction, Φ	39.39°

Generally, all the perforated wellbore model failed and sand particles were produced. The wellbore stability and sand particles production basically depend on the wellbore inclination angle, short density and perforation pattern.

3.1 Effects of wellbore angle

Figure 1, Figure 2 and Figure 3 show that as the inclination angle increases the wellbore stability decreases for spiral, inplane and inline respectively. Whereas, the amount of sand fragments produced increases as the wellbore stability decreases. The results show that the sand fragment produced is depending upon the wellbore stability where the wellbore stability depends on the wellbore inclination angle. As the results, for all the perforation patterns (spiral, inplane and inline), the wellbore stability decreases as the wellbore angle increases which increase the sand fragments produced.

When wellbore angle increased, it produced higher shear stress along the borehole surface. Thus as the wellbore inclining the stability declines since the stress along the wellbore reachs its peak and intend to fail.

3.2 Effects of shot density

Figure 4, Figure 5 and Figure 6 show the effects of wellbore stability due to increament of shot density and its effects to sand fragment produced for spiral, inplane and inline respectively. The results show that as the shot density increases the wellbore stability decrease and the amount of sand fragment produced increases. Again the phenomenon concluded that as the wellbore stability decreases the total sand fragment produced would increases. In other word unstable wellbore produced more sand fragment.

When the wellbore was perforated, higher shot density will removed more rock mass. Hence, more stress have to be redistributed and the wellbore model fails at lower stress.

3.3 Effects of perforation pattern

Figure 7, Figure 8, Figure 9 and Figure 10 show the influences of the perforation pattern to wellbore stability and sand fragments produced. The results show that the spiral pattern exhibit the most stable pattern followed by inplane and inline pattern. This phenomenon is due the arrangement of the perforation patterns. The inline pattern was arranged in paralel to the applied axial load, resulting in the lowest strength. Whereas the inplane was arranged horizontal, perpendicular to the applied axial load or major stress. This will leading to the lower in rock structure strength. As for the spiral pattern, the arrangement was inclined to the major stress (axial load), resulting in the stronger rock structure compare to inplane and inline pattern.

CONCLUSIONS.

The study has shown that the perforated wellbore failed and sand fragments were produced. The mode and stress at failure depend on the wellbore inclination angle, shot density and perforation pattern. The sand fragments produced depends on the wellbore stabitliy.

The wellbore stability decreases as the wellbore inclination angle increases, shot density increases and the perforation patten change from spiral to inplane and inline. The amount of sand fragment produced increases as the wellbore stability decreases. In other word the amount sand fragment produced increases as the wellbore inclination angle increases, shot density increases with perforation pattern changes from spiral to inplane and inline.

More sand fragments were produced by the unstable perforated wellbore. Therefore, knowing the effect of wellbore inclination angle, shot density and perforation pattern to the wellbore stability and sand production, we can optimize the production and minimize the sand production problem. This can be accomplished by considering the wellbore stability effects in designing phase of a petroleum field development. Designing a stable wellbore basically will minise the sand production problem.

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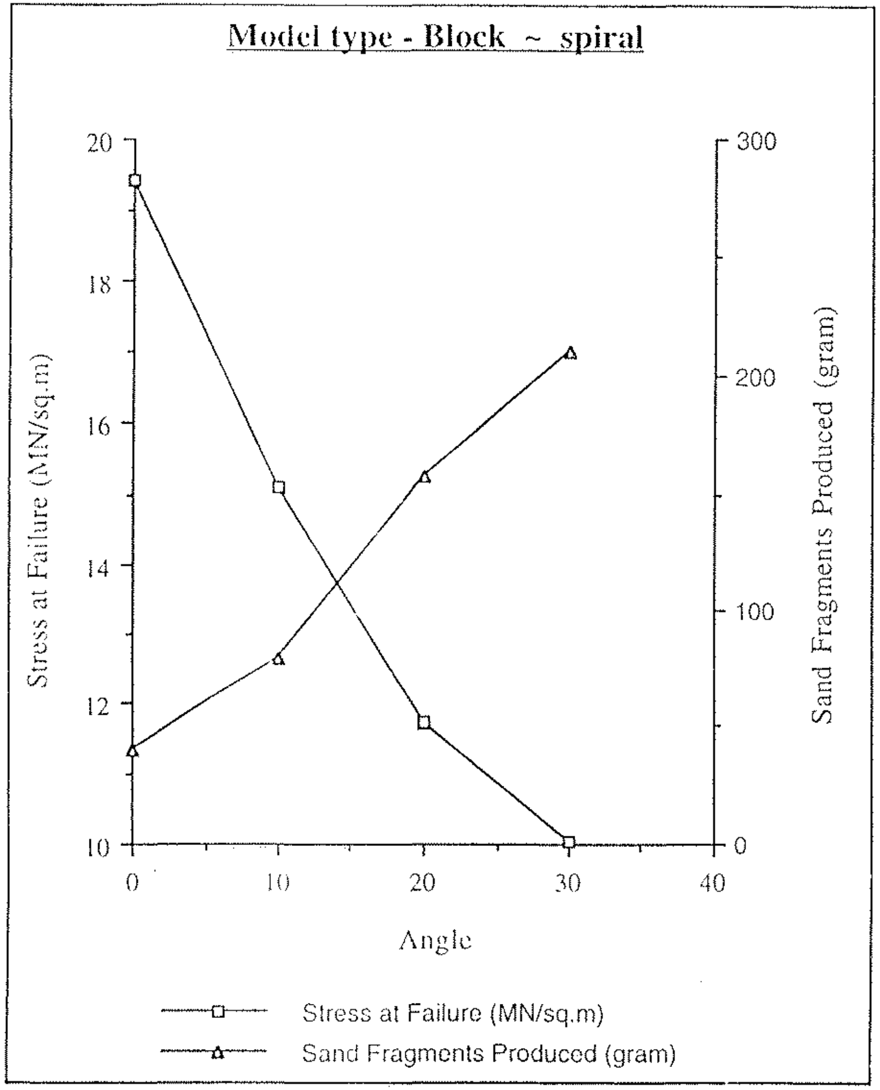

Figure 1 - Relationship Between Wellbore Instability And Sand Production For SPIRAL Pattern (Block Model).

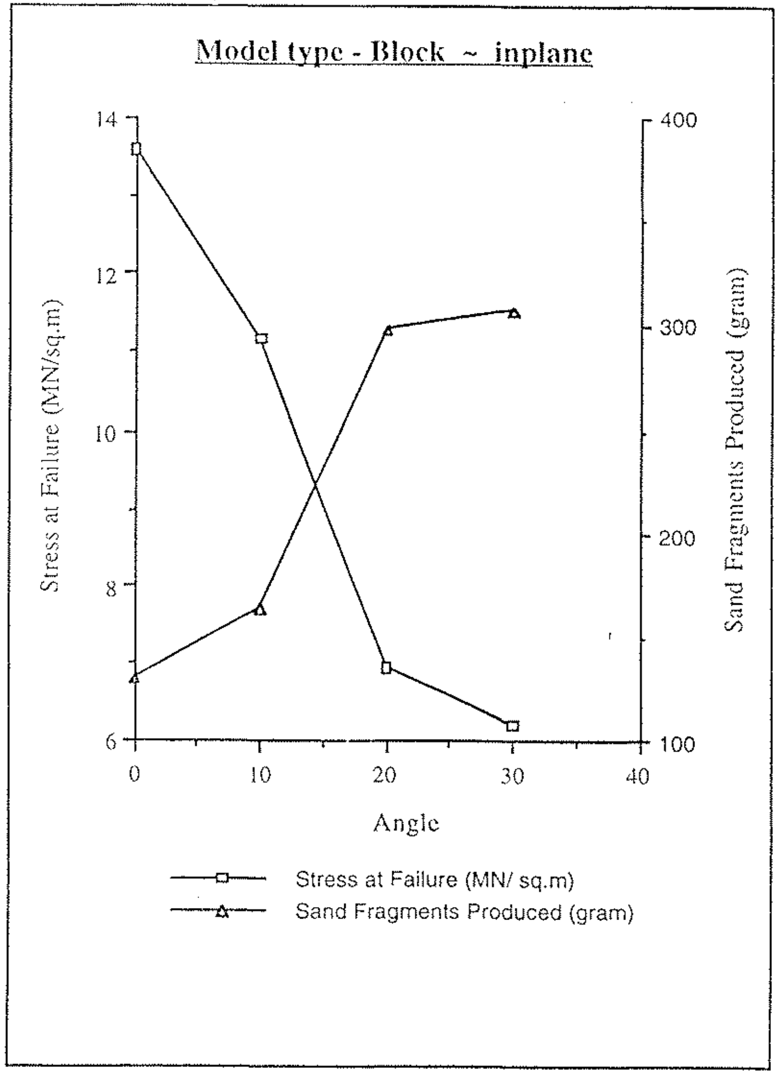

Figure 2 - Relationship Between Wellbore Instability And Sand Production For INPLANE Pattern (Block Model).

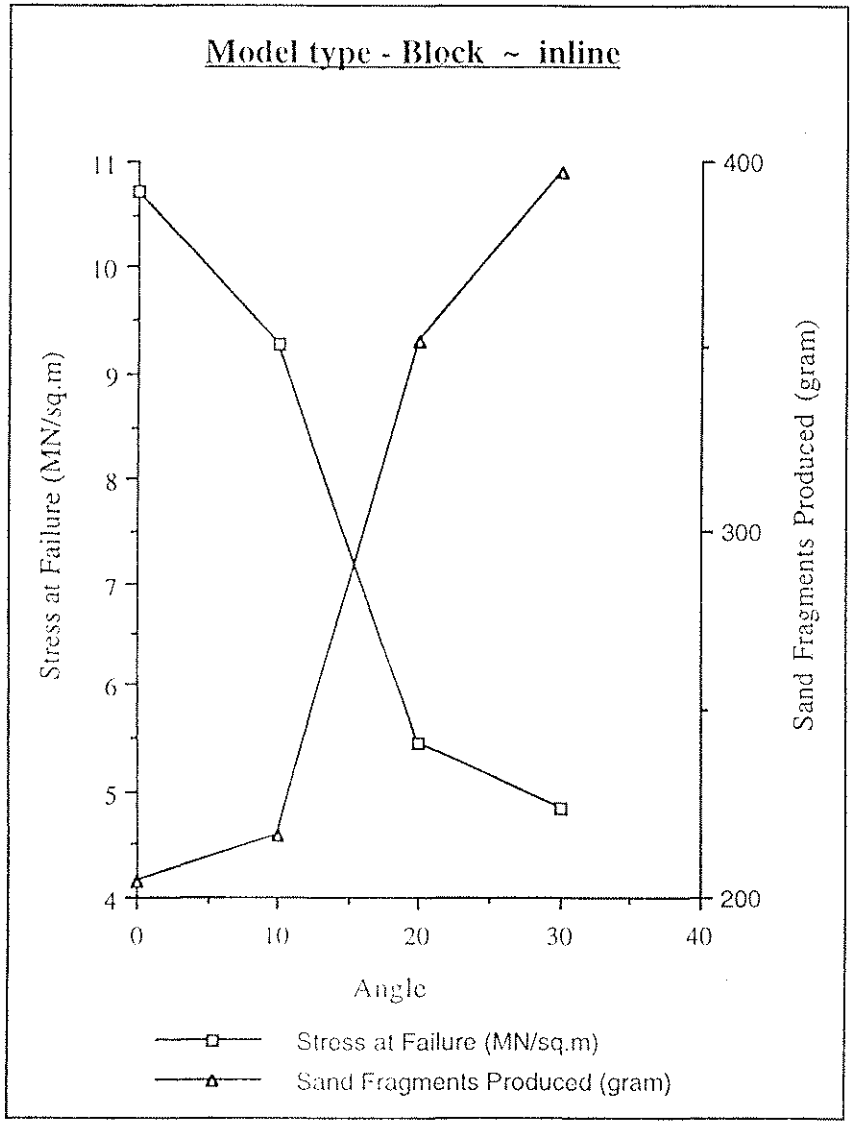

Figure 3 - Relationship Between Wellbore Instability And Sand Production For INLINE Pattern (Block Model).

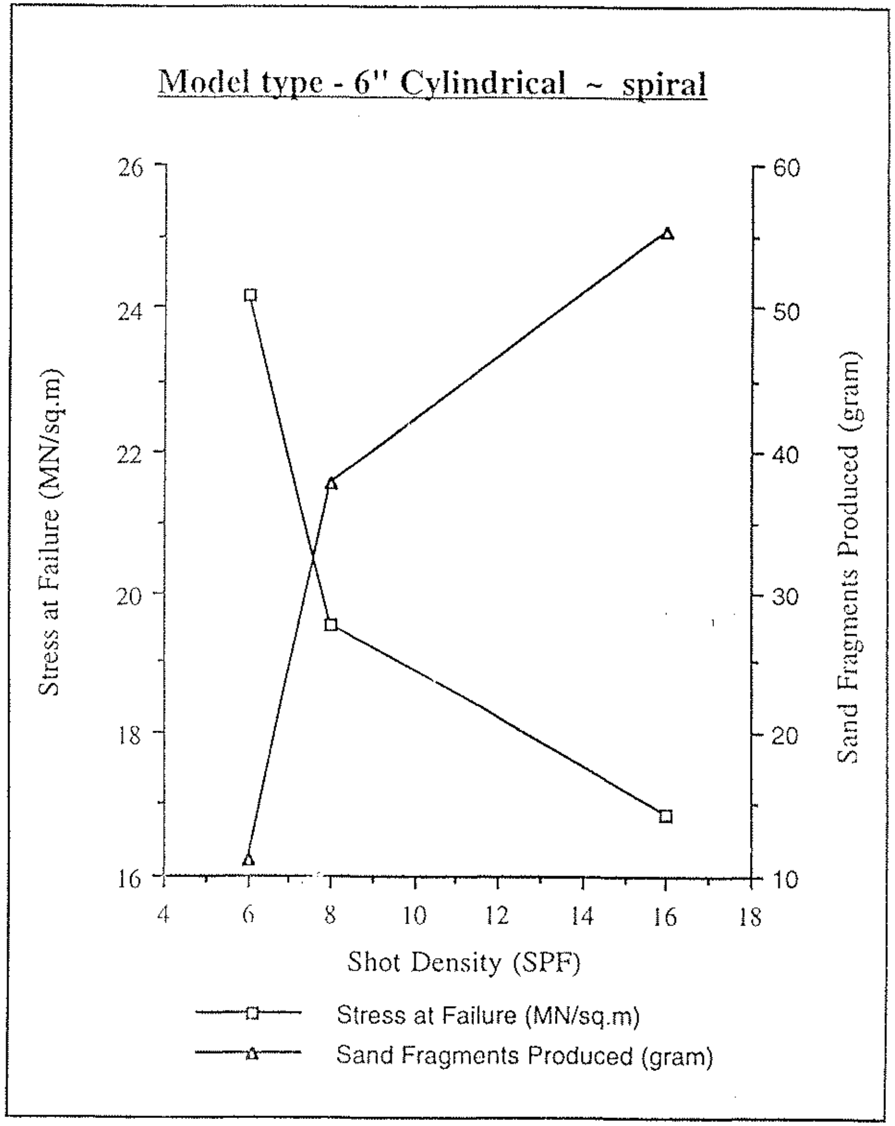

Figure 4 - Relationship Between Wellbore Instability And Production For Cylindron Model (SPIRAL Pattern).

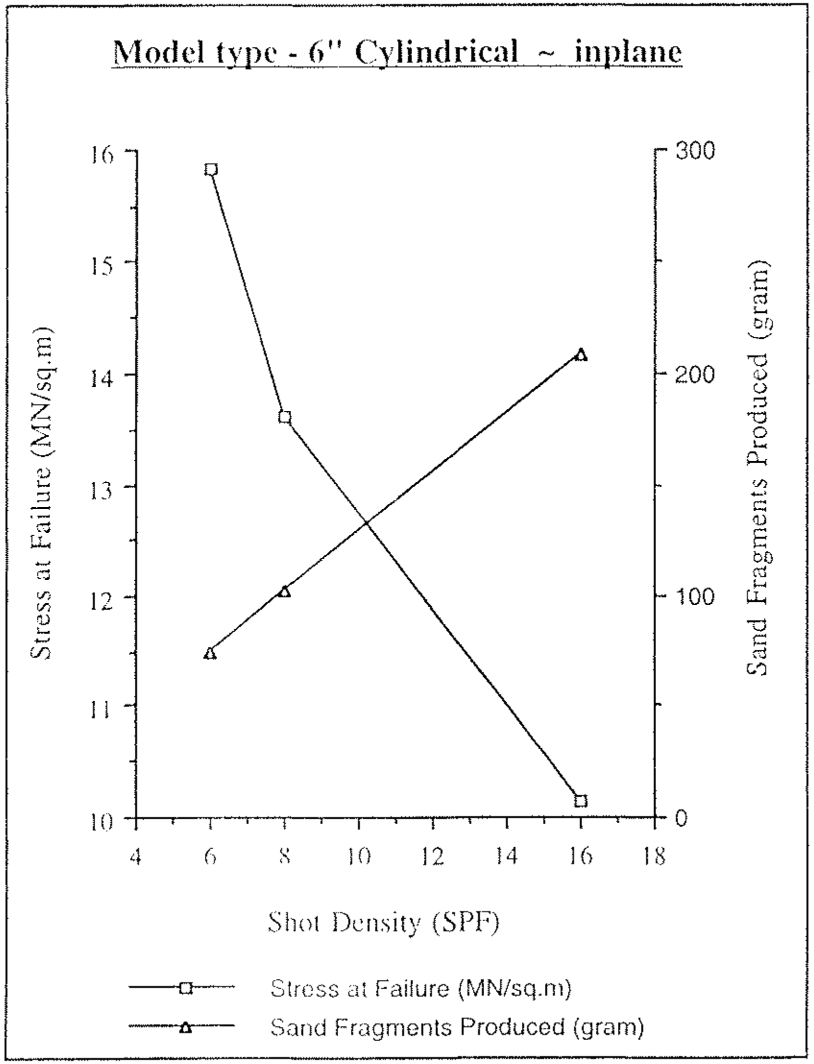

Figure 5 - Relationship Between Wellbore Instability And Production For Cylindron Model (INPLANE Pattern).

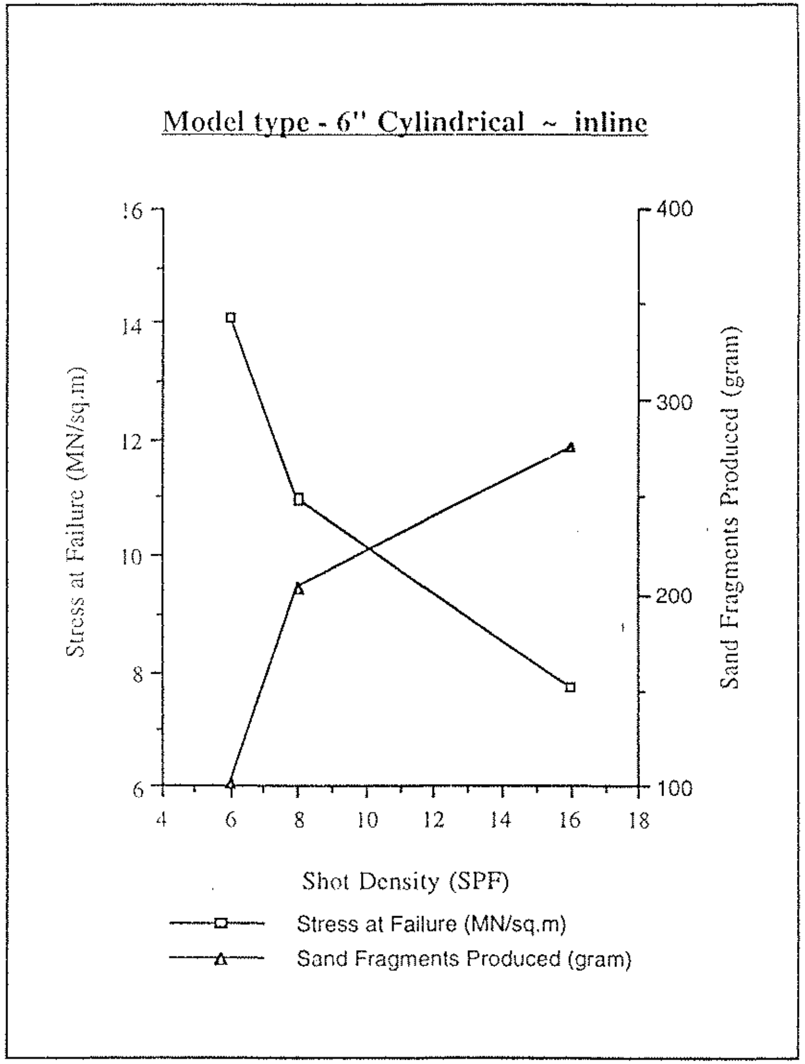

Figure 6 - Relationship Between Wellbore Instability And Production For Cylindron Model (INLINE Pattern).

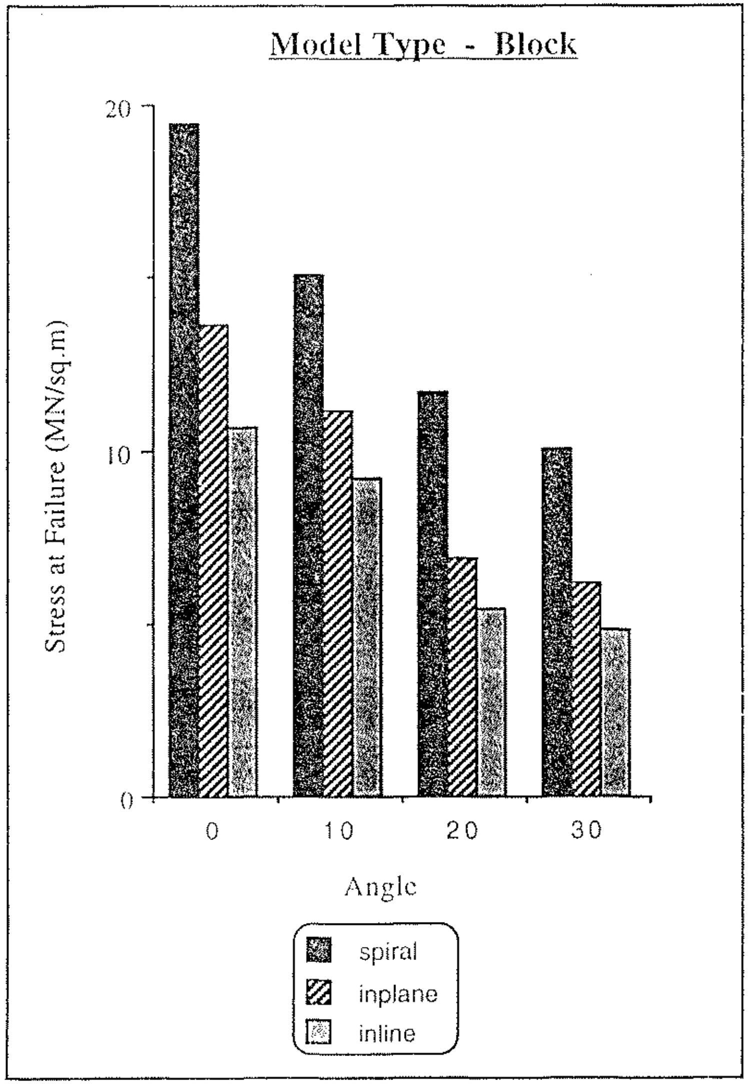

Figure 7 - Effects Of Perforation On Wellbore Stability (Block Model).

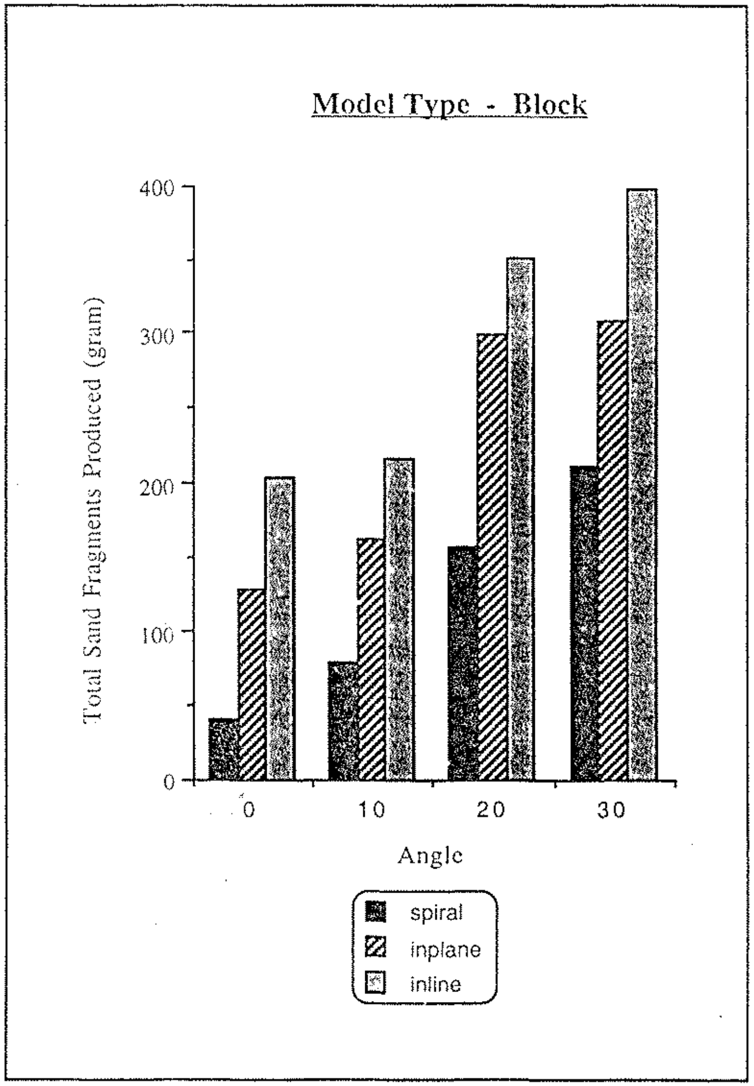

Figure 8 - Effects Of Perforation Pattern On Sand Fragments Produced (Block Model).

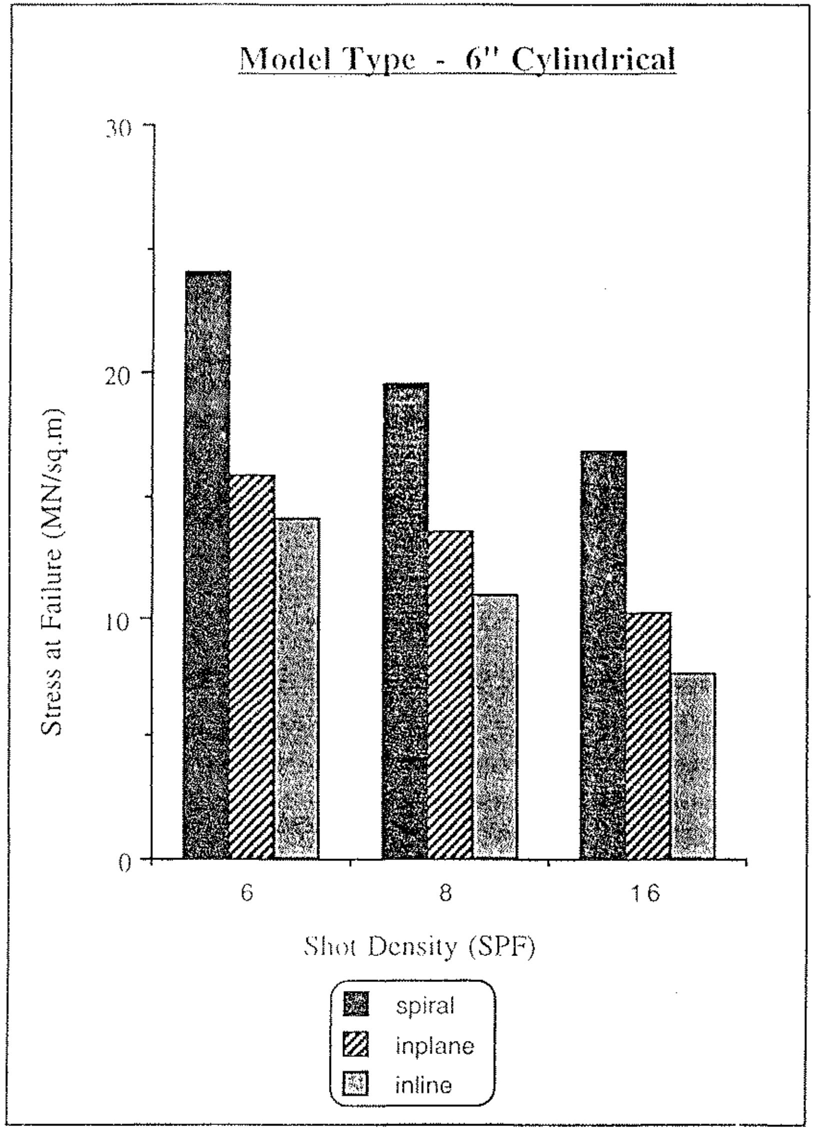

Figure 9 - Effects Of Perforation On Wellbore Stability (Cylindrical Model).

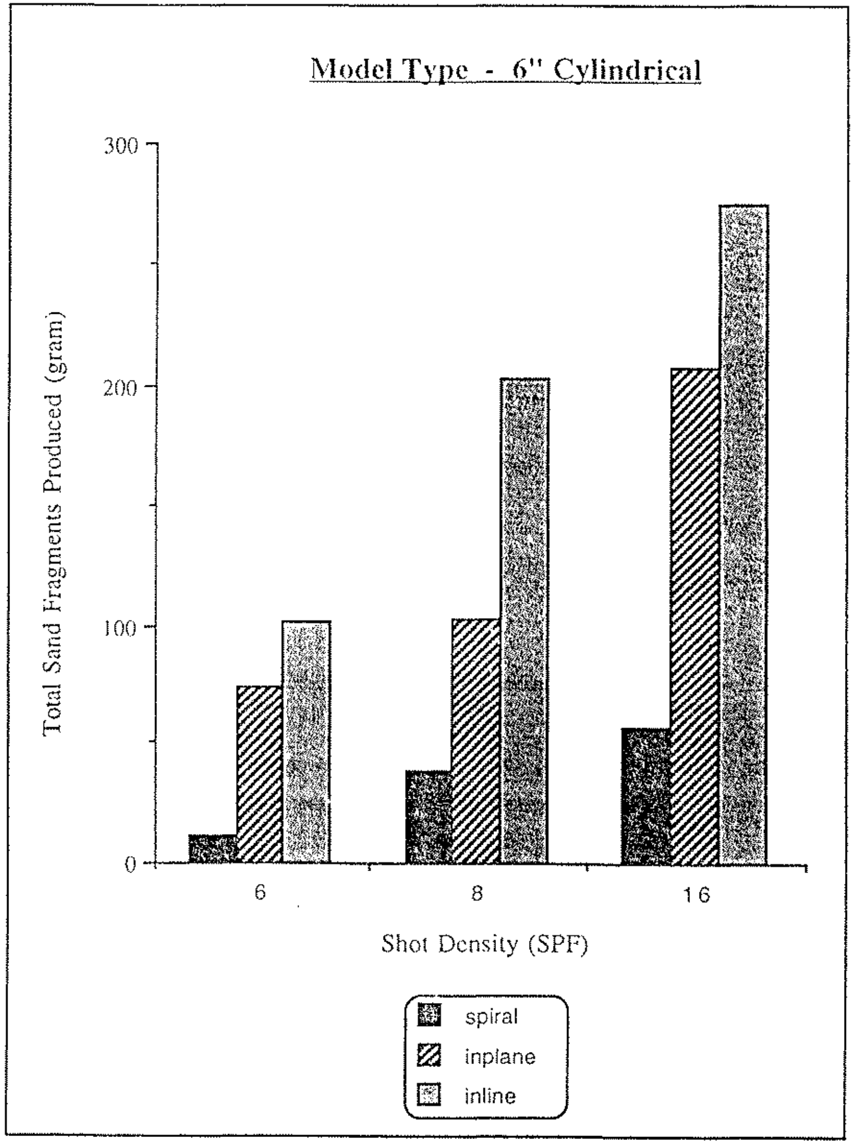

Figure 10 - Effects Of Perforation Pattern On Sand Fragments Produced (Cylindrical Model).