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Research Article

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Simulation analysis of the oil pipe between injection-production system packers

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ABSTRACT

Downhole oil-water separation and reinjection technology can effectively solve the problem that the moisture of produced fluid is getting higher and higher, and as a key component of the injection-production system, injection-production string withstands packer's seating axial force, internal pressure, external pressure of oil and multi-load conditions, thereby resulting in the bending deformation of oil tube, and then causing the systems running eccentric wear, cards pumps and other phenomena. In this paper, the deformation of oil pipe between the injection-production system packers were mechanical simulation analyzed, and obtained the effective measures to reduce pipes bending deformation, to guarantee efficient and safe operation of the pipe, and then the injection-production system can run smoothly for a long time.

Key words: Injection-production system; packer; string; mechanics analysis

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INTRODUCTION

With the operation of oil field enters into the middle-last development time, the water content ratio of outputted liquid from oil well is increasing high, produced water treatment is a growing prominent problem, the same well injection-production system can carry out Downhole Water/Oil Separation and the separated water will be injected into the layer, effectively solve the problem of produced water treatment. The injection layers need to be separated by the packer. Packer setting force and injection pressure, the sinking pressure, liquid pressure, gives rise to bending deformation on injection-production pipe string. The analytical deformation expressions of tubing string were derived by solving buckling equations—fourth order nonlinear ordinary differential equations with end condition and continuous condition of the buckled tubular, and analyses the influence of packer string buckling effect in literature [2]. Literature [3] designs the injection-production system in the same well and establishes the string mechanical model and analyzes the string axial deformation in the process of running up and down using finite element analysis software ANSYS.

SIMULATION SECTION

Figure 1 is the schematic of the pipe string at the injection-production system packer section, packer string of the same well injection-production system consists of upper and lower two levels of packer and inside and outside the middle of two layers of pipe string. through two packer setting to separate injection and production layer sealing, the separated water will be injected into the injection layer through the inner tube, after separation, the concentrate liquor is inhaled into the production pump through the annular passage between the inside and outside the tube .

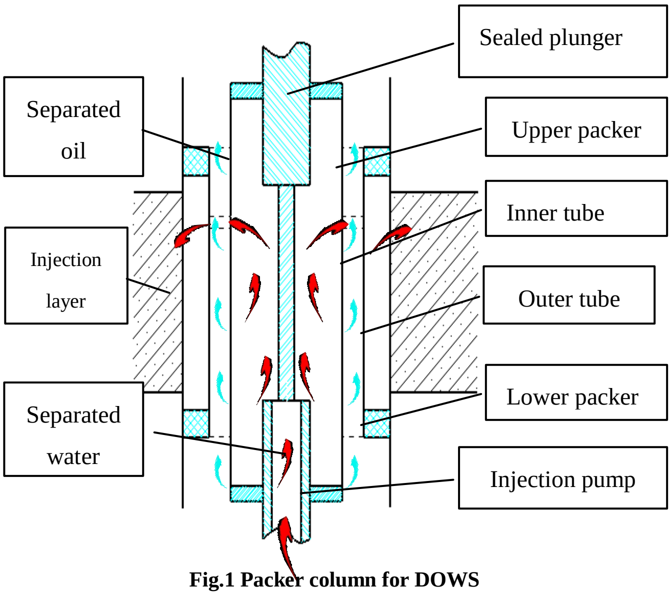


Fig.1 Packer column for DOWS

The pipe string structure of the injection-production system for the same well mainly includes spatial structure of the pipe string and geometric structure of the pipe string section, the spatial structure of the pipe string axis is structure of the borehole axis, the geometric structure of the pipe string section mainly is cyclic symmetry structure, the annular inner and outer diameter can be arbitrarily given, making the following simplification for the pipe string:

The outer tube and the inner wall of casing is rigid, diameter can be arbitrarily changed along the direction of the well bore.

This pipe string structure and its attachments are flexible structure, the axis in front of the deformation of pipe string is coincident with the pipe string axis, and the annular gap exists between the two layers of pipe string.

Under the pressure the unstable pipe string occur random deformation along the circumferential direction of the borehole, and contacting with the outer tube wall, and there is the contact counterforce at the contact point.

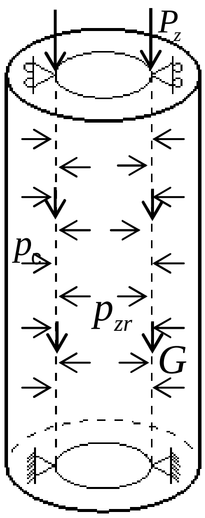
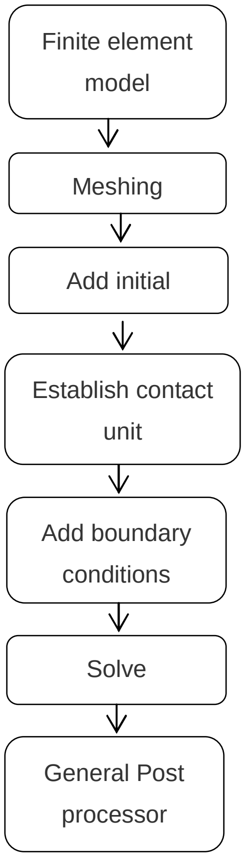


Fig.2 Mechanical model of column

Simulation Model

As shown in figure 2, down hole the packer mainly suffers by the action of the load of the tubing weight, the setting force and the liquid pressure, the constraints subjected mainly are the clamped constraints of the lower packer, the hinged constraints of the higher packer and the steel ball centralizer.



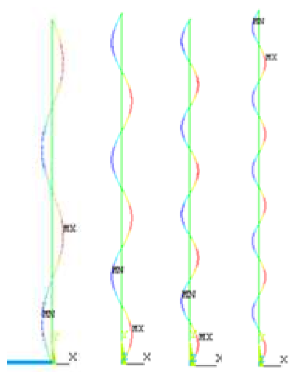


Fig.3 Enlarged deformation maps of column of 60m, 90m, 120m and

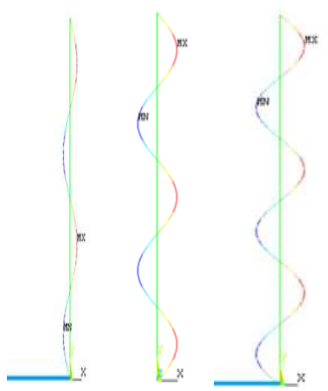


Fig.4 Enlarged deformation maps when axial load 5000N, 10000N and 15000N

The simulation process

The simulation step of pipe string buckling is shown in figure 3. First of all establish finite element model for inner tube and outer tube in packer string. Because of this part of string with large slenderness ratio, so chose suitable element, beam188 element, for analysis of slender beam when modeling. Secondly, use regular hexahedron element as mesh model. The hexahedral element than tetrahedron element has higher accuracy, and it could hold its shape in orders to reduce the destruction of the element when the string deformation occurs. Thirdly, string will has some defects in the process of fabrication and installation. So in order to reflect the deflection of the pipe string, through the characteristic value method introduce initial defects. Fourthly, after the deformation of string, inner tube and outer tube will contact, so need to establish contact element between inner tube and outer tube. The simulation established contact pairs by the conta176 element and targe170 element. Conta176 is 3-D lines contact element, mainly used to describe the phenomenon such as the movement, the bending deformation and so on for a string in another string. Fifthly, adding constraints and load boundary conditions. Finally, calculate and post-process the results.

Analysis of the Influential Factors of Buckling Configuration

Single well injection-production system of downhole strings were affected by multiple loads and constraints, In order to decrease the strings buckling configuration, analysis of the factors of the influence of deformation of tubing string such as length, load section constraints etc. so that making reasonable optimization design.

Fig 3 shows that different length of tubing string under the condition of load, section, constraints etc. were equal. As can be seen from the figure, with the increasing of length of tubing string, there is no change that the maximum deformation of String, but the String of flexural number with the increasing of the length leads to The linear increasing trend, so the length of tubing string of the influence for bending is smaller。

Fig 4 shows that with the increasing of axial load result in tubing string radial deflection gradually increasing, string under the affection of axial load, from the Line balance status to buckling balance status, as the increasing of load, from one order to multiple order ,so the String of flexural number gradually increasing, when radial deformation reach the value of the gap for the between string and outer tube, it will produce contact. Inter tube and outer tube will produce contact force, in conclusion, axial load is the important influence factor on tubing string buckling configuration.

Fig 5 is in the situation of the tubular column for 62 mm in inner diameter, outer diameter is 73 mm, 78 mm, 83 mm, and the deflection of the other conditions are same, It can be seen from the figure that the biggest deformation of tubular column decrease gradually, the number of flexural wave also gradually reduced and the moment of inertia I and bending section coefficient W of the tubular column increase as the rising of the section dimension, moment of inertia I and the instability of bending wave number n is inversely proportional That is to say with the increase of section moment of inertia, tubular column bending wave number decreases, and with the increase of bending section modulus, bending deformation of tubular column is also decreases.

RESULTS AND DISCUSSION

According to the impact of length, load, cross section and centralizer on tubular column bending, the optimization design of different packer tubular column structures of product and inject in the same well system, and within the packer on the tube of different structures are analyzed in the simulation[3].

Tab 1: String structure and parameter between two packer

String structure and parameter	Inner tube	Winged tube	Outer tube	Connecting rod	centralizer
Inner diameter/mm	62	62	95	0	62
Out diameter/mm	73	93	106	25	89
Coupling diameter/mm	89.5	93	106	56	—

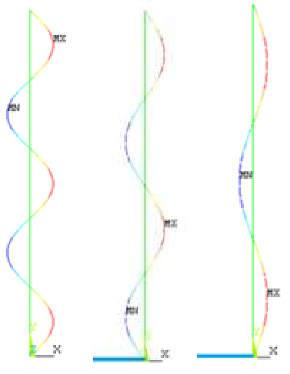


Fig.5 Enlarged deformation maps of column of different diameter

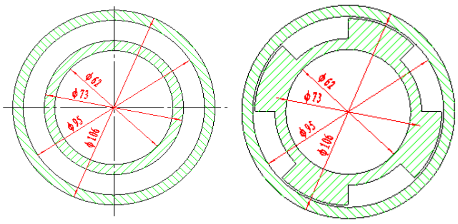


Fig.6 sectional view of ordinary tubing and winged tubing

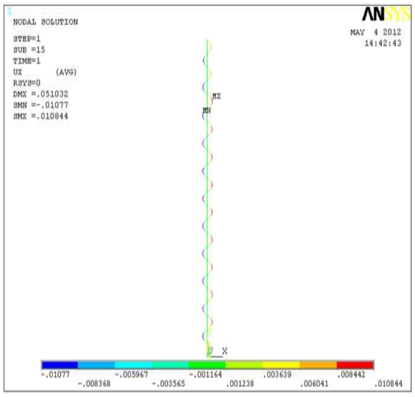


Fig.7 Enlarged deformation maps of ordinary tubing out of centralizer

As can be seen from the fig 7, the inner tube causes buckling deformation under the axial load, and the maximum deformation is 10.84 mm, after bending, the inner tube and outer tube has had the contact, appeared string within 60 m, a total of 11.5 bend.

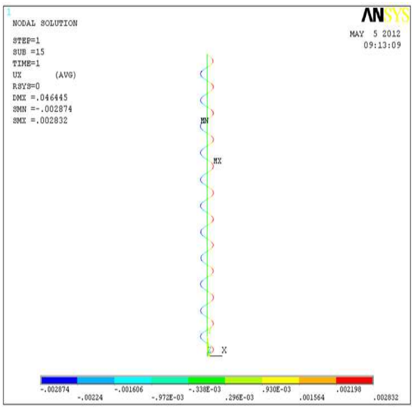


Fig.8 Enlarged deformation maps of ordinary tubing with centralizer of every 2.5m

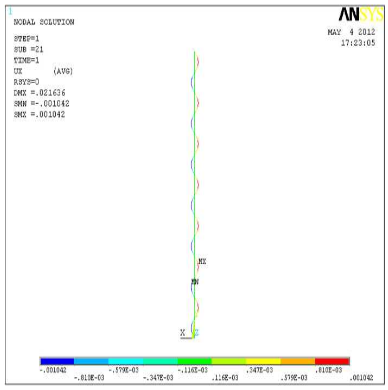


Fig.9 Enlarged deformation maps of singed tubing

As can be seen from the fig 8, the maximum bending of the inner tube is 2.87mm, in the range of 60m, a total of 11.5 bend there, the same as without centering device. Centering device was applied only reduces the amount of radial bending, did not reduce the number of bends, which in the previous section is consistent with the conclusion.

Variable cross section can change the buckling of pipe string, since there is a gap between the inner tube and the outer tube, considering change the sectional shape of the inner tube to improve its bent condition, on the basis of there is enough space In the guarantee the path of circulation between the inner tube and outer tube, designed the structure of the winged tube.

As can be seen from the fig 9, the maximum deformation of the inner tube is 1.04mm,in the range of 60m, a total of 7 half-wave there, remaining after the bending of the inner tube diameter is 59.92mm,greater than the rod collar of 56mm, the use of the inner tube of the rod to avoid frictional contact with the inner tube, the deformation of the sealing piston cylinder will be reduced, which reduces the probability of the pump piston is sealed .

FIELD EXPERIMENTS

In the field test of three Wells, the consecutive operating time of strings without optimal designed was short and the longest was less than three months. The major cause is the buckling of tubing which caused wear and the different centers when the piston moves up and down. After a period of operation, the pump and the packed plunger blocked[4]. From the picture of string without optimal designed (Fig 10), we can know that strings were severely wearied.

Fig.10 worn column before optimization

Fig.11 without wearied winged column after optimization

We tested the optimal designed system in the oil well. There was no pump-block during operating over one year. Before and after optimization, the time of continue trouble-free operating and the pump-block were significant improved. Practical result shows, the optimal designing project is reasonable.

CONCLUSION

This paper studies the finite element simulation of compression of tubing string bending method, simulation analysis of the factors affecting the deformation of tubing string, and according to the simulation results to optimized design the injection production system of well[5].

(1) When other things being equal, with the increase of axial load, the maximum deformation of the tubing string value increases gradually, the same length of the string in the flexural wave number gradually increase, with the increase of length, the maximum deformation of the tubing string value did not change, only the bending wave number along with the length of the corresponding increase, but the half wave length does not change；with the increase of the cross-sectional area, the maximum deformation value of the string gradually decreases, and the same length of the string in the flexural wave number is reducing gradually[6],Reasonable exerts centralizers can effectively reduce the maximum deformation value of the string, and if the centralizers impose unreasonable can cause local bending increasing, but exerts centralizers are not large influence on the bending wave number.

(2) Based on the conclusions above, the inner pipes between two levels of packers with well injection-production system are optimized designed, through the comparison between inner pipe using common tubing without centralizer and pipe using a winged tubing with centralizer every 5 meters, the conclusion is got that while the inner pipe using a winged tubing, the pipe string buckling deformation can be effectively reduced, the eccentric wear of sucker rod in the movement and stuck pump phenomenon of sealing piston are avoided.

(3) The field test shows that the optimized tubing string greatly extends the string’s trouble-free continuous working time to more than one year, compared with three months before optimization, and the phenomenon of wear and tear of the string are eliminated.

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