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# A Semi-Analytical Models to Investigate Performance of Herringbone Wells

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**Abstract:** For herringbone wells with antisymmetrical and curved laterals, the effects of lateral symmetry and camber on production of herringbone wells are analyzed by semi-analytical model. The effects of laterals with different angles, different number and different spans on production of herringbone wells are analyzed on this base. The results indicate that the contribution of mainbore of production is smaller than symmetrical herringbone well whereas the contribution of laterals of antisymmetrical herringbone well is bigger. The total production of antisymmetrical herringbone well is bigger than that of symmetrical herringbone well. The curved laterals will cause less production comparing with deviated laterals. The bigger the lateral angle is the higher is production of herringbone wells. The contribution of 1/3 lateral end accounts for about 50% of the total lateral contribution. While total length of laterals is the same, the production of well with two laterals on different sides of mainbore is the highest. Besides, laterals should be put as near as possible to the middle mainbore and there is an optimum span existed.

**Keywords:** herringbone well, complex structure well, semi-analytics modeling, production forecasting, laterals configuration, optimization.

## 1 Introduction

In order to enhance production of single well and achieve higher oil recovery rate, multi-lateral well technique has been widely used in oil and gas development of many oil fields like Bohai, Shengli, Jidong, Liaohe and so on with a good repay. For a better fulfillment of advantages of the herringbone well, it is quite necessary to optimize the lateral configuration on the purpose of productivity. In the previous study of herringbone wells, the general model is symmetrical one with lateral angle over 30°. However, the actual herringbone well is antisymmetrical and its lateral

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angle opens gradually to less than 20° generally. Therefore, it is significant to set a more accurate model to adapt to the fact and optimize lateral configuration for a better original production, which will provide a more practical guidance for the oil and gas development with herringbone well.

## 2 Influences to herringbone well production caused by the lateral symmetry and bending degree

The established semi-analytics model is dividing the lateral branches and the main wellbore into small sections and then giving out expressions of seepage in reservoir and wellbore flow in analytic way for each section. The seepage in reservoir is coupled to wellbore flow later to work out the pressure distribution and influx distribution of the oil well by iterative method so as to obtain productivity of the herringbone well. Because of the complexity of the herringbone well in shapes, the semi-analytics model has its own great advantages over the analytic model and the numerical model.

Fan Yuping et al concluded forecasting analysis of productivity for herringbone well with ideal configuration (having symmetrical lateral branches in vertical direction) as: it is no worthy pursuing too much big lateral branch angle of herringbone wells for it has less effects to the total production as the angle is over 45°; it would be better to have less than 3 branches in the same side with the permanent total drilling length.

In order to analyze the influences caused by the antisymmetry and bendability of herringbone well to production in practical case, the associated accumulations and comparisons were conducted in semi-analytics model, whose basic parameters were in table.1.

### *2.1 Influences of herringbone well in symmetry lateral branch to its productivity*

In order to conduct analysis contrastively of influences caused by the symmetry of lateral branches to well production, four types of herringbone wells' productions in fig.1 with different lateral angles were worked out and then did comparisons with the symmetric one respectively. According to the results in fig.2, the antisymmetrical lateral branch increased the length of interfered main wellbore, which resulted in the production decreasing of the main wellbore; meanwhile, compared with the symmetric herringbone well, different lateral branches' contributions to the main wellbore vary. Namely, production of branch 1 and 4 and both ends of the main wellbore decreased because of the interference caused by the main wellbore, while production of the two branches in the middle changed less; All in all, taking all the

Table 1: Basic Parameters

| **Name of the data** | **value** |
|---|---|
| Formation size/m | 610 * 610 * 18 |
| Formation permeability/mD | 3600(H)/ 360(V) |
| Formation porosity | 0.2 |
| Formation pressure/MPa | 14.4 |
| Producing pressure/MPa | 1 |
| Density of the fluids/ ( kg· $m^{-3}$) | 961.5 |
| Viscosity of the fuilds/cp | 380 |
| Volume factor | 1.05 |
| Wellbore radius/m | 0.089 |
| Surface roughness of the case/m | 0.0003 |
| Mainbore length/m | 400 |
| Length of laterals/m | 100 |

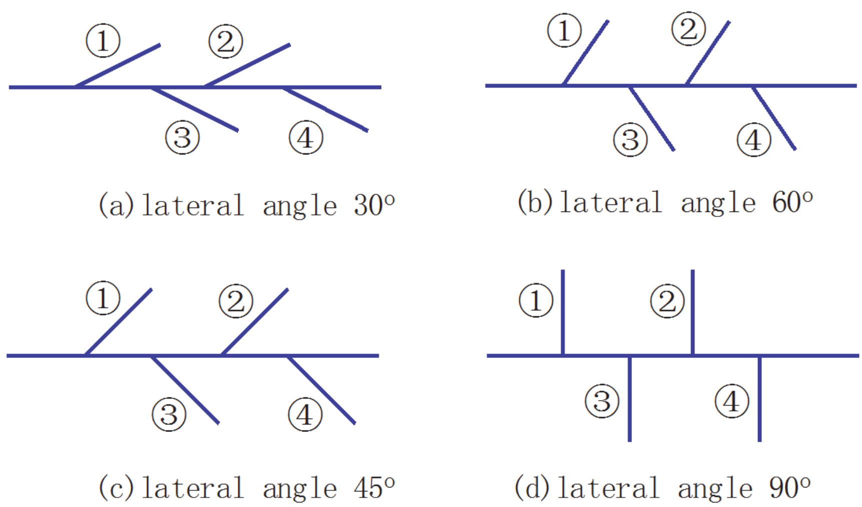


Figure 1: Schematic diagram of antisymmetrical herringbone wells with different lateral angles.

production changes into consideration, the total production amount of the antisymmetrical herringbone well is a little bigger than that of the symmetric one.

Table 2: Comparison of effect of branch symmetry on production of herringbone wells Angle of the laterals.

| Angle of the laterals /° | Production of mainbore /($m^3$•$d^{-1}$) | | Production of lateral 1 /($m^3$•$d^{-1}$) | | Production of lateral 2 /($m^3$•$d^{-1}$) | |
|---|---|---|---|---|---|---|
| | symmetric | antisymmetric | symmetric | antisymmetric | symmetric | antisymmetric |
| 30 | 33.2 | 32.0 | 6.6 | 7.8 | 8.8 | 7.2 |
| 45 | 33.4 | 32.5 | 7.0 | 8.3 | 8.8 | 7.5 |
| 60 | 33.5 | 32.2 | 7.4 | 9.6 | 8.8 | 7.6 |
| 90 | 33.5 | 32.7 | 7.9 | 9.7 | 8.6 | 7.8 |
| Angle of the laterals /° | Production of lateral 3 /($m^3$•$d^{-1}$) | | Production of lateral 4 /($m^3$•$d^{-1}$) | | Total production /($m^3$•$d^{-1}$) | |
| | symmetric | antisymmetric | symmetric | antisymmetric | symmetric | antisymmetric |
| 30 | 6.4 | 6.6 | 8.7 | 10.7 | 63.7 | 64.3 |
| 45 | 7.0 | 7.0 | 9.0 | 10.4 | 65.2 | 65.7 |
| 60 | 7.4 | 7.2 | 9.0 | 10.2 | 66.1 | 66.9 |
| 90 | 7.9 | 7.8 | 8.7 | 9.7 | 66.6 | 67.8 |

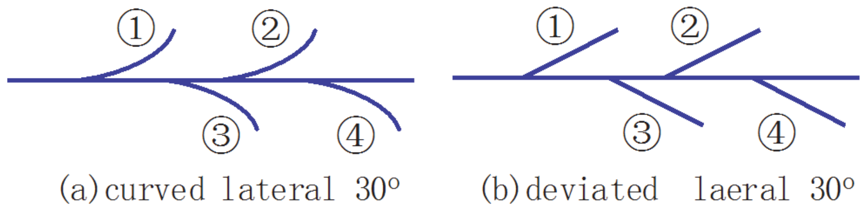


Figure 2: Schematic diagram of herringbone wells with curved and deviated laterals.

### *2.2 Influences of bendability of the herringbone well to its production*

Limited by the drilling technology, the real lateral angle of branch of the herringbone well increases gradually from the connection point between the branch and the main wellbore, which results in the curved configuration of the branch outward the main wellbore. In order to study the influences of bendability of branch to the herringbone well's main wellbore, taking the antisymmetrical herringbone well with the maximum lateral angle of the branch as 30° for an example, production and the influx profile of the curved and straight lateral branch were calculated.

The influx profile diagrams of the main wellbore and its lateral branches were shown in fig.3 and fig.4 respectively. According to the results, due to the interference of the lateral branch, the inflow of each section in the main wellbore is smaller than that of the same length of horizontal well, especially for the connection point for the main wellbore and its branch. However, influences of the curved lateral branch and the straight lateral branch to the main wellbore are nearly the same as the fig.3 indicates. While the influx profile diagrams of the curved one and the straight one are quite different, which is caused by the curved trend inward the main wellbore of the lateral branch. It results in that the influx profile of the lateral branch near the connection point moves down and that which is far away from the point moves up. According to the analysis, the production of the herringbone well with curved lateral branches is smaller than that with the straight lateral branches.

## 3 Optimization of the lateral configuration of the antisymmetrical herringbone well

### *3.1 Optimization of the angle of the lateral branch*

Limited by the drilling technology at present, the general angle of lateral branch of herringbone wells is less than $20^o$. It is significant to analyze influences caused

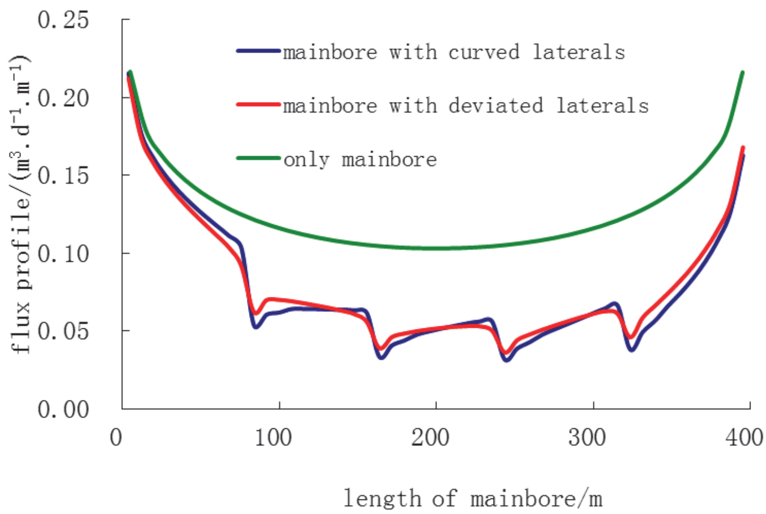


Figure 3: Inflow profile diagram of main wellbore with curved and deviated laterals.

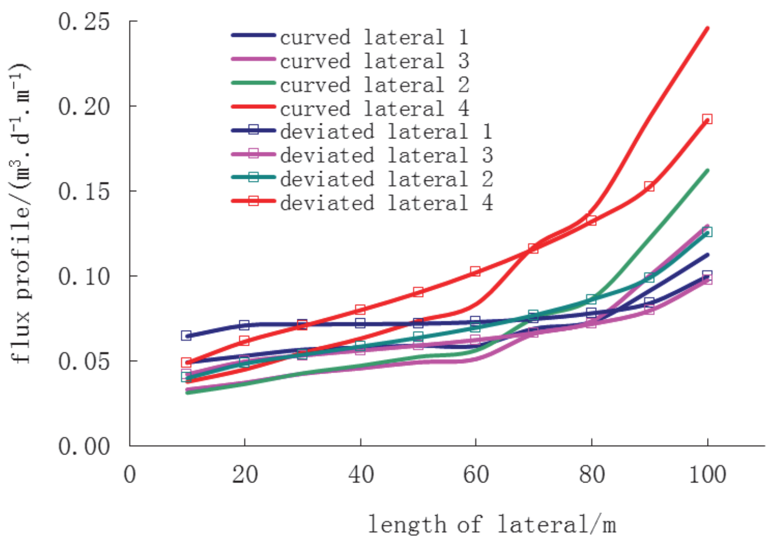


Figure 4: Inflow profile diagram of each lateral.

by different angles to the herringbone well production and contributions of each lateral branch within such limited conditions. Four types of herringbone wells with different angles of lateral branches have been worked out. The results have been presented in table.3.

As the results indicates, production of the main wellbore changes slightly when the lateral branch's angle is less than 20°. The production of each branch goes up as the angle increases. The production of its end with the 1/3 length of the whole branch accounts for 50% or so, which is due to the angle is relatively small and the section near the connection wellbore contributes little to the production. Therefore, it would achieve better results to increase the length of the lateral branch and make full use of the section far away from the connection point when the drilling technology is limited other than add another lateral branch.

### *3.2 Optimization of the number of lateral branches*

The number of lateral branches is another vital factor in the configuration of herringbone wells. With the same total drilling length, the more lateral branches mean the rise in drilling cost. In order to analyze the influences caused by the lateral branch's number to the production of herringbone wells, six types of herringbone wells with different lateral branch's numbers but the same total well length, which are shown in fig.5. Four of the six wells' lateral angle is $20^o$ and their total length is 800m.

As the calculating results indicate, the inflow of the main wellbore decreases to certain extent compared with the wellbore without lateral branches due to the branch interference as the fig.6 shows. The less lateral branches, the less effects the branch has to the main wellbore's inflow and the total inflow of the lateral branches increases at the same time. That is because the less branches means the length growth of single lateral branch and the section far away from the connection point when the well length is permanent. Therefore, the less branches the herringbone well has, the higher production it obtains. Furthermore, with the same lateral branches, the production of the herringbone well with branches at the same side is higher than that with branches at both sides. It is because even though branches at the both sides will strengthen the interference, they will also increase the well control area and well inflow. Therefore, less lateral branches and both sides' distribution of branches will improve the well production as the fig.4 presents.

### *3.3 Optimization of the distance between lateral branches*

Besides the lateral angle and number, the place of the connection points and the distance between branches also decide the configuration of herringbone well. In order to analyze the effects they have to the well production, the herringbone well with two branches at the same side which are both 130m has been chosen to conduct the contrastive analysis on the effects of different distances between branches to the main wellbore and branches' interference.

According to the table.5, the shorter distance between branches and the connection

Table 3: Comparison of effect of different lateral angles on production of herringbone wells.

| Angle of the lateral /° | Production of mainbore /($m^3$·d-1) | Production of lateral 1 /($m^3$·d-1) | | Production of lateral 2 /($m^3 \cdot d^{-1}$) | | Production of lateral 3 /($m^3 \cdot d^{-1}$) | | Production of lateral 4 /($m^3 \cdot d^{-1}$) | | Total production /($m^3 \cdot d^{-1}$) |
|---|---|---|---|---|---|---|---|---|---|---|
| | | The whole section | 1/3 at the end of lateral | The whole section | 1/3 at the end of lateral | The whole section | 1/3 at the end of lateral | The whole section | 1/3 at the end of lateral | |
| 5 | 30.8 | 6.3 | 2.6 | 5.9 | 2.9 | 5.4 | 2.5 | 9.9 | 5.9 | 58.5 |
| 10 | 31.0 | 6.3 | 2.6 | 5.9 | 2.9 | 5.4 | 2.5 | 9.9 | 5.9 | 58.5 |
| 15 | 31.0 | 6.7 | 3.2 | 6.3 | 3.5 | 5.8 | 3.0 | 10.2 | 6.3 | 60.0 |
| 20 | 31.3 | 7.0 | 3.4 | 6.5 | 3.8 | 5.9 | 3.2 | 10.3 | 6.5 | 61.0 |

Table 4: Comparison of effect of different lateral number on production of herringbone wells.

| Configuration of wells | Production of mainbore /($m^3 \cdot d^{-1}$) | Production of lateral 1 /($m^3 \cdot d^{-1}$) | Production of lateral 2 /($m^3 \cdot d^{-1}$) | Production of lateral 3 /($m^3 \cdot d^{-1}$) | Production of lateral 4 /($m^3 \cdot d^{-1}$) | Total production of branches /($m^3 \cdot d^{-1}$) | Total production /($m^3 \cdot d^{-1}$) |
|---|---|---|---|---|---|---|---|
| Four laterals at both sides | 31.3 | 7.0 | 6.5 | 5.9 | 10.3 | 29.7 | 61.0 |
| Three laterals at both sides | 32.2 | 8.9 | 13.4 | 8.5 | - | 30.8 | 63.0 |
| Three branches at the same side | 32.7 | 8.8 | 13.2 | 8.0 | - | 30.0 | 62.7 |
| Two branches at both sides | 33.5 | 13.7 | 20.5 | - | - | 34.2 | 67.7 |
| Two branches at the same side | 34.0 | 13.2 | 20.0 | - | - | 33.2 | 67.2 |
| One branch | 36.1 | 35.5 | - | - | - | 35.5 | 71.6 |

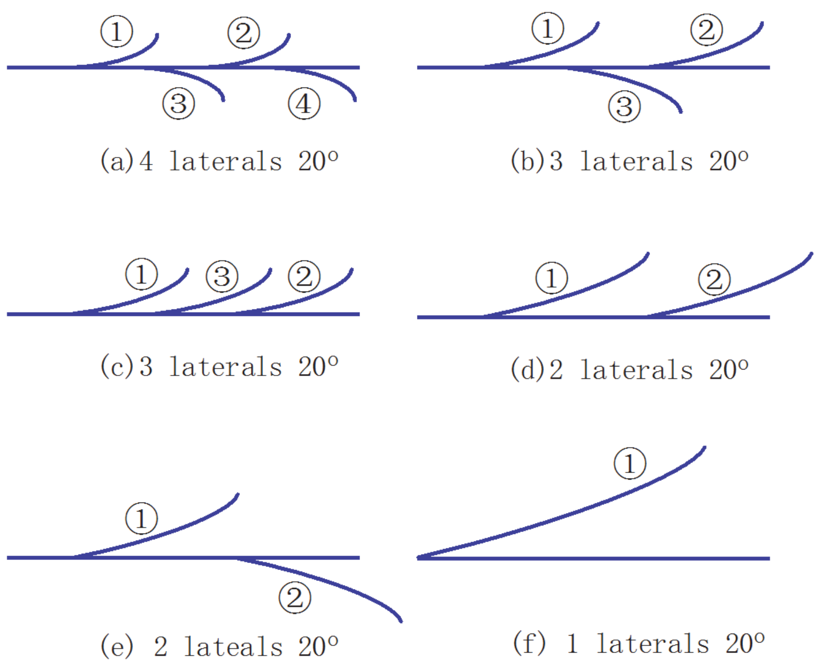


Figure 5: Schematic diagram of herringbone wells with different lateral number.

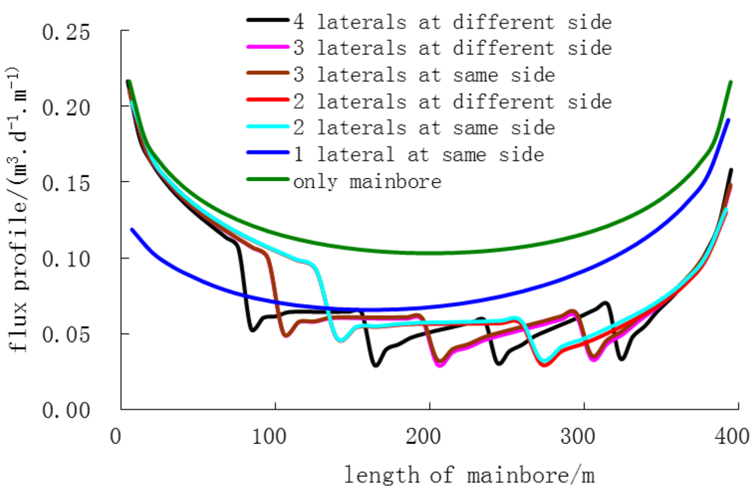


Figure 6: Inflow profile diagram of main wellbore with different lateral number.

point closer to the middle of the main wellbore perform better in well production with less interference between wellbore and branches and more inflow of the main wellbore; Meanwhile, the interference between branches also decreases and the inflow of branches increases. It is because that the influx profile diagram in "U" form indicates that the inflow at the both ends of main wellbore is higher than that of the middle part. Therefore, when the connection points at the both ends of the wellbore, inflow of the lateral branches will interfere with the inflow of the main wellbore and the mutual interference between branches will decrease as the distance lengthened. Taking the two aspects into consideration, there will be an optimal distance between lateral braches. In this paper, the optimal distance is 200m for the four types of herringbone wells mentioned above.

Table 5: Comparison of effect of different lateral spans on production of herringbone wells.

| Distance between branches /(m) | Production of main wellbore /($m^3 \cdot d^{-1}$) | Production of lateral 1 /($m^3 \cdot d^{-1}$) | Production of lateral 2 /($m^3 \cdot d^{-1}$) | Total production /($m^3 \cdot d^{-1}$) |
|---|---|---|---|---|
| 300 | 35.3 | 12.4 | 11.6 | 59.3 |
| 200 | 37.1 | 9.4 | 14.3 | 60.8 |
| 100 | 38.1 | 8.9 | 10.6 | 57.6 |
| 50 | 39.5 | 8.3 | 8.7 | 56.5 |

## 4 Conclusions

- There is a certain difference of production between herringbone well with curved and deviated lateral branches and the herringbone well in ideal lateral configuration. Therefore, the semi-analytic model for production predicting should adapt to the actual herringbone well configuration.

- When the lateral angle is less than $20^o$, the production of the main wellbore changes slightly. Production of each branch goes up as the lateral angle increases and the contribution of the branch end in 1/3 length of the whole branch accounts for 50% or so of the branch production.

- The less lateral branches the well has, the less interference it has to the inflow of the main wellbore. At the same time, the total production of branches increases. With the same lateral branches, production of the herringbone well with branches at the same side is less than that with braches at both sides of the main wellbore.

- It would be better to have lateral branches near the middle place of the main wellbore. Besides, there is an optimal distance between lateral branches in the herringbone well.

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