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The Design and Realization of Swabbing Wells Liquid Recovery Interpretation Software

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***Abstract*—To get the working fluid level data by using the liquid level detector and to interpret formation parameters is undoubtedly the hot direction of interpretation formation parameters in future; because it overcomes the traditional technical shortcomings: there are higher input costs and the high construction risks; but, it just only need install a set of liquid level detector in the wellhead of the swabbing well. This paper is based on the reservoir percolation theory and the numerical simulation method, using VS2010 in Windows, and developing a set of well testing software, which is named swabbing wells liquid recovery interpretation software (referred to as SWLRIS). This software deems the working fluid level data as input, calculates the downhole pressure and flowrate, and then interprets formation parameters. The subsequent instance application results show that the results that this software uses liquid recovery data to interpret is consistent with the results that Saphir uses measured pressure to do.**

Keywords-Well testing; Swabbing well; Liquid recovery; SWLRIS; VS2010

I INTRODUCTION

In the non-flowing well, due to lack of formation energy, the formation fluid can not be lifted to the ground by its own energy, so many wells have conducted extracting oil by means of swabbing[1]. The traditional way to obtain swabbing well formation parameters is mainly using formation testing or well testing. As this process needs undergo some construction process, for example, the formation cable testing requires download the test cable to the downhole, so there are some shortcomings: higher input costs and some construction risks[2]. In particular, shut-in well testing method has been currently adopted more in the test-oil field of the Xinjiang Karamay Oilfield. This method needs to stop production for a day or two, even if dozens of days or months in the low-permeability wells[3]; therefore, it will affect the normal production of oil filed, which may lead to the result that oil extraction plant can not properly complete the production indicators developed at the beginning of the year. When using the liquid recovery data to interpret formation parameters, we just need to place a set of ultrasonic liquid level detector in the wellhead of in swabbing wells[4-5], and let it continuously measure the working fluid level depth, and then calculates the downhole pressure from the working fluid level and interprets formation parameters by this software[6-7]. Compared to conventional well-testing method, this way to interpret formation parameters by using of the liquid recovery data is more efficient, safer, and lower cost, so it can be said that this method is undoubtedly a future important direction of well-testing development[4].

II DESIGN IDEAS AND ALGORITHMS OF SWLRIS

Based on the percolation mechanics theory, through requirement analysis, what the SWLRIS need to finish are as follows:

(1)Calculate the downhole pressure by combining the way of three-stage method with an average density of law[7-8]. That is to say, divides the fluid within normal production well bore of water cut swabbing well into three sections: Gas stage, oil stage and water stage, and then the downhole pressure is equal to the three stages fluid pressure sum; meanwhile, in calculating each stage pressure, it is deemed that this stage fluid is homogeneous and its density is a constant。

(2)Calculate production by the use of wellbore storage factor and the derivative of buildup data, and then smooth the production curve by the “curve fitting method” in order to filter singular data in the production curve. The principle of “curve fitting method” is that[9]: the liquid surface gradually pick up after declined due to the effect of formation pressure. And after a period of time, if you connect the data which is a serial of liquid depth data by continuously measuring in this process into line segments, then you can get a liquid recovery curve, which is similar to the capacitor charging curve.

(3)Use the superposition principle to improve the conventional multi-level flow method, and then the measured data can be drawn as a curve[10]. After users select a short line segment on the curve, software calculates its slope and intercept by means of least-squares regression analysis, in order to calculate the permeability K by using improved multi-level flow formula.

(4)Deem the DST flow period or the slug flow period as a seepage physical process of the downhole flowrate continuously decreasing and the downhole pressure continuously rising. Based on the ideas of Horner method, and combined DST flow period production test characteristics, the measured data can be drawn as a MFRH curve[11]. After users select a short line segment on the curve, software calculates its slope and intercept by the use of

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least-squares regression analysis, in order to calculate the skin factor S by using MFRH formula.

(5)Calculate the original formation pressure by using the typical curve matching method[12]. Its fundamental principle is firstly to draw a double logarithmic diagram including a measured pressure curve and lots of chart curves on the same page, and then to move the measured pressure curve from head to foot and from left to right in order to optimally match the measured pressure with one chart curve. After the best matching results are achieved, the original formation pressure is calculated by means of measured pressure curve longitudinal displacement.

(6)Calculate the downhole pressure data through the inversion method by using the formation parameters including the permeability, the skin factor and the original formation pressure[13]. Its fundamental principle is to combine the partial differential equation describing the oil reservoir pressure variation with the boundary conditions of well bore storage effect, to interrelate the downhole flowrate and the downhole pressure variation by using Darcy law, and to calculate the downhole pressure based on difference and iterative method, through the mutual recursive of flow and pressure.

(7)Solve the single swabbing and the total swabbing yield which is in the swabbing operation process. Its fundamental principle is as follows: firstly calculate the downhole flow data by means of the inversion method, using lots of swabbing operation related parameters, such as the swabbing time, the swabbing frequency, the working fluid level depth before and after swabbing operations; then, simulate this swabbing process and the swabbing yield which has been pumped in this process.

(8)Calculate the formation supplying liquid volume under the condition of the scheduled swabbing rules. Its fundamental principle is: firstly arrange fixed swabbing rules; next input the given swabbing operations parameters, including the maximum swabbing depth, the swabbing time, the swabbing frequency; thirdly, calculate the downhole flow data using the inversion method; finally, simulate in a time unit(or a day)the swabbing process and the formation supplying liquid volume.

III SOFTWARE FRAMEWORK AND FUNCTIONAL DESIGN

A. *Software framework design*

Based on the above requirement analysis and application of software engineering ideas, the author has designed a set of swabbing wells liquid recovery interpretation software, whose functional operation and flow chart has been shown in figure 1.

B. *Software functional requirements design*

It can be seen from the above design that the software need completed different capabilities and operation on different pages. Therefore, for each different operation, the author has designed a working mode to support the corresponding operation; moreover, different graphics pages support different working modes. For example, the pressure page can support the filter mode in order to complete the pressure data filter operation, and the chart curves page can support shift mode in order to complete the moving and matching curve operation. So, according to the function of all of the pages in the SWLRIS requirements, the author has designed five kinds of function modes. They are respectively: the mouse capture mode, filter mode, edit mode, fitting mode and shifting curves mode. In addition, in order to accomplish these function modes better, the author has designed four types of auxiliary modes, namely: selecting mode, dragging canvas mode, zooming in mode and zooming out mode. These auxiliary work modes are the pattern which all graphics pages should support.

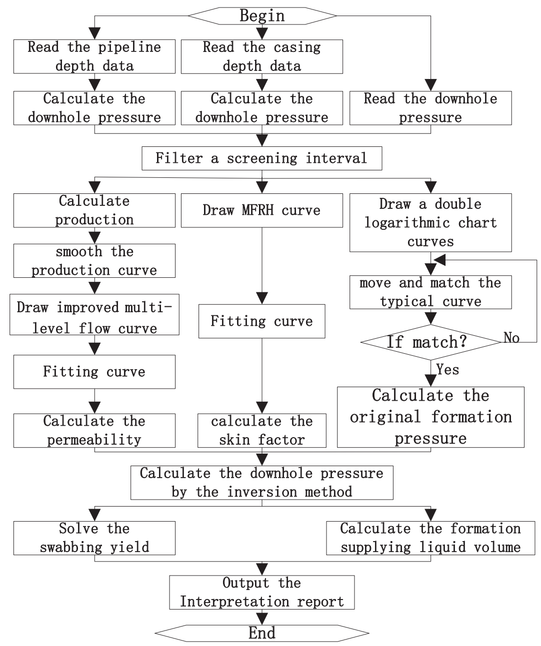

Figure 1. The functional operation and flow chart

The function of above nine modes is expounded as follows.

(1)The purpose of designing selecting mode is to make it convenient for users to select different curves according to applied needs, so that curves relevant operations can be completed. In this mode, users can either select one curve by clicking or dragging a rectangle box, or select multiple curves at the same time. In order to facilitate the distinction, key points of selected curve are shown with circular and key points of unselected curve are displayed with square.

(2)Dragging the canvas can browse local data of curves, especially those which are beyond the scope in magnified view. In this mode, dragging the left mouse button can shuffle the canvas.

(3)The purpose of designing zooming in mode is to make it convenient for users to zoom in the curve view to see curve local shape or local data. In this mode, if users click or double-click the graphics page, the software will double enlarge the curve view taking the clicking place as the center. If users drag the left mouse button to shape a rectangular area, then the software will magnify this area into entire view.

(4)The zooming out mode is usually used to match with the zoom in mode, for example, users may shrink the enlarged curve partial into an appropriate size to see the curve part or whole shape. In this mode, if users click or double-click graphics page, the software will double shrink the curve view taking the clicking place as the center.

(5)The purpose of designing mouse capture mode is to let the software real-time display the vertical and horizontal coordinates value of the mouse in the current graphics page, which is convenient for users to contrastively check the corresponding key points horizontal and vertical coordinates matching degree; For instance, in the fitting pressure page, users can contrastively check the matching degree between the calculation pressure and the measured pressure.

(6)The purpose of designing filter mode is to make it convenient for users to filter the curve singular data, in order to prevent such errors from accumulation and amplification as filtering the liquid depth data that have been read. In this mode, dragging the left mouse button can draw a screening interval, if the dragging rectangular box contains at least one curve key point. Note that if the dragging rectangular area doesn't select any curve key point, then the filter operation will not be recorded, namely filter operation fails. In addition, the model supports multi-range filter. And if the screening interval number does not meet the calculation requirements, the software will automatically prompt users. If wanting to move the screening interval, users can place the mouse within the selection range and drag the mouse. And if users want to change the screening interval size, they can move the mouse and drag where the screening interval edge eight control points. This process is similar to the Windows system to change a form's window size, as is shown in figure 2. If users prefer to delete a screening interval, they can move the screening interval that does not contain any key point position, and then it will automatically disappear.

(7)The purpose of designing edit mode is to make it convenient for users to delete the key points. Some singular data, especially those who still can not be removed by using the filtering operation, can be eliminated in the edit mode in order to prevent errors from accumulation and amplification. To deleting a key point just needs click or double-click this key point.

(8)The purpose of designing fitting mode is that, after users select a short straight line segments, the software can fit a straight line, then calculates its slope m and intercept b by least-squares method to facilitate the calculation method computing the formation parameters using this slope and intercept. For example, in solving the permeability, users need fit the improved multi-level curve, as is shown in figure 3. To facilitate filtering singular points and fitting out of a satisfactory straight line to a maximum degree, this model supports a variety of ways to choose whether to fit one key point: users can either click or double-click to select a key point, can drag to shape a rectangle area to select all the key points within the scope of it, and can also use the Ctrl key or Shift key to cooperate with making multiple selections.

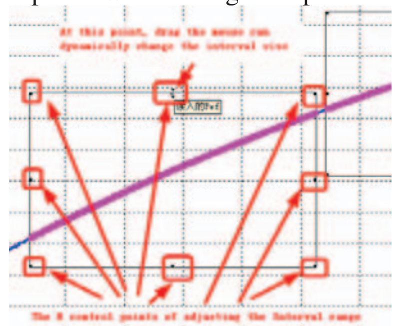

Figure 2. How to adjust the size of a screening interval

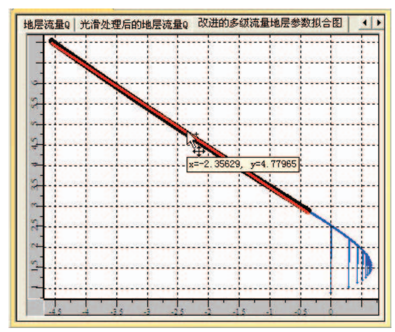

Figure 3. The screenshot of fitting improved multi-level curve

(9)The purpose of designing shifting curves mode is that, in the typical curve matching method calculation, the pressure curve under the double-logarithmic coordinates need to be moved in order to calculate formation parameters. In this mode, to move the pressure curve from head to foot, from left to right, users not only can directly drag with the mouse but also can use the navigation keys. Among them, in using the navigation key move, users can cooperate to use the Shift key or Ctrl key, but difference lies in that the former can move to a larger extent while the latter only can move smaller.

To set the graphics page in one of above model, users just need click the corresponding toolbar button; of course, a prerequisite is that this graphics page supports this mode page; otherwise, the corresponding toolbar button displays for gray and is unavailable. In addition, the mouse style under above nine function modes are designed to be different from each other, to facilitate users to judge the function mode of current graphics page by using the mouse style.

Following the above design ideas, the software main interface is achieved as is shown in figure 4. Judging from the figure, the interface can be divided into six parts: the top menu and toolbar operation area, the left calculation steps console, the intermediate drawing results view, the right curve properties display area and the below status bar.

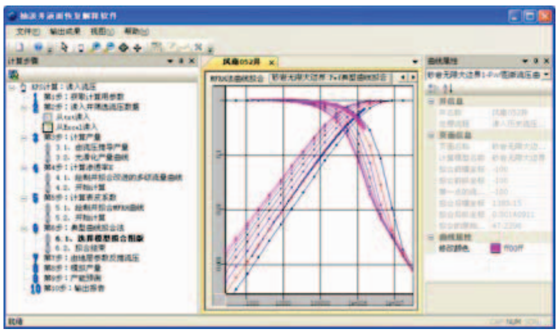

Figure 4. The SWLRIS main interface

IV THE INSTANCE APPLICATIONS OF SWLRIS

To inspect the SWLRIS interpretation results, the author carries out evaluation on 5 Wells layers by using the SWLRIS, and makes a comparison with the results interpreted by Saphir using the measured pressure, which is shown in table 1.

TABLE I. THE INTERPRETATION RESULTS COMPARATIVE TABLE

Wells/ layers		**SM2 Well**	**H401 Well S1 layer**	**H401 Well S2 layer**	**F3 Well**	**M13 Well**
Saphir interpretation results	**K**	0.03286	0.07975	0.07975	0.01418	0.038
	Pi	67.481	14.135	12.746	112.715	47.237
	S	6.9	-4.21	-2.13	-2.14	-1.43
SWLRIS interpretation results	**K**	0.02934	0.08637	0.08132	0.0136	0.0395
	Pi	70.016	13.54	13.34	107.14	45.445
	S	6.556	-3.85	-2.093	-2	-1.34
Error	**K**	10.712	8.301	1.969	4.09	3.947
	Pi	3.757	4.209	4.66	4.946	3.794
	S	4.985	8.551	1.737	6.542	6.294

Judging from the Table 1, in the existing simple reservoir model, comparing the SWLRIS interpretation results with the Saphir interpretation results; it can be seen that the permeability K error is less than 11% and the average error is 5.816%; the original formation pressure Pi error is less than 5% and the average error is 4.273%; the skin factor S error is less than 9% and the average error is 5.622%.

V CONCLUSION

(1)This paper, based percolation mechanics theory, has given the calculation downhole pressure formula and the formation parameters interpretation method, and has completed the SWLRIS requirements analysis.

(2)The ideas of applying software engineering, has designed the basic structure framework and related functions of the SWLRIS, and has elaborated the design goal, operating methods and precautions of these function mode, and also, has developed SWLRIS using Visual Studio 2010 in Windows XP environment.

(3)The application of SWLRIS in Xinjiang Karamay five well-tier shows that the software interpretation results are consistent with the results of conventional interpretation method, such as Saphir, therefore it has good practical value.

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REFERENCES

1. Xu Chun-bi,Huang Bing-guang,Li Shun-chu, et al.Development and Solution of a New Mathematics Model in Swabbing Well-testing Analysis[J].Journal of Southwest Petroleum University(Science & Technology Edition),1999,21(2):1-4.
2. SPE Annual Technical Conference and Exhibition. 1998: New Orleans, Louisiana
3. Tian Leng,He Shun-li,Li Xiu-sheng, et al.Calculating method of shut-in time for pressure survey in production wells in low permeability oil reservoirs and its application[J].Petroleum Exploration and Development,2007,34(2):226-229.
4. Chen Dianfang,Han Xingli,Yang Jing.Discuss on Survey Method for Liquid Level of Oil Well[J].Well Testing,2008,17(2):60-61.
5. Fu Ya-li,Yu Xiu-juan,Lin Zhong-yu.SL-MSL-I-automatic liquid level monitor performance analysis[J].Journal of Daqing Normal University,2006,26(2):35-38.
6. Gu Shang-hong.Application of echo data calculated surface pressure pumping oil wells in central reservoir[J].Oil Driling & Production Technology,1983,5(5):79-82.
7. Zhou Ji-de,Wan Ya-hui,Zhang Xiao-qin.To Calculate The Formation Pressure Of Mechanical Producing Wells Using Three-Stage Method[J].Petroleum Geology &Oilfield Development in Daqing,2000,19(3):30-31.
8. Zhou Jide.Method For Pressure Calculation In Pumping Wells[J].Petroleum Geology & Oilfield Development in Daqing,1986,5(3):57-65.
9. Yang Chen-xi. A preliminary study of Liquid oil recovery curve and its application[J].Xinjiang Petroleum Geology,1988,9(2):59-63.
10. Lin Jia-en,Zhang Lian-zhong,Han Feng-rui, et al.A New method of directly comprehensive well test interpretation of multiple variable flow rate[J].Petroleum Geology and Recovery Efficiency,2006,13(4):99-101.
11. Yu Shao-yong.A new method of historical analysis of the DST pressure[J].Drilling & Production Technology,1991,14(4):45-50.
12. Chen Yuan-Qian.Determining Reservoir Pressure from Type Curve Graphs[J].Petroleum Geology & Oilfield Development in Daqing,1987,6(4):37-44.
13. Liu Hong,Wang Xin-hai,Yang Feng, et al.The Pressure Response Feature of Low Permeability and Triple-media Reservoirs[J].Journal of Oil and Gas Technology,2011,33(8):134-137.