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Fluid Flow Analysis of Hydraulic Coring System for Offshore Gas Hydrate Research

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Abstract

Evaluation of gas hydrate deposits has imposed a large number of explorations. This has involved the design of new drilling and logging tools. In this paper are presented the results of the analysis of the fluid flow in the coring HRC used for logging works for offshore gas hydrate. The analysis showed the correlation between pressure losses in the flow system with pressure loss on the hydraulic motor. Has been carried out and a numerical analysis with bay-pas FLOTRAN area. The results confirmed the analytical method of the analysis of the fluid flow.

Key words: *coring system, flow, FEM, gas hydrate*

Introduction

Logging works for offshore gas hydrate have used different types of coring system. In Figure 1 is shown core HRC [1]. Of particular importance in the functioning of this system is accurate evaluation of correlation flow-loss of pressure on different areas. Still, an analytical method is presented for the evaluation of local pressure loss depending on the geometry of the space of flow and flow.

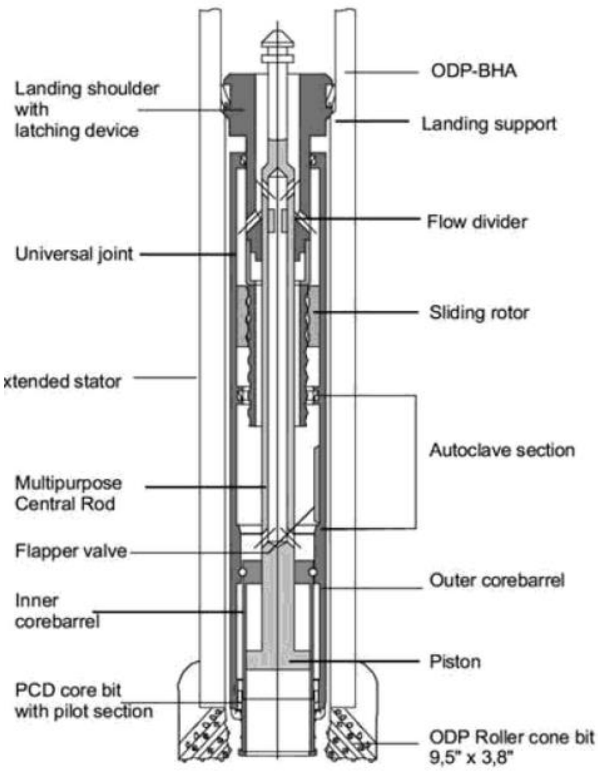

Fig. 1. HRC coring system [1]

Theoretical Approach

Loss of pressure in moving Newtonian fluids to pipes can be estimated by the fallowing parameters:

- Line loss of pressure (defined by Darcy) is given by [2]:

$$\Delta p_d = \lambda \frac{L}{D} \frac{\rho v^2}{2} \quad [\text{Pa}] \qquad (1)$$

- Local loss of pressure is given by:

$$\Delta p_l = \xi \frac{\rho v^2}{2} \quad \text{[Pa]} \tag{2}$$

where: L is length of pipe, in m; D – diameter of pipe, in m; ρ – density of fluid, in kg/m^3; v – speed of fluid, in m/s; λ – line loss of pressure factor (is function by rate of flow and state of wall of pipe); in laminar motion ($\mathrm{Re} = \dfrac{\rho v D}{\mu}$ < 2300) (μ – dynamics viscosity, in kg/m·s) the λ factor is given by:

$$\lambda = \frac{64}{\mathrm{Re}}, \tag{3}$$

and in turbulent motion (defined by Celebrook and White) the λ factor is given by [2]:

$$\lambda = \frac{1}{\left[-2\lg\left(\dfrac{2{,}51}{\mathrm{Re}\sqrt{\lambda}} + \dfrac{k}{3{,}71D}\right)\right]^2}; \tag{4}$$

where k is apparently roughness of pipe, in m; ξ – local loss of pressure factor.

For pipe with ring section is used the equivalent diameter D_e:

$$D_e = (D-d)\sqrt{\frac{\left[1+\left(\dfrac{d}{D}\right)^2\right]\ln\left(\dfrac{d}{D}\right)+\left[1-\left(\dfrac{d}{D}\right)^2\right]}{\left(1-\dfrac{d}{D}\right)^2\ln\left(\dfrac{d}{D}\right)}}; \tag{5}$$

where d is inside diameter and D – outside diameter to flow section.

The pipes are classified in function by $\lambda L/D$ factor thus:

- If $\lambda L/D > 50$ then, we have long pipe and in this case the line loss of pressure are important and the local loss of pressure are neglected;
- If $0.2 < \lambda L/D \leq 50$ then , we have little pipe and in this case the line loss and local loss of pressure are considerate.
- If $\lambda L/D < 0.2$ we have short pipe and in this case the line loss of pressure are neglected.

Pipes in series connection

In the pipes in series connection system the equations of energy and continuity give us the next system of equations:

$$Q = Q_1 = Q_2 = \ldots = Q_i = \ldots. = Q_n, \tag{6}$$

$$\Delta p = \Delta p_1 + \Delta p_2 + \ldots + \Delta p_i + \ldots. + \Delta p_n = \sum_{i=1}^{n}\left(\lambda_i \frac{L_i}{D_i} + \xi_i\right)\frac{\rho v_i^2}{2}, \tag{7}$$

where Q is total fluid flow, and Δp the total loss of pressure.

Pipes in parallels connection

In the pipes in parallels connection the equations of energy and continuity give us the next system of equations:

$$Q = Q_1 + Q_2 + \ldots + Q_i + \ldots. + Q_n, \tag{8}$$

$$\Delta p = \Delta p_1 = \Delta p_2 = \ldots = \Delta p_i = \ldots. = \Delta p_{n.} \tag{9}$$

If we know the total loss of pressure Δp we can calculate the total fluid flow:

$$Q = \sum_{i=1}^{n} K_i \sqrt{\Delta p}\ , \quad [\mathrm{m^3/s}] \tag{10}$$

where

$$K_i = A_i \sqrt{\frac{2}{\rho\left(\lambda_i \dfrac{L_i}{D_i} + \xi_i\right)}}\ , \tag{11}$$

A_i is the sectional area from *i* pipe, in m^2.

The Hydraulic Model from HRC

In HRC system the fluid is used, on the one hand for hydraulic motor and on the other hand for washing the bottom of well and clearing the cuttings. For this the fluid traverses lots holes and annular spaces, what can be assimilate with pipes in series and parallels connection.

In Figure 2 is presented the hydraulic model of HRC. Each zone was divided in sections what have distinct geometrical dimensions (figs. 3, 4 and 5). The sections 1.2, 1.4, 2.1, 2.4, 3.1 and 4.1 correspond to pipes in parallels connection. The other sections correspond to pipes in series connection.

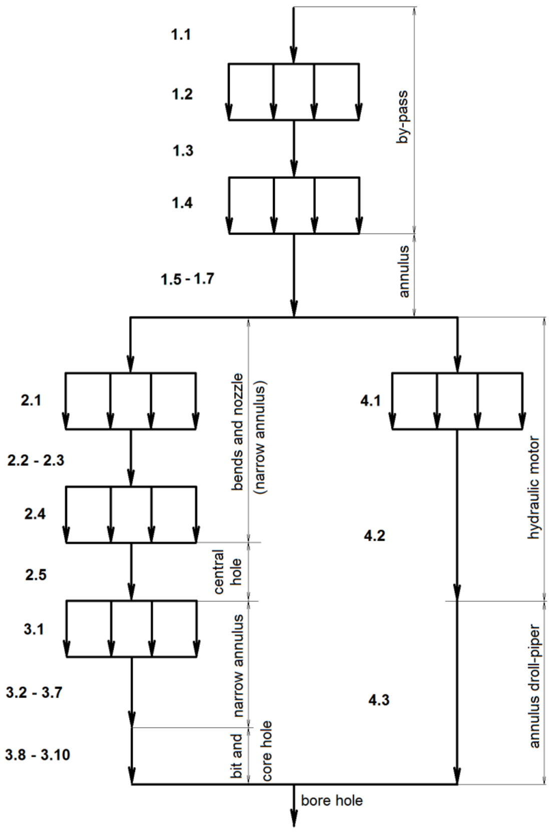

Fig. 2. The fluid flow in coring system

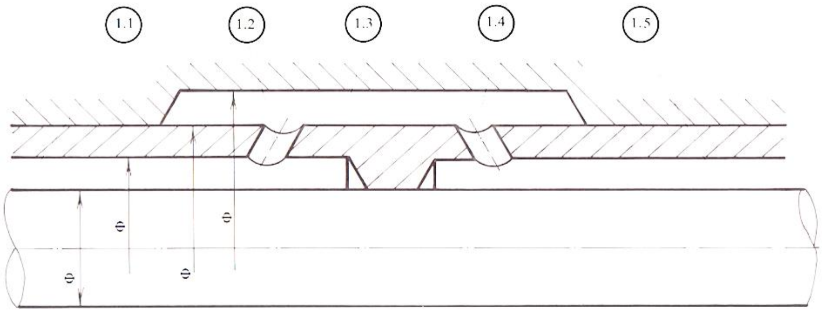

Fig. 3. The flow geometry of by-pas and annulus

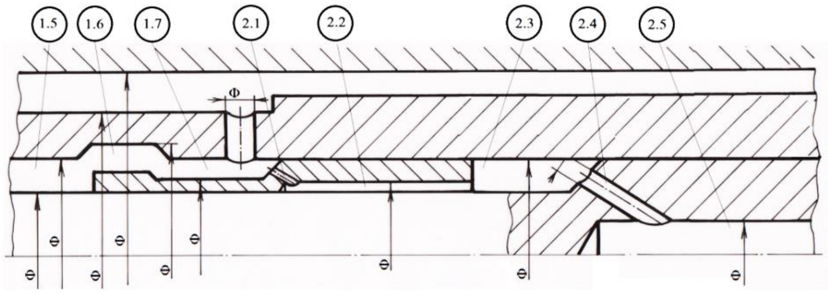

Fig. 4. The flow geometry of bends and nozzle and central hole

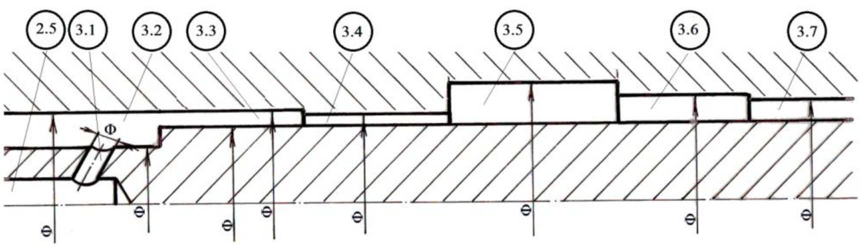

Fig. 5. The flow geometry of narrow annulus

Calculus of loss pressure

Because the route of fluid is consisting from pipes with small diameters the losses of pressure are important. For this is important to know the flow and the pressure for hydraulic motor and for the core. If Q is total flow then:

$$Q = Q_m + Q_c \tag{12}$$

where Q_m is hydraulic motor flow, Q_c – core flow.

In concordance with the theoretical consideration:

$$\Delta p = \Delta p_m = \Delta p_c \tag{13}$$

that is loss of pressure in core zone Δp_c is the same wits the loss of pressure in motor zone Δp_m.

Loss of pressure in core zone (1-2-3)

In concordance with the theoretical consideration (§.1) was calculated the line and local loss of pressure in core zone in situations when the motor flow was closed.

Table 1. The loss of pressure in coring system for Q = 81 l/min.

Name of section	Nr. of section	Section A mm^2	D_e mm	L mm	Re	Line loss of pressure k = 0,01mm		Local loss of pressure	
						λ	Δp_d Pa	ξ	Δp_l Pa
by-pass	1.1	490.1	9.798	170	13190	0.031	$1.131 \cdot 10^3$	-	-
	1.2	50.3	8	-	-	-	-	0.3	$3.71 \cdot 10^3$
	1.3	1428.6	13.881	40	6402	0.036	26	-	-
	1.4	50.3	8	-	-	-	-	0.3	$3.71 \cdot 10^3$
annulus	1.5	490.1	9.798	5216	13190	0.031	$3.469 \cdot 10^4$	-	-
	1.6	452.4	-	-	-	-	-	0.35	$2.25 \cdot 10^3$
	1.7	273.3	-	-	-	-	-	0.35	$2.25 \cdot 10^3$
bends and nozzle	2.1	7.1	3	-	-	-	-	0.35	$1.326 \cdot 10^4$
	2.2	66.0	1.63	60	16340	0.037	$1.556 \cdot 10^5$	-	-
	2.3	97.4	-	-	-	-	-	0.9216	$1.059 \cdot 10^5$
	2.4	19.6	5	-	-	-	-	0.3	$3.82 \cdot 10^3$
central hole	2.5	78.6	10	5195	83590	0.023	$9.554 \cdot 10^5$	-	-
narrow annulus	3.1	50.3	8	-	-	-	-	0.3	$3.71 \cdot 10^3$
	3.2	2209.3	-	-	-	-	-	0.35	60
	3.3	654.2	5.714	355	5752	0.038	$2.755 \cdot 10^3$	-	-
	3.4	179.1	1.633	555	6004	0.043	$2.272 \cdot 10^5$	-	-
	3.5	2315.3	18	475	5112	0.038	93	-	-
	3.6	1608.5	13	100	5350	0.038	56	-	-
	3.7	855.3	7.35	155	5657	0.038	543	-	-

Table 2. Total loss of pressure.

Zone	Δp [bar]		
	Q = 81 l/min k = 0.01mm	Q = 70 l/min k = 0.01mm	Q = 60 l/min k = 0.01mm
1	8.831	0.638	0.477
2	28.256	17.138	12.698
3	3.94	3.085	2.244
Total	33.027	20.861	15.419

Table 3. Loss of pressure in bit.

Section	Nr. of section	Δp [bar]		
		Q = 81 l/min	Q = 70 l/min	Q = 60 l/min
Bit	3.8	1.334	1.003	0.732
Core hole	3.9	2.201	1.702	1.286
	3.10	0.405	0.380	0.229

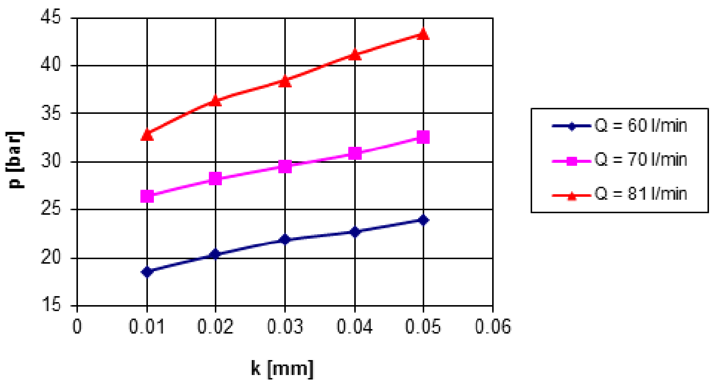

Fig. 6. The correlation between pressure loss, k factor and flow rate

The numerical applications was do with: ρ = 100 kg/m^3; μ = 1.519·10^3 kg/m·s, k = 0.01 ... 0.05 mm, Q = 81 l/min; 70 l/m; 60 l/min. The results, for Q = 60 l/min are presented in Table 1.

In Table 2 are presented the loss of pressure for each zone. The Δp values for bit and core hole zone are presented in Table 3. Figure 6 is presenting the correlation between pressure loss, k factor and flow rate.

The loss of pressure for 2+3 zone is:

$$Q = 81 \text{ l/ min} \rightarrow \Delta p_{2+3} = 32.196 \text{ bar};$$

$$Q = 70 \text{ l/ min} \rightarrow \Delta p_{2+3} = 20.223 \text{ bar};$$

$$Q = 60 \text{ l/ min} \rightarrow \Delta p_{2+3} = 14.942 \text{ bar}.$$

In concordance with (13) and because hydraulic motor need, for n = 113 1/min Q = 244 l/min for Δp_m = 8 bar, the difference $\Delta p = \Delta p_{2+3} - \Delta p_m$ represents the loss of pressure in 4.3 section.

FEM model

Because the values of local loss of pressure factor ξ are establish empirically, in HRC hydraulic model the local loss of pressure must be calculate with more accurate.

For this can use FEM and Flotran soft. The FEM allow calculating with more accurate the loss of pressure and the distribution of speed but require much time.

For example was modelled the by-pass zone (fig.7 and 8).

The loss of pressure was calculated for Q = 60 l/min (see fig. 7 where is presented the distribution of speed). Can see that the loss pressure in out section is

$$\Delta p = 14365 \text{ Pa} = 0.14365 \text{ bar (fig. 6 – brown color)}.$$

Because the analytical value of loss of pressure in by-pass zone was (tab. 1)

$$\Delta p = 0.1131 + 0.0371 + 0.0371 = 0.1873 \text{ bar},$$

we can validate the analytical model (fig. 2).

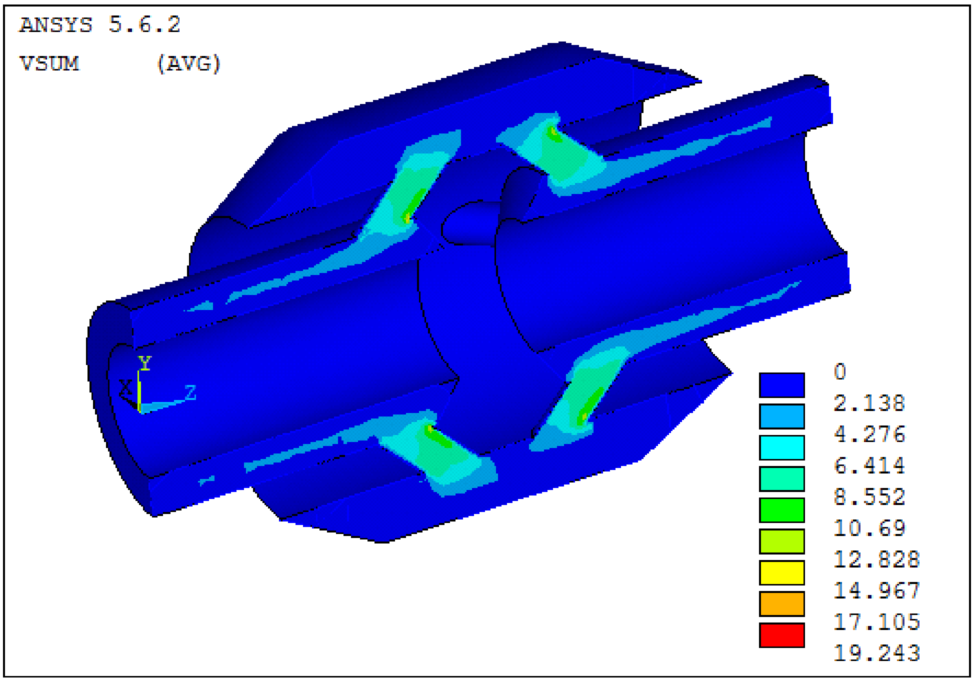

Fig. 7. The distribution of speeds in by-pass for Q = 60 l/min

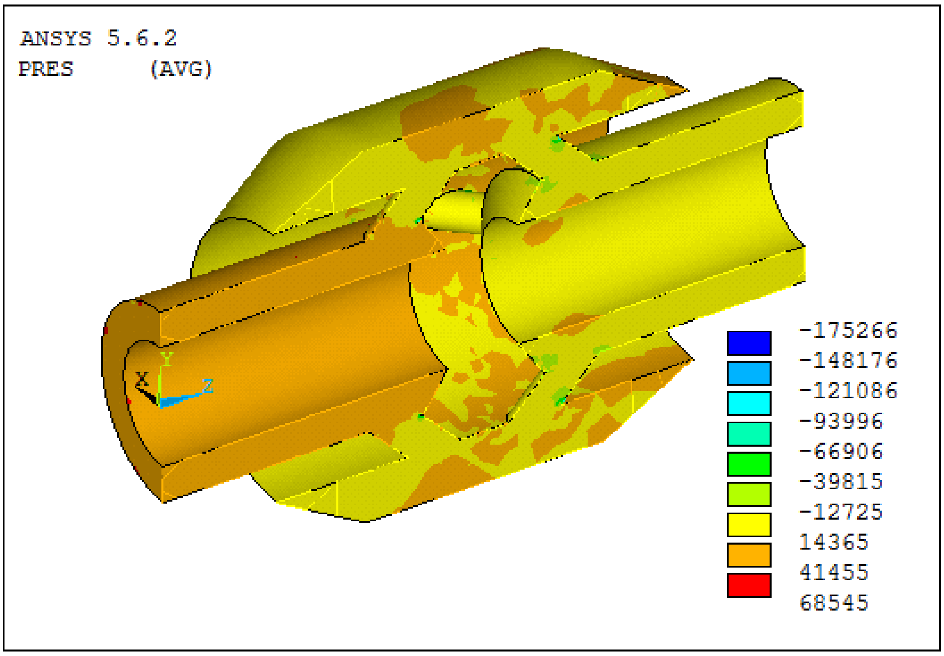

Fig. 8. The distribution of pressures in by-pass for Q = 60 l/min

Conclusions

Evaluation of loss of pressure falls for coring system for offshore gas hydrate research is an important issue in the process of prospecting and drilling. The proposed analytical model for HRC core, validated numerical analysis carried out for the by-pass area, can be applied and for other geometries of flow. Based on the results can correlate with hydraulic motor flow pressure drop so as to ensure optimal functioning of the system of the coring system for offshore gas hydrate.

References

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Calculul hidraulic al carotierei pentru prospectarea hidraţilor de metan

Rezumat

Evaluarea căderilor de presiune in carotiere este o problemă importantă în procesul de foraj de prospecţiune. Modelul analitic propus pentru carotiera HRC, validat de analiza numerică efectuată pentru zona baipasului, poate fi aplicat şi pentru alte geometrii de curgere. Pe baza rezultatelor se poate corela debitul motorului hidraulic cu căderea de presiune astfel încât să se asigure o funcţionare optimă a sistemului de carotare.