International Journal of Research in Engineering and Science (IJRES)
ISSN (Online): 2320-9364, ISSN (Print): 2320-9356
www.ijres.org Volume 3 Issue 11 ǁ November. 2015 ǁ PP.29-33

The Design of Hydraulic Distribution Module of Subsea Distribution Unit

LeFang,Yan Cui
(Shanghai University of Engineering Science, Shanghai 201620,China)

Abstract: The paper analyses the structure of hydraulic distribution module. For piping structure design and calculation of the hydraulic distribution module, it analyzes the uniformity of fluid distribution in the pipeline, considering the condition that the multi-port well are working simultaneously. The finite models of 5 kinds of schemes are established that are set according two factors of the diameter of main pipe and distance between branch pipes, on the premise of other factors unchanged. And they are simulated combining with engineering cases by the FLUNET software. The results show that the scheme gets a good distribution uniformity in which the diameter of main pipe is 1/2 in, and the distance between branch pipes is 20in. It also determines the design steps of the pipe structure of hydraulic distribution module.

Keywords:subsea distribution unit; hydraulic distribution module; pipe structure design; distribution uniformity.

I. PREFACE

With the development of global economy, the increasing demand for energy, especially fossil energy, consumption growth is much higher than production growth around the world.Global land and shallow sea after a long period of exploration and development, the number of major oil and gas discovery has less and less, the scale is becoming more and moresmall. The proportion of deepwateroil and gasexploration and development field exploration and development are increased in the global oil and gas exploration and development.Therefore, with the vigorous development of ocean oil and gas industry,subsea production system are widely used which is one of the main development mode of the deepwater oil and gas fields [1].

Subsea production system is the important development modeof the deepwater oil and gas field, and subsea control system is the key subsystem, which keepsubsea production system operation safely and effectively. Subsea distribution(SDU) as the hub of the subsea control system, controls the hydraulic fluid, chemicals, electric power and signal which come from the umbilicalterminal distribute to subsea X-mas tree, manifold valve, injection point and underwater control module. SDU is mainly composed ofhydraulic distribution module, electrical distribution module, umbilical terminals and infrastructure [2-3]. The hydraulic distribution module (HDM) is the key among SDU design. HDM is also an important part of subsea hydraulic control system, so the in-depth study of HDM is beneficial to our country to form independentdesign and manufacturingcapacityofsubsea distribution unit as soon as possible.

II. OVERALL ANALYSIS OF THE HYDRAULIC DISTRIBUTION MODULE

Subsea distribution unit can be divided into monomer type,modular structure type and manifold integrated type. The principle of these three kinds of SDU is basically same in electric power, signal and principle of hydraulic fluid and chemical distribution [4]. The main function of HDMis distributing the high and low pressure hydraulic fluid which is from umbilical terminal. Then the fluid gothrough hydraulic flyinglead to multiple underwater facilities. HDMconsist of the structure framing, fluid pipeline, multiple quick connect(MQC) stab plate, ribbed plate and subsea robot operating handle components[5].Among them, the structure framework plays a role in protecting the internal fluid piping and other components.Internal fluid pipeline is an important component for distribution of hydraulic fluid and chemicals. If necessary HDM might be set robot (ROV) operated isolation valve in the input and output ports to isolate the fault fluid piping.MQC stab plate is designed in two mating halves, an outboard on the flying lead, and an inboard plate on the HDM. The plate realizes fast connection and separation of multiple hydraulic pipes [6]. The chequeredplate not only can reduce the weight of the structure and the probability of pipeline damage, also facilitate the ROV to observe the internal structure.

The structure framework of the HDMnormally is a cuboid, which benefitinstallation of other parts components and operation of the ROV.[7]There are lifting eyes at the top of Structure , the shape design at the bottom, which was used to connected to theinfrastructure. Its four sides have several piece of operation panel. MQC stab inboardplateis the input and output interface of HDM, and the plate is fixed by bolt onthe operation panel.

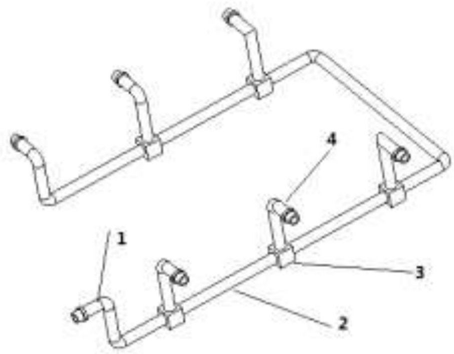
Among the deepwater work condition, HDM is setisolation valves in the input and output pipes. It not only can isolate the fault fluid pipeeffectively, and extend the life of the subsea distribution unit online, also facilitate online repair.

Internal piping design is the main components to realize of distribution function, it is also one of key designof hydraulic distribution module. So, the author takesengineering parameters of oil field in the South China Sea as example to design low pressure hydraulic pipeline of HDM.

III. PIPING DESIGN OF HYDRAULIC DISTRIBUTION MODULE

3.1 Hydraulic piping design

The pipeline of HDM mainly divided into low pressure hydraulic pipeline, high pressure hydraulic pipe lines andchemical pipeline, but their structure design and layout structure basically similar. The author takes low pressure hydraulic distribution pipeline as the research object, its structure is shown in figure 1.Theoverall structure of hydraulic control line is the symmetrical arrangement of six branch pipeline. The input and output ports of hydraulic distribution lineare Settings on the MQC stab plate, and the tee structure is used to realizefluid branch. Hydraulic fluid from the umbilical terminal goes into input port, then through tee structure distributing the fluid, finally flow outfrom branch output port. Each branch can set a ball isolation valve thatachieves the isolation fault hydraulic pipeline. The isolation valves are usually operated by underwater ROV.



1. Hydraulic couple connector on the stab plate(input port) 2. Hydraulic pipeline 3.Tee branch structure 4. Hydraulic couple connector on the stab plate(input port)

Fig.1 A pipeline structure of hydraulic distribution unit

The design schemes of SDU's internal hydraulic linehave a direct impact on the performance of control system. Hydraulic pipeline structure design should meet variety of complex working conditions of the subsea production system. Thanks to the HDM, subsea production control system not only can supply hydraulic fluid to subsea control module on the single well, but can ensure the supply of hydraulic fluid to open valves of the multi wells

Actuator ofsubsea X-mas tree has two automatic shutdown protection functions,that the first level is in SCM control valve, and the second level is on the actuator[8]. If multi SCMs receive control signal, the internal hydraulic distribution line structure of SDU must be considered to ensure that after the distribution hydraulic fluid can still drive actuatorsin order opening and closing the corresponding valves, without affecting the other opened valve.Pipe diameter between SDU and SCM usually can be determinedaccording to hydraulic line damping matching, therefore this paper set hydraulic pipe diameter of input pipe and output pipe as 1/2in. Combined with multiple well SCMs open tree valve at the same time, this paper design the internal pipeline structure of hydraulic distribution module. When multiple tree actuators work at the same time, the hydraulic system shall ensure provide enough hydraulic fluid to openvalves in the subsea X-mas tree. So HDM should have certain uniformity under this condition.Using uniformity as experiment index, the main parameters affecting the flow distribution is the diameter of main duct and spacing between each branch pipe. Each factor is set high, medium and low three levels, thus it can design 9 group experiments to determine how the two factors influenced SDU's hydraulic distribution line uniformity. The simulation results are show in table 1 below.The five kinddesign schemes of low pressure hydraulic pipeline of HDM in table 1 can achieve analysis aim, and get optimization scheme of internal pipeline design of SDU.

Table1The design scheme of inner hydraulic pile

	Diameter of main duct(in)	Space between each branch pipe(in)
Schemes 1	1/2	12
Schemes 2	1/2	20
Schemes 3	1/2	22
Schemes 4	3/4	20
Schemes 5	1	20

3.2 Pipeline structure internal flow field numerical simulation

Hydraulic fluid flow is turbulent flow in the hydraulic distribution module. The flow of fluid in the pipe should satisfy mass conservation, momentum conservation, energy conservation, equation of state, etc.The flow in the pipeline of Hydraulic distribution module are complicated, the numerical simulation adopts standard $\kappa-\varepsilon$ turbulence model.

Among the model, turbulent kinetic energy κ and turbulent dissipation rate ε are two basic unknown quantities that represent turbulent viscosity.And the matching transport equation is:

Transport equation of turbulent kinetic energy κ:

$$\rho U_i \frac{\partial \kappa}{\partial x_i} = \mu_t \left(\frac{\partial U_j}{\partial x_i} + \frac{\partial U_i}{\partial x_j}\right)\frac{\partial U_j}{\partial x_i} + \frac{\partial}{\partial x_i}\left\{\left({}^{\mu_i}/_{\sigma_\kappa}\right)\frac{\partial \kappa}{\partial x_i}\right\} - \rho\varepsilon (1)$$

Transport equation of turbulent dissipation rate ε:

$$\rho U_i \frac{\partial \varepsilon}{\partial x_i} = C_{1\varepsilon}\left(\frac{\varepsilon}{\kappa}\right)\mu_i \left(\frac{\partial U_j}{\partial x_i} + \frac{\partial U_i}{\partial x_j}\right)\frac{\partial U_j}{\partial x_i} + \frac{\partial}{\partial x_i}\left\{\left({}^{\mu_i}/_{\sigma_\varepsilon}\right)\frac{\partial \varepsilon}{\partial x_i}\right\} - C_{2\varepsilon}\rho\left(\frac{\varepsilon^2}{\kappa}\right) (2)$$

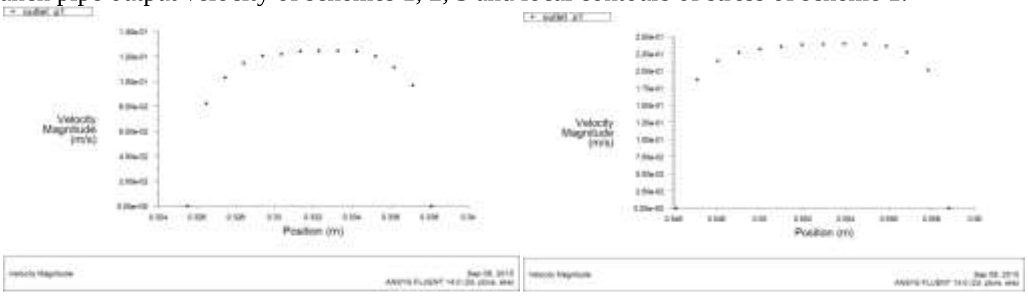
According to engineering parameters, hydraulic pipe inlet flow of HDM is set as 10L/min (1.32m/s). Subsea production control system uses high water-based hydraulic fluid as hydraulic fluid.High water-based hydraulic fluid parameters are as follows: density 999.1kg/m^3, kinematic viscosity 8.49235×10^{-04}kg/(m`s). Pipeline structure of HDMis the symmetric, so the numerical calculation can be simplified as two-dimensional geometric model. Applying structure grid and windward first-order solver method, the numerical research on this pipeline is presented [10].Each branch pipe output mass flow rate of each scheme is calculated by Fluent, as shown in table 2.

Table 2 The mass flow rate of each branch output

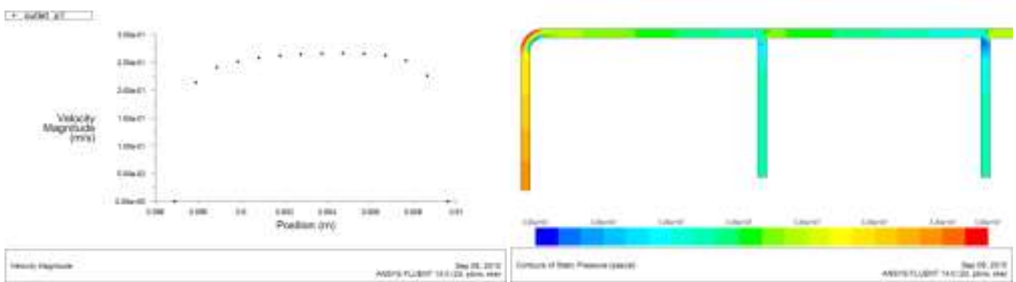
	Branch pipe 1	Branch pipe 2	Branch pipe 3	Branch pipe 4	Branch pipe 5	Branch pipe 6
Schemes1	1.39	3.00	2.94	2.90	2.66	4.24
Schemes 2	2.82	3.04	3.02	2.74	2.41	3.12
Schemes 3	3.15	3.33	3.14	2.74	2.32	2.44
Schemes 4	1.89	2.14	2.45	2.75	3.18	4.70
Schemes 5	1.59	1.91	2.05	2.70	3.45	5.45

Table 2shows that when the input flow is constant, output flow rate of each branch of scheme 2 is most balanced;Hydraulic fluid goes via the inlet pipe, the flow of the 6^{th}branch pipe is the largest,reaching 3.12kg/s which is 1.09 times of average value 2.86 kg/s.And themass flow rate of the 5^{th}branch pipe is reaching 2.41 kg/s, which is 77.24% of the maximum.

By each branch pipe the output mass flow rate of schemes 1, 2, 3, when the main diameter is 1/2 in, the output flow rate of the first three branch pipe showsincreasing trend, and the later three is decreased.And the change of spacing between branch pipehave great influence on the output flow rate of the first branch pipe.So this paper chooses velocity ofthe first branch pipe to analyze the quality of pipeline structure of HDM.Figure 2 shows the first branch pipe output velocity of schemes 1, 2, 3 and local contours of stress of scheme 1.



(a) The output velocity of scheme 1 (b) The output velocity of scheme 2

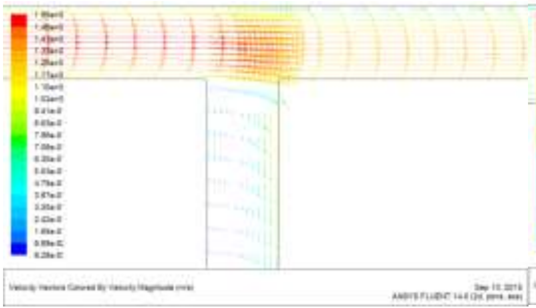


(c) The output velocity of scheme 3 (d) the local static pressure contours of scheme 2

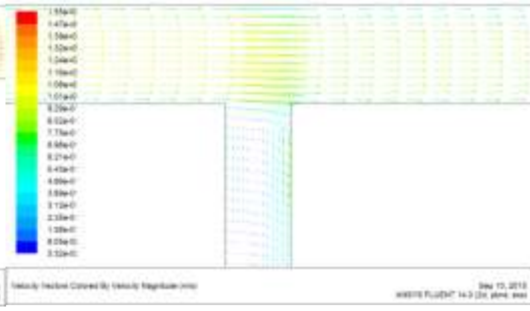
Fig.2 The output velocity of the first branch of scheme 1,2,3 and the static pressure contours of scheme 2

From figure 2 (a), (b), (c), the output flow rate of the first branch pipe increase with the increase in the spacing of branch pipe. The output center velocity of the first branch of scheme 1 is 0.12 m/s;The outputvelocity of the first branch of scheme 2 is between 0.175m/s and 0.225 m/s;The output velocity of the first branch of scheme 3is more than 0.25 m/s.This is because that after the hydraulic fluid goes though bending pipe and Tee-junction, the static pressure in the main duck increases abruptly, and increase margin is increasing with the spacing of branch pipe.In scenario 2, branch 1 output velocity is close to ideal branch velocity 0.225 m/s.And byfigure (d), when the pipe spacing is 20in, after the hydraulic fluidof the inlet pipe thought the first branch, static pressure rise rapidlyfirst, then reduce gradually, which makes the hydraulic oil in the main duck has more uniform velocity distribution and pressure distribution after distribution. Therefore, in the case of other factors fixed, the schemehas good flow uniformity in the pipeline structure which selects the main pipe diameterof 1/2inches andthe branch pipe spacing of 20 inches. For chemical piping, the same method may be used for the simulation analysis, the optimized chemical pipeline structure.

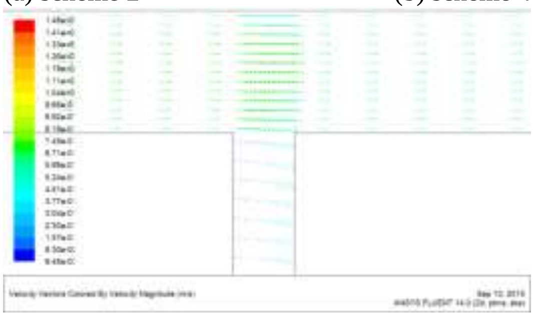
Scheme 2, 4, 5 is based on the optimization scheme in the branch pipe spacing. The paper studies the effect of diameter of duct pipe on distribution uniformity.By the output of mass flow rate of each branch pipe in the scheme 2, 4, 5, the regulation of main pipe diameter always cause great changes in the output flow rate of each branch pipe.Along with the rising of the diameter of main pipe, the mass flow rate of first three branch pipe showed decreasing trend. The mass flow rate of the 4thbranch pipe basically remains unchanged, and the output mass flow rate of the 5th and 6thbranch pipe increased dramatically.This is because with the increase diameter of main pipe, the fluid velocity of duck tube decreases. Main pipe diameter changes directly affect the fluid velocityof duck pipe and relative mutations in branch pipe. And the two factors both have impact on the eddy current size of the manifold leeward side. This often takes the velocity vector of the first branch pipe as the representation, as shown in figure 3.



(a) scheme 2



(b) scheme 4



(c)scheme 5

Fig.3 the velocity vector diagram of the first branch of scheme 2, 3, 4

By figure 3 (a), (b), (c), the eddy size of the first branch pipe of the scheme 2, 4, 5 are generally similar, but the fluid velocity decreases with the diameter of duck pipe increasing diameter of main pipe. So the fluid velocity of the branch pipe also will decrease. Comparing to scheme 4, thevelocity of the 5th branch pipe in scheme 5 bigger, because the first four branch distribution inadequate in the scheme 5, which also lead to the main flow velocity larger.By plan 4 or 5, when the main pipe diameter greater than or equal to 3/4 inches, the output mass flow rate of the hydraulic fluid in the pipe increased in turn.

IV. CONCLUSION

1. Using FLUENT software to study pipeline structureof HDM.And it is necessary of analysis of fluid distribution uniformity of the pipeline structure.Research shows thatthe main parametersaffecting the flow distribution are diameter of main pipe, branch pipe spacing.Using the same diameter as the output pipe and selecting 20in branch pipe spacing can get better fluid uniformity effect.

2. In the case of other factors constant, along with the increase of main pipe diameter, eddy size change of the first branch pipe is not big. And the output flow rate decreases with the decrease of the main flow. Increasin g the inlet pipe flow could improve the uniformity of fluid delivery pipeline.
3. The study is to determine the design steps of HDM. It usually can be identified thediameter of inlet pipe and output pipeby the size of umbilical and actuator of HDM. According tosimulation of this paper, the branch pipe spacing is determined. Finally it determines the main pipe diameter of all kinds of fluid pipeline.

REFERENCES

[1] Taiyuan Liu,ChengsuoHuo,Qingping Li,Trends in subsea production systemand its application in offshore oil andgas field develo pment in South ChinaSea*Engineering Sciences,* 17(1),2015,51-55.
[2] International Organization for Standardization, ISO 13628-6:2006(E) Petroleum and gas industries—Design and operation of sub sea production systems Part 6：Subsea production control system.
[3] Lixin Liu,Meizhen Zhou, Feng Su, Comparison and application of the structural form of the subsea distribution unit, Petro & Che mical Equipment,18(6),2015,42-44.
[4] Feng Su,Lixin Liu, Lei Zhang, Subsea electro-hydraulic distribution device.China,2014105268.1.2014-06-25.
[5] Norsok Standard Common Requirements, Subsea Production Control System.1995.
[6] International Organization forStandardization, ISO 13628-5:2006, Petroleum and gas industries—Design and operation of subsea production systems Part5：Subsea umbilical.
[7] Huafeng Li, Hydraulic control system design and simulation research of offshore oilfield subsea production facilities,Hangzhou: Zhejiang University.
[8] Y. Bai, Q. Bai. Subsea Engineering Handbook(Holland: elsevier,2010).
[9] Xiaosa Li. Simulation research for branching-pipe structure and turbulent field law, Haerbing：Haring Engineering University.
[10] XianheZhong, Li Zhang, Chengbo Wu, Experiments and numerical simulation of flow distribution with larger flux in multi-branc h pipe, Journal of Chongqing University, 29(1),2006, 41-44.