ISBN 978-952-5726-06-0
Proceedings of the 2009 International Workshop on Information Security and Application (IWISA 2009)
Qingdao, China, November 21-22, 2009

Research and Analysis of the Resistance Characteristic of Combined Flow Channel

Zhi'An Song[1], Wang Yong'An[2],
[1] *Shandong University of Science And Technology, QingDao,China*
Email: songzhian2005@126.com
[2] Dalian University of Technology, DaLian,China
Email: wangyong_an@126.com

***Abstract*—This article unified BP neural network with the computation hydrodynamics to carry on the research of hydraulic manifold block interior combined flow channel's resistance characteristic. The numerical method confirmed that the input parameter of combined flow channel model has the influence to the pressure drop, according to this, the BP neural network model variable is established to carry on the forecast of combined flow channel's pressure drop; the resistance characteristic curves of different structure channels are obtained, through to mathematical analysis of pipe network's resistance characteristic curve, proposed the through flow performance parameter of pipe network. The forecasting result tallies with the numerical calculus result, which indicated that this method may determine the combined flow channel's resistance characteristic accurately and efficiently.**

***Index Terms*—computational fluid dynamics, BP neural network, Hydraulic Manifold block, combination channel, resistance characteristic**

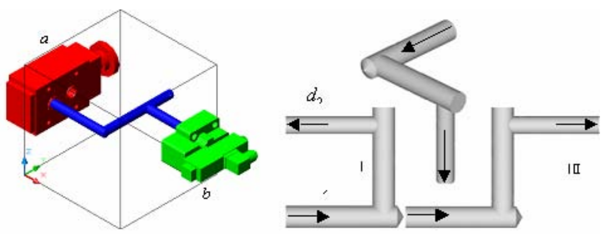
1 INTRODUCTION

The right-angle turn is one kind of common partial hindrance in the hydraulic manifold block, the fluid will have the energy loss after the right-angle turn [1, 2].Diverse combined flow channels are constituted under the different combinations of right-angle turn, there are also difference in the structure size even the flow channel under the same combination. Flow channel's structure is different, the pressure drop produced interior and the fluid flow quality is also different. The relations between the flow rate and the channel pressure drop under constant flow are called flow channel's resistance characteristic, which must be considered when carries on the hydraulic system design as well as the appraisal of hydraulic manifold block's quality.

The computation hydrodynamics (CFD) may forecast the flow quality and the energy loss accurately [3, 4]. However the computation of this method is very time-consuming, it need to carries on the redundant computation when predict specific flow channel's resistance characteristic by numerical method; what's more, when the flow channel model which studied are similar in the structure but different in certain sizes, it must carry on redundant modelling which is greatly cut down the efficiency of the research. The BP network is one kind of unidirectional dissemination multi-layer forward neural network, it can realize any nonlinear mapping from input to output after trained [5, 6], when the solves questions are essentially similar, the BP network does not need to carry on the redundant modelling and the computation changes may realize the goal result batch output. This article unifies CFD and the BP network to carries on the research of combined flow channel's resistance characteristic: Produces the sampled data and the variable which must be used in establishing the BP network by the CFD method, according the different input variable, the BP neural network's goal is to forecast the different flow channel's pressure drop and determine the resistance characteristic curve of different structure flow channel finally.

II PHYSICAL MODEL

The combined flow channel that this article studied is constituted by two same structure right-angle turns, in order to make sure that there is no slanting passageway in block body, the passageways which constitutes the flow channel should be vertical with the block body surface, which had defined the combination of the right-angle turn, namely the 0° combination, the 90° combination, the 180° combination, as shown in Figure 1. In the flow channel model the inside diameter of passageway D is certain, under this three combinations the length of passageways are corresponding equivalent, Based on the principle that the manifold block structure is compact and reduce the pressure drop loses, the length of the flow channel's fabrication hole L and the internal flow rate Q should not be too big; Certain fabrication holes are simplified in the model for which redundant cavity has little impact to the flow channel pressure drop .



（Ⅰ）assemble of 0^0 Ⅱ）assemble of 90^0 （Ⅲ）assemble of 180^0

Fig 1. Three kinds of model structures

III CFD SIMULATION AND RESULT DISCUSSION

In order to meet the numerical calculus needs, makes the following supposition to the flow channel and the actuating medium: 1) the flow channel is the rigid wall surface; 2)the medium is the coherency incompressibility Newtonian fluid; 3) the medium carries on the stable state to be mobile. Based on the above supposition, the description medium movement's equation of continuity and the momentum equation respectively are:

$$\nabla \cdot \vec{V} = 0 \tag{1}$$

$$\left(\vec{V} \cdot \nabla\right) \vec{V} = -\frac{1}{\rho}\nabla p + \nu\nabla^2\vec{V} \tag{2}$$

Which, $\vec{V}$ is the velocity vector， p is the pressure, ρ is the density, ν is the movement viscosity。

This article uses commercial CFD software [7] to carry on the solution of the flow channel model. The separate equation to solve is based on the finite volume method, in order to eliminate the fake diffusing phenomena in the numerical calculus and improve the calculation accuracy, to the convection term uses the second-order upwind scheme to carry on the separate, to diffusion term to use the equation of center cellular; The simulation process uses the standard $k-\varepsilon$ model, in the near wall region of the model, because the solution variable's gradient change is big, it is necessary to carry on processing to the area near wall. Considered that refinement grid in the near wall area will enlarge the computation load, we will use the standard wall surface function to replace the wall surface refinement grid ,by which to carry on the near wall processing; Assigns the boundary condition, use the SIMPLE algorithm to iterative the separate equation of variables under the body fitted coordination.

A The pressure drop analyzes of the right-angle turn

The right-angle turn is the basic unit which constituted the combined flow channel, before research the combined flow channel's mobile rule, it is necessary to study the flow quality of each right-angle turn. Like figure 2.a shows, when uniform stream through the flow channel, under the influence of the right-angle turn, on the upstream section o_1 of right-angle turn the flow starts to transform to the non-uniform flow, the distance l_1 which is from this section to the right-angle turn is the upstream influence length; The fluid flows out from the right-angle turn, develops into uniform flow again in the section o_2 after velocity distribution's adjustment, this length l_2 is the downstream influence length of the right-

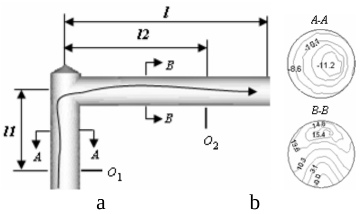


Fig 2. Characteristics of the right-angle changes upstream and downstream mobile
(The Unit of speed is: m/s, '-' expresses the speed direction)

angle turn. In addition, the section o_1 , o_2 defines the import and export of the right-angle turn separately.Velocity distribution of the passageway cross section is shown in figuer2.b: The flow nucleus (i.e. high flow rate area)of right-angle turn cross's section A is near to the inside sidewall of the turn, suppose that the right-angle turn have no influence to the fluid state in the process to change, then the flow nucleus position will not change after the fluid from the cross section A to the cross section B , namely it will still close up to the inside sidewall of right-angle turn; In fact, after the process changes, the flow nucleus of cross section B is actually partial to its outside sidewall, therefore the speed nucleus has realized the upstream-downstream fluid state opposition under the influence of right-angle turn. The opposition process within the momentum transfer among fluid particle, certain pressure drop loss is produced. On the downstream of right-angle turn, the velocity distribution carries on further adjustment, in the downstream pipe the nucleus of flow gradually moves to the through-flow section center, in this process the fluid particle carry on the momentum transfer too, and some pressure drop loss is produced. If the downstream pipe of the right-angle turn l is bigger than the downstream influence length l_2 , then the velocity distribution of the right-angle turn downstream may obtain full development, the flow nucleus transfer to the through-flow section centre again. If $l > l_2$, the speed nucleus arrives at the pipeline section the centre after l_2 , the velocity distribution becomes uniform, the fluid pressure drop in the upstream and downstream influence length are namely the local resistance loss of the right-angle turn. Otherwise, this conclusion is then untenable.

B The affection of fabrication holes' length on the flow channel's pressure drop

As shown in Figure 3, combined flow channel's pressure drop is related to the fabrication holes' length, the pressure drop Δp rises while L/D increases under the identical flow rate condition. First Δp according to the curve relations which turns up increases progressively along with L/D increases, afterward increasing by close straight line relation; L_0/D_0 ,Where the inflexion

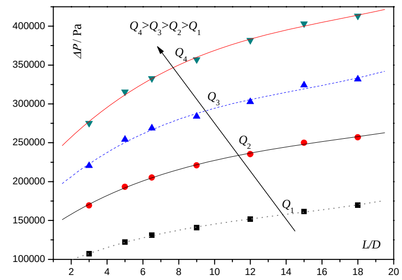


Fig 3. The relationship between the fabrication hole's length and the pressure drop in $0°$ combines

point K_i ($i = 1, 2, 3, 4$) corresponding, is the fabrication hole's critical length which this flow rate corresponding to, its size also rise along with the increases of the flow rate in flow channel. Other two kind of combination their curves also have the similar characteristics; here we only take the curve of $0°$ combines for example to carry on further explanation.

For the convenience, firstly an explication is given about the downstream right-angle turn's import position: When $L > l_{21}$, the right-angle turn's import located at the section a, as shown in Figure 4; When $L < l_{21}$, the import located at the fabrication hole's mid-section.

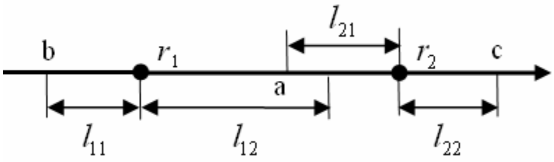
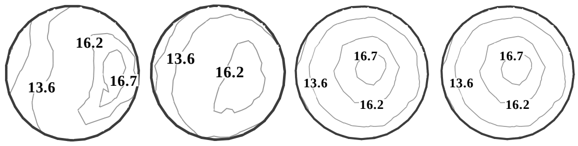


Fig 4. Influence length of two overlapped right-angle turns

When L/D is small, the downstream right-angle turn r_2 is in the downstream influence length l_{12} ,of which is the upstream right-angle turn r_1, as figure 5 (a), (b) shows, the fluid entered the downstream right-angle turn r_2 when the velocity distribution has not in full development , two right-angle turns influence mutually; along with the increase of L/D , the fluid speed distribution is further adjusted on the fabrication hole length, there are more momentum transfers among the fluid particles, thus more energy loss is produced; Because the fluid in the fabrication hole is a turbulent flow, the pressure drop in the fabrication hole grow region must be bigger than that in laminar flow with the same Reynolds number in this length, this is why the curve turns up when being smaller than L_0/D_0; When L/D increases to L_0/D_0, the entrance of r_2 is exactly the export of r_1, the velocity distribution that fluid enters the downstream right-angle turn is nearly uniform, like figure 5 (c) , two right-angle turns are mutually independence. Here the flow channel pressure drop is equal to the sum of two local resistance loss; Along with the further increases of L/D, just as figure 5 (d) shows, there presents a section of laminar flow regions between the influence length in two right-angle turn, then the flow channel pressure drop is equal to the sum of two local resistance loss and the along regulation loss of laminar flow region:

$$\Delta p = \frac{8}{\pi^2}(\xi_1+\xi_2)\rho\frac{Q^2}{D^4} + \lambda\rho\frac{2Q}{\pi D^2}l_0 \\ = \Delta p_0 + k\cdot l_0 \tag{3}$$

Which l_0 expresses the length of the laminar flow region in fabrication hole, k is the constant; this formula exactly explained the reason that Δp increases along with L/D by linear relation when $L/D > L_0/D_0$. According to the above formula, under the premise of $L/D > L_0/D_0$, the flow channel pressure drop is no longer related with the flow channel combination form. The Reynolds number has attributed the ratio of inertia force to the viscosity of the fluid particle, according to $R_e = 4Q/\pi\nu D$, R_e enhances along with the rise of Q, fluid particle's inertia force enhancement along with it, the fluid particle wants the process longer transition length of pipe inevitably under the perturbation of the upstream right-angle turn to be able to evolve the uniform stream, namely the downstream influence length of the upstream right-angle turn increases along with it, the critical length L_0/D_0 also increases along with the flow capacity rise



a. L/D=5 b. L/D=8 c. L/D=11 d. L/D=14

Fig 5. Inlet velocity distribution of r_2 under the flow rate Q_3

C The Influence that right-angle turn's combination to the flow channel pressure drop

Like what 2.2 states, when fabrication hole length $L \geq L_0$, the flow channel pressure drop have nothing to do with the combination of the right-angle turn; while $L < L_0$,the influence length of the upstream and the downstream right-angle turn in the flow channel occurs overlaps, the import flow nucleus of the downstream right-angle turn r_2 is located at the r_1 's downstream influence length l_{12}, as shown in Figure 5. In this case, under the three combinations, the inlet velocity distribution of the flow channel's downstream right-angle turns is nearly the same, which is similar with what shown in Figure 2, therefore the pressure drop between section a, b is equal in three kind of combination flow channels.

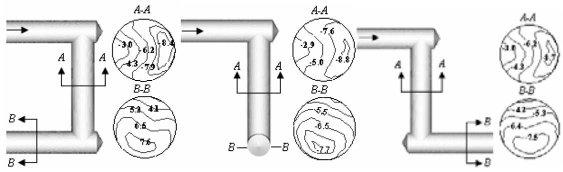


Fig 6. Import flow nucleus of right-angle turn r_2

(Speed unit is m/s, "-" express the direction of speed)

VI CHANNEL PRESSURE DROP LOSS

According to the preceding text's analysis, the primary factors that affect the flow channel pressure drop are the flow capacity, the fabrication hole length and the right-angle turn's combination, namely $\Delta p = f\left(Q, L/D, \Phi\right)$, which Φ is the vector of the right-angle turn's combination:

$$\Phi = \begin{cases} 001 & 0^0\text{combination} \\ 010 & 90^0\text{combination} \\ 100 & 180^0\text{combination} \end{cases}$$

The BP network's input neuron number is equal to that the influencing factor vector, namely the input vector is 5 Uygur vectors; the goal vector is flow channel's pressure drop, which is 1 Uygur vector. Through the experimental cut and try method, definite the implicit strata neuron integer is 11. This article uses neural network toolbox function which Matlab provides: The intermediate level neuron's transfer function uses S tangent function tansig, the output level neuron's transfer function uses S logarithmic function logsig, the training function uses trainlm function which is based on Levenberg-Marquardt algorithm, the network goal error establishes as 10^{-5}. In order to cause the input and output data at the [0, 1] sector, it is need to carry on normalized processing to the sampled data.

It may be seen from Figure 7: The flow channel pressure drop that BP network forecast is close to the result CFD computed, the biggest error of two is only 3.58%, so it can satisfy the request of project application. Carries on the error analysis to the BP network's other forecasting result, we can also draw the similar conclusion. Therefore, the BP network can be used for forecasting the flow channel model's resistance characteristic accurately. Figure 8 has given the several forecasting result of BP network.

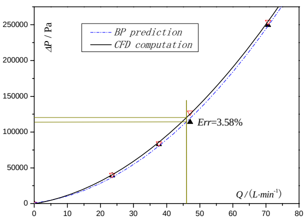


Fig 7. error analysis of Bp network forecasting result ($0°$ combination, $L/D=5$)

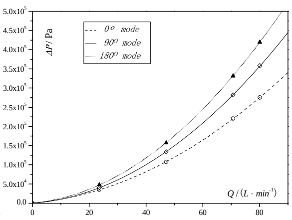


Fig 8. flow channel's resistance characteristic Bp network forecasted ($L/D=3$)

According to the curve shown in Figure 8 and Figure 7, we may draw the following conclusion: (1) Regarding the flow channel under different combinations, the pressure drop is not the same under the same fluid state, the pressure drop of 180^0 combination is the biggest, the 0^0 combination is smallest, this is consistent with what analyses in 2.3; (2) it is approximately satisfies the power-law relation between the flow channel pressure drop and the flow capacity, namely, the relations between flow channel pressure drop and the flow capacity may express as the following form:

$$\Delta p = RQ^n \qquad (4)$$

In the formula, R and n is the constant bigger than zero. R is flow channel's fluid anti-attributes, which attribute the strong and weak that the flow channel act to the fluid damper, its size is only decided by the flow channel's structure, the value size expresses the flow channel's through-flow characteristic. In addition, R also has attributed the soft and hard degree of the resistance characteristic curve, along with reduce of the R , the resistance characteristic curve changes soft, flow channel model's through-flow quality enhancement.

V CONCLUSION

This article analyzed the parameters which have influence to combined flow channel's pressure drop through the numerical method, according to this ,established the BP neural network to carry on the forecast to flow channel's resistance characteristic.

(1) The flow channel pressure drop is related to the flow rate, the right-angle turn's combination and the fabrication hole's length L : Speaking of the one flow channel, the pressure drop elevates along with the flow rate increases; when $L/D < L_0/D_0$, the flow channel pressure drop is related to the right-angle turn's combination, under the same flow rate, the pressure drop was biggest when it's 180^0 combination, while 0^0 combination was smallest; when $L/D \ge L_0/D_0$, the right-angle turn's combination has nothing to do with the flow channel pressure drop, the flow channel pressure drop is only decided by the flow rate and the fabrication hole's length.

(2) Establishes the BP network , input of which is the flow rate, the fabrication hole's length and the combination, the output goal is the flow channel pressure drop, this has carried on the perfect forecast to the flow channel model's resistance characteristic, reduced the computation cost, raised the working efficiency.

(3) In order to appraise the manifold block flow channel's through-flow quality, carries on the mathematical analysis to flow channel's resistance characteristic curve, take the fluid anti- achievement R as the reference index. This method not only suits the flow channel which discussed in this article, it is also suitable to other type of flow channel.

REFERENCES

[1]. Zhang Hong, Tian Shu-jun. CFD-based Optimal Design of Duct Nets in Hydraulic Manifold Block [J]. Journal of WuHan University of Technology, 2006, 28 (164):621-625.

[2]. Idelchik IE, Malysvskaya GR, Martynenko OG, Fried E. Handbook of hydraulic resistance. Cleveland, OH: CRC Press, 1994.

[3]. Anderson, John David. Computational Fluid Dynamics: the Basis with Applications [M]. New York: McGraw-Hill, 1995:23-30

[4]. Wang Fu-jun. Computation hydrodynamics analysis [M]. Beijing: Tsinghua University publishing house, 2004. 9.

[5]. 5 Haykin S. Neural Network: A comprehensive Foundation (2nd Edition)[M]. New York: New York Pearson Education Inc, 1999

[6]. Y.Fujii, W.E.Tobler, G.M.Pitron, T.Tibbles, J.McCalum. Steady State Hydraulic Valve Fluid Field Estimator Based on Non-Dimensional Artificial Neural Network (NDANN) [J]. Journal of Computing and Information Science in Engineering, 2004, 9: 257-270.

[7]. FLUENT, FLUENT Users Manual. Fluent Inc., Lebanon, NH, 1993

[8]. Fei-si technical product R&D center. The neural network theory and MATLAB 7 realize [M]. Beijing: Electronics industry