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Research on optimization and reconstruction of ventilation system of Tenghui coal mine based on Ventsim

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Abstract Mine ventilation system is a general term for the structural entity composed of ventilation power, ventilation network and control facilities, etc. With the orderly conduct of mine production activities, the existing ventilation system may not be able to meet the current needs of the mine, and the ventilation system itself may have some defects, which will inevitably have an important impact on the safe and efficient production of the mine. Therefore, it is of great significance to choose scientific and reasonable methods to optimize the mine ventilation system in time. This paper takes the ventilation system of Tenghui Mine as the research object, and based on the determination of ventilation resistance, a three-dimensional ventilation system simulation model of Tenghui Mine is constructed based on Ventsim ventilation simulation software. Based on the existing problems of the ventilation system, three optimization schemes are proposed, and through the feasibility analysis of the three optimization schemes, Scheme 2 is finally determined as the best scheme. After the modification, the resistance of the ventilation system of Tenghui Mine is reduced, the phenomenon of over-limit of wind speed is relieved, and the problem of insufficient airflow in the air-using place is also effectively improved, which is conducive to the safe and stable operation of the ventilation system of Tenghui Mine in the next stage of production, and saves a large amount of cost, and guarantees the production activities of the mine to be carried out in a safe and effective way.

Keywords ventilation system, ventilation resistance measurement, ventsim, 3D simulation model, ventilation system optimization

1. Introduction

Mine ventilation system is a general term for the structural entity composed of elements such as ventilation power, ventilation network and control facilities. The main function of the mine ventilation system is to supply fresh air to the mining operation site and the place needing wind during the normal production period of the mine to create a working environment that meets the health and hygiene standards; and to prevent the expansion of disaster, reduce the loss of the disaster, and create a safe environment and conditions for the relief of the disaster during the period of the disaster. Therefore, the establishment and maintenance of a safe, reliable and reasonable mine ventilation system is crucial to the safe production of the mine [1-3].

However, with the orderly progress of mine production activities, the ventilation parameters of the mine gradually change, the existing ventilation system may not be able to meet the needs of the mine, and the ventilation system itself will produce some defects and problems, which is not conducive to the safe production of the mine and may even cause serious disasters. At this time, it is of great significance to choose a scientific and reasonable method to optimize the mine ventilation system in time. At present, with the gradual increase in the production capacity of the mine, the ventilation system has gradually become more complex, compared with the manual solution requires a lot of time and energy, and with the ventilation simulation software has a greater superiority, has gradually become the mainstream trend. Among them, Ventsim ventilation simulation software, as one of the most mainstream ventilation simulation software, ranks among the world's advanced level in ventilation management, ventilation network solving and three-dimensional simulation, etc., and it has been widely used in the optimization and transformation of the ventilation system of coal mines. Zhang Yaming et al. for plateau mines with thin air, insufficient oxygen supply, natural ventilation conditions are complex and variable, etc., plateau adaptive correction of ventilation key parameters as the basis for a plateau mine ventilation system optimization and transformation based on Ventsim software [4]; Li Meiting et al. for better control of the spread of the wind flow in the fire period as well as the development of the relevant emergency plan, the use of Ventsim visualization In order to better control the spread of wind flow during the fire period and the formulation of related emergency plans, Ventsim visualization software was used to establish a three-dimensional model of the ventilation system in metal mines to simulate the underground fire, and it was found that the roadway directly connected to the return-air alley caused wind flow reversal due to thermal expansion and other factors, and the concentration of its CO gas tended to be close to zero in the midst of the fire [5]; Tan Xingyu et al. used the Ventsim system to conduct the economic section selection for the optimized section, and the economic optimization, safety and reliability of the roadway section were the main evaluation indexes, and the optimized section was selected. In order to reduce the impact of air leakage from the mining airspace on the working face and reduce the risk level of impact pressure on the working face, Lu Hui and others used Ventsim three-dimensional ventilation simulation software to simulate and analyze the ventilation system and wind pressure distribution status of the working face, and optimized the ventilation system [7]. The above scholars mainly analyzed the stability of the mine ventilation system and disaster prevention and control through Ventsim ventilation simulation software, but lacked the study of regulating the working face airflow and reducing resistance.

This paper takes 2-205 working face of Tenghui Coal Mine of Huozhou Coal & Electricity Group of Shanxi Coking Coal as the engineering background, and establishes a three-dimensional ventilation network model by using Ventsim software. Based on the model, the ventilation system is optimized for the existence of such problems as long ventilation routes, high resistance, unreasonable local wind speed, unbalanced ventilation structure, etc. as well as the production planning of the next stage, which provides a basis for the mine's ventilation system It provides the basis for the transformation of the mine ventilation system.

2. Overview of the mine

Tenghui Coal Mine is located in the west of Diangou Village, Zaoling Township, Xiangning County, Shanxi Province, with a production capacity of 1.2 million tons/year and a service life of 17.2 years. The mine field area is 6.5276km2, and the main mineable coal seams are 2# and 10#, and the 2# coal seam is now being mined. The spontaneous combustion tendency nature class is III. At present, the shaft field adopts the mixed development method of inclined shaft and vertical shaft, and there are 4 shafts in total. The main inclined shaft is responsible for coal transportation and air intake of the whole mine; the secondary vertical shaft is responsible for personnel, equipment and material lifting and transportation and air intake; the pipeline vertical shaft is responsible for pipeline laying and air intake; and the return vertical shaft is responsible for air return of the whole mine. The ventilation mode is extract type, and the ventilation method is mixed type, and the main ventilator installed in the return air shaft is FBCDZ-No27 explosion-proof counter-rotating axial flow fan, with a rated power of 2×450kW, one working and one standby. At present, the mining area of 2-205 working face of Tenghui Mine is near to completion, and the next stage is planned to mine the coal seam of 2-206 working face and the third mining area, and the preparation roadway is being developed.

3. Determination of ventilation resistance and analysis of ventilation system

In order to objectively and accurately evaluate the ventilation system of TengHui Mine, the first step is to measure the ventilation resistance of TengHui Mine. Through the measurement of ventilation resistance, we can not only understand the distribution of ventilation resistance in the ventilation system, but also understand the ventilation parameters of each roadway intuitively and quickly, so as to provide a basis for the evaluation of the ventilation system, the ventilation network solution and the optimization of the ventilation system. According to the "mine ventilation resistance determination method" (MT/T 440-2008) standard, there are three methods for mine ventilation resistance determination: inclined differential pressure meter method, barometer base point method and barometer synchronization method [8]. Here, TengHui mine ventilation resistance is measured using the base point barometer base point method. Firstly, the ventilation resistance measurement route of Tenghui Mine is selected, and two barometers of the same type are used, one of which is arranged at the entrance of the main inclined shaft of Tenghui Mine to measure the atmospheric pressure; the measurement personnel carries the other one to follow the ventilation resistance measurement route, and then measure the barometric pressure, humidity, temperature, and ventilation parameters of the measurement points in turn. Reasonable ventilation resistance measurement routes have a significant impact on the measurement of ventilation resistance, and the resistance measurement routes should usually be chosen with longer ventilation routes, larger and more stable airflow, and through the backhoe. The resistance measurement route should usually be chosen as the main wind flow route with a long ventilation route, a larger and more stable wind flow, and through the return mining face. According to the above resistance measurement principles and the current situation of Tenghui Mine ventilation system, Tenghui Mine has a total of one main measurement route and one axial measurement route. The measurement routes are shown below:

Main test route: main inclined shaft → main transportation alley → belt alley → material a joint alley → material alley → 2-2051 alley → 2-205 working face → 2-2052 alley → 2-2052 back wind joint alley → back wind alley → back wind shaft

Axial measurement route: deputy shaft → deputy shaft pedestrian joint alley → deputy shaft winding alley → material alley → 2# coal centralized material alley → material alley of the third mining area → second joint alley → return air alley of the third mining area → 2# coal centralized return air alley → return air alley → return air shaft

Ventilation resistance measurement data is shown in Table 1:

Table 1: Summary of resistance measurements for measured routes

Measurement point Name	sectional area /m^2	cross-section shape	lengths /m	Support Forms of support	air velocity /m/s	Air humidity /%	air volume /m^3/s	draft resistance /Pa
Main Transportation Alley	7.6	bins	3627.6	anchor spray	1.4	23.5	10.9	157.3
belt alley	7.6	bins	1399.4	anchor spray	1.4	23.4	10.9	44.0
material alley	22.0	rectangles	1012.2	anchor spray	4.1	23.2	82.7	89.8
Material 1 Union Lane	10.5	rectangles	103.2	anchor spray	3.5	23.3	37.1	15.5
2-2051 Lane	9.9	rectangles	925.6	anchor net	1.3	23.4	13.3	43.1
2-205 working face	6.9	rectangles	605.2	anchor net	1.9	23.5	13.3	70.6
2-2052 Lane	8.7	rectangles	729.8	anchor net	1.5	23.1	13.3	46.7
2-2052 Return Lane	16.4	rectangles	81.6	anchor spray	1.2	23.2	19.1	0.9
Pedestrian Link Lane of Deputy Shaft	13.0	rectangles	214.8	anchor spray	2.7	23.5	35.5	22.4
Secondary shaft around the alley	12.4	rectangles	125.4	anchor spray	4.4	23.4	54.5	31.7
2#Coal centralized material alley	22.5	rectangles	678.1	anchor spray	0.3	23.4	5.9	0.4
Material Lane in the third mining area	25	rectangles	524.3	anchor spray	0.1	23.4	1.4	0.1
Erlian Lane	25	rectangles	85.6	anchor	0.1	23.3	1.4	0.1

				spray				
Third mining area back to the wind alley	25	rectangles	524.3	anchor spray	0.1	23.3	1.4	0.1
2#Coal centralized return air lane	24.8	rectangles	586.4	anchor spray	0.2	23.4	5.8	0.2
winding alley	22.5	rectangles	180.7	anchor spray	8.0	23.6	180.7	50.2
return air shaft	25	rectangles	44	anchor spray	7.4	23.6	184.6	23

In the process of resistance measurement and through calculation and analysis, it can be found that the main problems in the ventilation system of Tenghui Mine are as follows:

(1) The wind speed of the material alley, the return air alley and the 2# coal concentrated material alley exceeds the standard, and some of the alleys are seriously deformed, poorly maintained, with a large amount of piles of materials stored, the local resistance increases, the negative pressure of the fan in the return air shaft is too large, and the efficiency of the fan is on the low side.

(2) Some of the mine's ventilation resistances and negative pressures are large, and the assigned air volume of 2-2601 tunneling lane, 2-2062 tunneling lane and the third mining area is small, which does not meet the design requirements of the air volume demanded by the working face, and may cause serious ventilation and safety hazards for the next stage of the mining plan.

(3) From the data of wind resistance and isotropic holes, Tenghui Mine is an easy to ventilate mine, but the resistance of the return air section accounts for a large proportion of the total resistance of the mine, and the effective airflow rate is low. The air intake of the main inclined shaft is low, and the management level of ventilation structures is low.

4. Ventilation system three-dimensional simulation modeling

A. Overview of Ventsim Software

Ventsim 3D simulation software was firstly designed by Australian CHASM Mining Consultants in 1993, and after 30 years of continuous innovation and improvement, it has become the world's mainstream mine ventilation simulation software, which is currently used by more than 1,000 organizations in more than 60 countries around the world. Ventsim 3D simulation software is mainly based on the three laws of wind volume balance, wind pressure balance and ventilation resistance, and establishes mathematical equations through the wind volume distribution and wind network solving, and then determines the corresponding wind volume of each branch, which has a high accuracy. Nowadays, most of the Ventsim 3D simulation software is built on 3D model, which integrates the functions of ventilation network solving, wind flow simulation, pollutant simulation, fire simulation, ventilation management and ventilation economic analysis, etc., and it can intuitively and concretely show the layout of the mine's roadway and the current status of the ventilation system, and realize real-time solving of the roadway's wind volume and direction, and it can also quickly identify some critical ventilation parameters and ventilation hazards in the whole ventilation system. It can also quickly identify some key ventilation parameters and hidden dangers in the whole ventilation system, which provides a reference basis for mine ventilation decision makers and facilitates the design of mine ventilation, optimization of mine ventilation system, dedusting and cooling, anti-wind drills, and ventilation decision making, etc. [9-11].

B. Tenghui Mine Ventilation System Simulation Model

Generally speaking, Ventsim ventilation system simulation model according to the mine excavation engineering plan, ventilation system map, measured roadway parameters such as one by one drawing roadway, shaft, and so on, and then in Ventsim software in order to supplement the input of each roadway and other ventilation parameters, but in this method not only need to spend a lot of time and energy, and easy to lead to the drawn model and the actual ventilation system of the mine has a larger However, this method not only requires a lot of time and effort, but also easily leads to a large discrepancy between the drawn model and the actual ventilation system. Therefore, this paper selects the method of using the centerline of the roadway to import directly. Use the elevation of the mining engineering plan to draw the centerline of the roadway, and save the complete roadway centerline layer as a CAD file in dwg format. The dwg file of the roadway centerline is imported into Ventsim software and converted into a solid roadway, the preliminary model of the mine is corrected, and then the ventilation parameters, fan parameters and ventilation structures of each roadway are input, which can be obtained to obtain the simulation model of the Ventsim ventilation system of Tenghui Mine [12]. As shown in Figure 1.

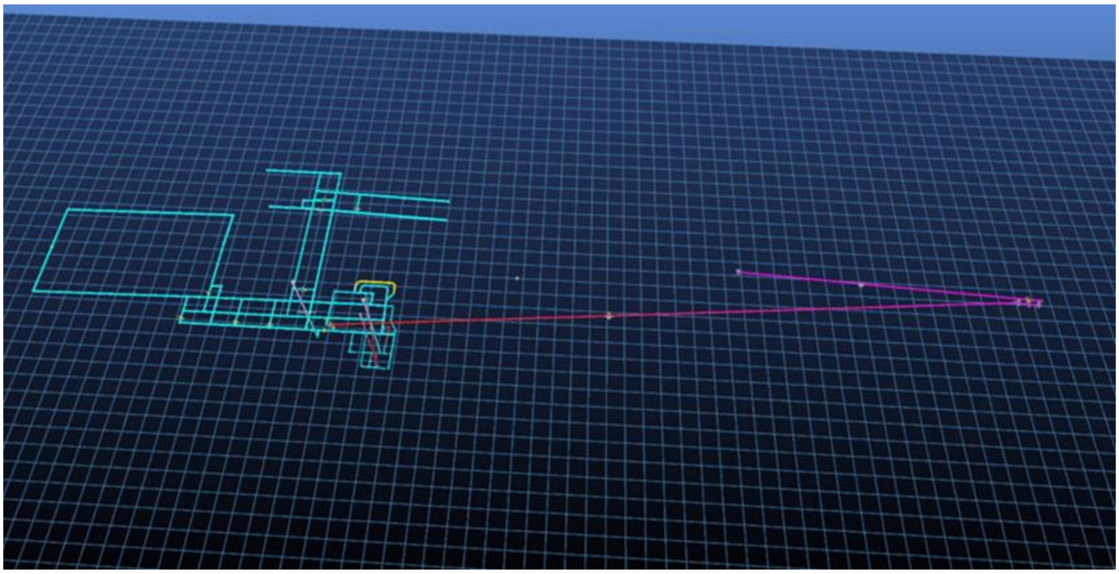

Figure 1: Schematic diagram of Ventsim 3D simulation model of ventilation system in Tenghui Mine

C. Model Reliability Verification

Since there may be deformation of the tunnel, gas outflow and air leakage in the actual operation of the mine, it is unavoidable that the 3D simulation model is different from the actual situation. In order to ensure that the Ventsim 3D simulation model can truly and accurately reflect the real situation of the mine, it is necessary to ensure that the error between the 3D simulation model and the actual measurement is within the permissible range, in general, the error between the 3D simulation model and the actual is less than 5% can be considered to meet the requirements [13]. In this paper, the simulation results and underground measurement are compared and verified, and the comparison results are shown in Table 2.

Table 2：Error analysis of simulated and measured airflow in each major roadway

Designation	**Simulated airflow** （**m^3/s**）	**measured airflow** （**m^3/s**）	**difference** （**m^3/s**）	**inaccuracies** （**%**）
Main Transportation Alley	10.6	10.9	0.3	2.75
material alley	86.4	82.7	3.7	4.47
2-2051 Lane	12.9	13.3	0.4	3.00
2-205 working face	12.9	13.3	0.4	3.00
2-2052 Lane	12.9	13.3	0.4	3.00
2#Coal centralized material alley	6.1	5.9	0.2	3.38
2#Coal centralized return air lane	6.0	5.8	0.2	3.44
winding alley	188.2	180.7	7.5	4.15

As can be seen from the table, the measured wind volume and the simulated wind volume of Ventsim 3D simulation software are basically the same, and the relative error between the simulated wind volume and the measured wind volume is less than 5%, so it can be concluded that the simulation results are real and reliable. Therefore, the three-dimensional simulation model constructed in this paper can be used as a model for simulation and ventilation optimization and transformation of the mine.

5. Tenghui mine ventilation system optimization and transformation analysis

A. Mine ventilation system optimization principles

Mine ventilation system in the optimization and transformation, generally should follow the following principles; first of all, can make the sufficient amount of airflow efficiently sent to the mine of the various air-use sites, to meet the needs of the air-use sites; try to make the mine ventilation system is simple, easy to manage and stable and reliable; to reduce the ventilation resistance of the mine, to reduce the energy loss, and the ventilation resistance in the whole ventilation line distribution is more reasonable; optimized ventilation system has a strong disaster-resistant ability, in the event of a disaster can be maximized to limit the expansion of the disaster; economically reasonable, low capital investment, maintenance, running costs are small [14-16]. The optimized ventilation system has strong disaster-resistant ability, which can maximally limit the expansion of the disaster when it occurs; it is economically reasonable, with low capital investment, low maintenance cost and small operation cost [14-16].

B. Determination of Optimized Retrofit Solutions

Based on the results of Ventsim software, the ventilation resistance measurement report and the problems of Tenghui mine ventilation system, combined with the production planning of Tenghui mine in the next stage, three optimization and reconstruction plans were made for the ventilation system of Tenghui mine in view of the problems of insufficient air supply, excessive wind speed in the local roadway and excessive resistance in the return air section.

Option 1: Pass through the deputy inclined shaft, open up the material alley of the third mining area, the transportation alley of the third mining area and the return-air alley of the third mining area, and set up dampers near the return-air alley.

Option 2: Passing through the secondary inclined shaft, opening up the material lane, transportation lane and return air lane of the third mining area, closing the main inclined shaft, and installing dampers in the return air lane.

Option 3: Passing through the secondary inclined shaft, opening up the material alley, transportation alley and return air alley of the third mining area, closing the main inclined shaft and opening up the special return air alley of the third mining area.

C. Feasibility analysis of optimization options

According to the three-dimensional simulation model of the ventilation system of Tenghui Mine established, Ventsim was used to simulate the ventilation system for the three optimization schemes, and the effects of the three schemes were analyzed according to the information provided by the software simulation as follows:

Analysis of the effect of Scheme 1 After passing through the deputy inclined shaft, opening up the material lane, transportation lane and return air lane of the third mining area, the total air intake increased by 234m3/min, at this time, the air intake of the pipeline shaft, the deputy shaft and the main inclined shaft were reduced, and the air intake task was mainly undertaken by the deputy shaft, which accounted for the proportion of the total intake of the air volume from the original 76% to the present 49%, and at this time, the main inclined shaft's air intake is still small, which accounted for 6% of the total intake before reduced to the present 4% of the total intake of air. At this time, the air intake of the main inclined shaft is still less, from 6% of the total air intake before to 4% of the total air intake now. The advantage of option 1 is that passing through the deputy inclined shaft, opening up the material lane of the third mining area, the transportation lane of the third mining area and the return air lane of the third mining area is conducive to the production tasks of the third mining area in the future of TengHui Mine, which greatly improves the tightness of the air volume of the 2-2061 Lane, the 2-2062 Lane, as well as the third mining area, and alleviates the problem of the overweight of the ventilation tasks of the deputy shaft and the excessive wind speed of the pedestrian lane of the deputy shaft; the disadvantage is that there is still a local phenomenon of excessive wind speed in the return air lane, and the resistance of the return air section is too high, and the resistance is too low. The disadvantage is that there are still local wind speed exceeding the standard in the return-air alley, the resistance of the return-air section is too large, and the number of shafts is not easy to manage.

Analysis of the effect of Scheme II Passing through the deputy inclined shaft, opening up the material lane of the third mining area, the transportation lane of the third mining area and the return air lane of the third mining area. Considering that the air intake of the main inclined shaft is less and the line is longer when it is used as a transportation lane, after closing the main inclined shaft, the total air intake is increased by 222 m^3/min, of which the air intake of the pipeline shaft is reduced by 594 m3/min and that of the deputy vertical shaft is reduced by 2,634 m^3/min, and the transport task of the whole mining area is mainly taken up by the transportation lane of the third mining area. At this time, the transportation task of the whole mining area is mainly taken by the transportation lane of the third mining area. After closing the main inclined shaft, the negative pressure of the fan in the return air shaft is reduced from 1894.4Pa to 1794.6Pa, the efficiency of the fan is increased from 58% to 61.2%, and the power of the fan is reduced to 619.3kw, which is a total reduction of 56kw. The advantage of this plan is that it reduces the burden of the air inlet of the deputy shaft, and the closing of the main inclined shaft can reduce the maintenance, electricity, and other expenses. The advantage of this program is to reduce the burden of air intake in the deputy shaft, and to close the main inclined shaft can reduce the maintenance, electricity and other costs totaling about 2 million, saving a lot of money, and at the same time, closing a shaft is conducive to the ventilation management work of the ventilation system; the disadvantage is that the phenomenon of exceeding the standard of the local wind speed of the return-air alley has been improved, but is not very obvious.

Analysis of the effect of Scheme III After passing through the deputy inclined shaft, opening up the material lane of the three mining areas, the transportation lane of the three mining areas and the return air lane of the three mining areas, closing the main inclined shaft and opening up the special return air lane of the three mining areas, the total air intake has increased by 312m3/min, among which the air intake of the deputy vertical shafts has been greatly reduced, the air intake of the deputy vertical shafts has been reduced by 3,306m3/min, and the air intake of the tubing shafts has been reduced by 744m3/min. At this time, the negative pressure of the fan of return air shaft has been reduced from 1894.4Pa to 1722.9Pa now. At this time, the negative pressure of the fan of the return air shaft is reduced from the original 1894.4Pa to the present 1722.9Pa, and the power of the fan is also reduced from the original 619.2kw to the present 440.6kw. The advantage of this program is that after opening up the special return air lane of the three mining areas, the wind speed of the return air lane is reduced from the original 8.1m/s to the present 2.2m/s, and the problem of exceeding local wind speed in the return air lane and the pedestrian lane of the subvertical shaft is greatly improved, and the drag reduction effect is also greatly improved, and the drag reduction effect is also improved. The problem of excessive local wind speed in the return-air alley and the pedestrian alley of the deputy vertical shaft has been greatly improved, and the effect of resistance reduction is also relatively obvious, while the fan of the return-air alley can save 2.4 million yuan of electricity and 900,000 yuan of maintenance and other costs every year; the disadvantage is that the fan wind pressure is too small at this time, the fan efficiency is low, and even the phenomenon of negative pressure of the fan is too low, which is not conducive to stable fan operation.

Comprehensive analysis of the above options, the final decision is that option 2 is the final option, the advantages of which are mainly reflected in the less amount of shaft work, shorter construction period, fast effect on the optimization of the mine ventilation network; reduce the number of shafts, which is convenient for the ventilation management; improve the 2-2061 lane, 2-2062 lane and the three mining areas of the air tightness, which is conducive to the safe and stable operation of TengHui Mine's next stage of the production of the ventilation system; and save about 2 million yuan per year for the mine from the economic aspect. It can save about 2 million dollars per year for the mine from the economic aspect.

6. Conclusion

Through the analysis of the current ventilation system of Tenghui Mine, we found the problems of the current ventilation system, and based on this, we formulated three ventilation system optimization and reconstruction plans, and simulated and analyzed the three optimization plans using Ventsim ventilation simulation software, and finally decided that Plan 2 is the best plan, which not only facilitates the production plan of the subsequent mining areas to be carried out in a safe and orderly manner, but also saves a lot of costs.

Ventsim ventilation simulation software has important guiding significance for the optimization and transformation of the mine ventilation system, and the application of Ventsim ventilation simulation software to analyze the effect of the optimization and transformation plan before the implementation of the plan so as to choose the best plan can effectively avoid the economic losses brought about by blind construction.

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