Residual mining caving face over the roadway and the key technology of deformation

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Abstract: Multi layer multi angle face roadway of coal mining face of residual mining brings technical challenges to the safety of the working face mining. With the background of the 6212 residual coal mining face in a mine in Shanxi, the deformation laws of the surrounding rock in the slanted roadway, the bottom coal slanting roadway and the intersection point are analyzed by numerical simulation. The simulation results show that at least the reinforcement measures should be carried out by 20m in the empty lane, and the plastic zone in the floor of the roadway along the top is obviously developed, and the stress concentration of the surrounding rock is high, and the support and management should be strengthened. In view of the space position of the site, the key technical measures are put forward, such as dense support or wood stack, anchor net cable, and super high water material grouting pre-filling, so as to ensure the safe recovery of the residual mining face.

1. Introduction
The empty lane mainly comes from the left lane way of small coal kiln, the geological exploration of underground geological exploration, the exploration of underground geological structure exploration and so on [1~3], such as the exploration of the tunnel, the empty lane opened for a long time, after being affected by many mining, there have been different degrees of damage or even collapse, some empty alleys even exist water, gas and other safety hazards [4~9]. According to the spatial layer relationship between the empty alley and the comprehensive collection work surface, the empty lane can be divided into parallel, diagonal and vertical relationship with the work surface [10]. Comprehensive mining top coal work surface to pressure strength, high degree of stress concentration, when the work surface pushed to the vicinity of empty alleys, empty alleys due to the original support difficult to carry the occurrence of roadway deformation, collapse, seriously affect the normal progress of the work surface. How to work surface safe and fast over the empty lane is a practical problem that has been troubled for many years in real mining.

2. Engineering Overview
Shanxi mine 6212 residual mining work surface for one side of the mining work surface, the main mining 3# coal seam, the use of reverse tilt longwall comprehensive mechanization low-top coal once high all down coal mining method. According to geological data, the recovery process will encounter multi-layer multi-angle empty alleys, and empty lane intersections (as shown in Figure 1). Among them, 62 raise belt lane, 62 upper leather water tank, 6208 wind lane along the 3rd coal seam bottom plate digging, 630 total return wind lane, 630 total return distribution wind lane, 62 raise track lane, 740 total return wind lane, 62 gunpowder depot, 630/2 special return wind lane to the 3rd coal seam
top plate digging. 6212 wind lane perpendicular to 6212 open-off cut; 630 total return wind lane, 630 total return wind lane, 62 uphill track lane, 62 uphill belt lane, 62 upper-skin water silo and 6212 eye-cutting angle of 29 degrees; the remaining empty alley and 6212 eye cut angle between 51 degrees.

The existence of empty alleys makes the work surface advance to the area near the empty alley, due to the stress concentration area of the empty alley surrounding rock and the pressure superposition of the work surface, coupled with the empty alley surrounding rock broken, and the end surface empty top area significantly increased, it is very easy to cause the work surface roofing accident.

Fig. 1 the scatter gram of empty lane in 6212 mine face

3. Simulation of the deformation law of the surrounding rock over the working surface

3.1. Model building
According to the geological conditions of 6212 working surface, the numerical calculation model is established by Flac3D, which is 250m long, 250m wide and 20m high. The length of the 6212 working surface and adjacent mining area is 100m, and the width of the narrow coal column in the section is 5m. A diagonal air lane (with the working surface angle 45 degrees) is arranged along the top coal, a diagonal air lane (with the working surface angle 45 degrees) and two empty lanes intersecting along the bottom coal. Simulated the deformation law of surrounding rock in different layers and intersections.

3.2. Analysis of simulation results
According to the simulation results, the main analysis of the different positions of the working surface from the empty lane and the work surface cuts through the empty lane process, the force deformation of the empty lane surrounding rock damage. For different work surfaces, the targeting and mapping are carried out along the direction of the empty alley. Due to space constraints, only plastic distribution cloud maps are posted below.

3.2.1. Analysis of the deformation law of the surrounding rock in the section of the over-top coal oblique air lane

(a) 20m from the empty lane of the work surface

(b) 10m from the empty lane of the work surface
Influenced by the near 6208 mining area, the empty lane surrounding rock near the side of the mining area has partially shaped the deformation, when the working surface is far from the empty lane location (20m), the surrounding rock around the empty lane began to appear plastic damage, when the working surface distance from the empty lane reduced from 20m to 10m, In the empty lane near the solid coal side roof plate appeared the increase of the shape damage area, when the work surface distance from the empty lane from 10m to 5m, the top plate shape dissection area further increased, when the work surface pushed to the empty lane position, along the empty lane direction about half the length of the shape deformation damage occurred.

Therefore, at least 20 m away from the empty roadway, it is necessary to start the empty roadway reinforcement measures to prepare for the rapid passage of the working face through the empty roadway.
3.2.2. Analysis of the law of rock activity in the under-coal slope-to-empty lane during the back-to-work recovery process

When the work surface is 20m away from the empty lane position, the empty lane near the solid coal side roof plate appears plastic damage, when the work surface is 10m away from the empty lane, the shape deformation destruction area continues to increase, when the work surface distance from the empty lane is reduced from 10m to 5m, the top plate shape damage area further increases, when the work surface is pushed to the empty lane position, Along the direction of the empty alley about half the length of the shape deformation damage.

Affected by 6212 work surface back to pick forward pressure, the area around the empty lane surrounding the plastic deformation area continues to increase, when the work surface cutting empty alley more than 16m, the surrounding rock around the empty alley almost all into the plastic area, until the work surface through the empty lane.
3.2.3. Analysis of the law of cross-point surrounding rock activity in the process of working surface back-picking

![Cross-point surrounding rock activity images](image)

Fig. 6 Plastic zone distribution of intersection points at different positions in front of the working face

When the work surface is pushed to the distance intersection 30 to 40m, the surrounding rock near the intersection does not fully enter the plastic state, there is still a certain elastic nuclear area inside the coal column between the empty lane and 6212 wind lane, when the push to the distance intersection 20m, affected by the back-picking pressure, the empty lane began to appear obvious plastic deformation and stress concentration. When the distance is reduced to 10m, the plastic area is further extended to the surrounding rock near the intersection, and when pushed to the intersection, more than half of the surrounding rock in the empty lane is in the plastic deformation state. The area is the intersection of three laneways, vertical air lane and 6212 wind lane, the vertical stress of surrounding rock is larger than other places, can reach 100~200MPa, the highest stress concentration coefficient.

4. Key technologies for over-empty lane rock control

In order to 6212 coal column comprehensive release surface back to the recovery process smoothly through all empty alleys, while taking into account the need to further reduce costs, it is necessary to different empty lane situation, respectively, to take different over-the-air lane methods.

4.1. Reinforcement of empty alleys dug along the coal seam bottom plate

Recycled empty lane in the original steel shed, using full anchor net support, and in the empty lane set up interlocking wooden pallets (vertical lane is 3m board, parallel lane way 1.6m roadwood) pitch 2m.

![Wooden pallets setup](image)

Fig. 7 Map of wooden pallets along the hollow alley slabs at the bottom of the coal seam

4.2. reinforcement of empty roadway driven along coal seam roof

The average thickness of coal seam in 6212 working face is 6.9 m, the cutting height is 3 m, the height of top coal caving is 3.9 m, and the net height of empty roadway is 3.2 m. If the cutting height of the
working face remains unchanged, there is only 0.7 m thick coal seam between the floor of the empty road way and the working face. Under the influence of empty roadway excavation and mining, this part of coal seam is difficult to effectively isolate the empty roadway, and even induce roof falling danger. The numerical simulation results show that the deformation and failure of surrounding rock is more serious in the empty roadway along the coal seam roof than in the floor empty roadway. Therefore, the roof and two sides of the empty roadway should be bolted and mesh supported, then the grouting of high water material should be strengthened, and then the wooden stack should be set up at an interval of 5 m to strengthen the support. When the working face is pushed to 3m from the empty roadway, the coal caving should be stopped and the mining height of the working face should be properly reduced until the working face passes through the empty roadway before resuming the normal operation[11].

4.3. reinforcement of intersection of empty roadway
From the shape of the intersection, there are "T" type and "X" type intersection. Generally speaking, the roadway near the intersection is large, the deformation of the surrounding rock is more serious, and the working surface is more difficult to cross the empty lane. According to the research, the "X" cross point is larger than the "T" cross point, the deformation of the surrounding rock is more serious, and the smaller the angle between the two lanes at the intersection point, the higher the degree of damage to the deformation of the surrounding rock deformation.

For the intersection of the roadway along the top plate or bottom plate of the coal seam, on the basis of the full anchor network support, increase the anchor rope density, and according to the specific situation of the scene set up a chain wooden pallet (vertical lane wayist is 3m board, parallel roadway is 1.6m sleeper). Dig along the top plate of the coal seam into the roadway intersection bottom plate also need to be filled with high water material slurry to do reinforcement treatment, and then the bottom plate first paved large plate, paved metal mesh, and then set up interlocking wood stacking, cross-junction on both sides of the wooden pallet lock. When the work surface is pushed to 5 m from the intersection, the coal release should be reduced or stopped appropriately, and the work surface should be properly reduced until the work surface passes through the empty lane before normal operation can be resumed.

6212 Wind Alley and 62 Upper Mountain Belt Lane is an "X" type intersection, the original 6209 Wind Lane and 62 uphill belt lane are "T" type intersections, and the two intersections are 5m apart, belong to the stress overlay area, should be attached great importance. Combined with numerical simulation results and field experience, in the intersection 10m range in the 6212 wind lane set up a beam four-pillar monolith pillar steel shed, the shack distance of 0.6m, and the intersection within 10m range of empty alleys should first make a closed wall, and then fill with ultra-high water material filling.

Fig. 8 Schematic diagram of reinforcement at the intersection of 6212 wind lane, original 6209 wind lane and 62 uphill belt lane
4.4. High-stakes lane reinforcement
The wall closes the high-risk area, drills into the top of the high-risk zone, and fills the high-risk zone with ultra-high water material in the high-risk area, as shown in Figure 9.

![Fig. 9 Reinforcement schematic diagram of high-rise area](image)

Specific construction should be based on the fall situation, coal rock accumulation height, drilling, etc. to determine the specific fall height of the top plate, to ensure that the slurry hole can reach the upper limit of the fall. An exhaust pipe is required to be laid on the top of the fall zone, and when the slurry cannot continue to be filled or when the slurry is returned from the exhaust pipe, the visible fill in zone is filled and compact before the operation can be stopped [4].

5. Over-empty lane safety measures and recovery effect
6212 coal column work surface back mining process will frequently through the empty lane, including along the coal seam roof dig into the empty lane, along the coal seam bottom plate digging into the empty lane, the same layer of empty alley intersection, cross-over lane intersection, the top board management, on-site safety management is difficult, in addition to the need to master the way of over-empty alley, the following safety technical measures need to be taken.

1) Coal release control
According to the 6212 working surface top plate to pressure the situation, combined with the work surface pressure appears and the degree of coal wall soft collapse to determine the specific measures. Work surface through the coal seam bottom plate digging into the empty lane, if the empty lane does not rise, generally can directly push and release the coal can be normal, work surface through the coal seam top plate digging into the empty lane, should be pushed to 3 m from the empty lane, stop releasing coal, at the same time should be appropriately reduced the work surface to extract height, work surface quickly pushed over the alley, to prevent the scaffolding die (Ensure stent front column 500 mm telescopic), minimize the damage of the bracket to the empty lane top anchor network support. Over the top area, because the top area has been filled with all the pulp, the work surface does not top coal; wait until the work surface through the area before continuing the normal cycle operation.

2) Top board management
Strict control of the speed of the shearer pusher, especially close to the empty lane should be completed in advance of the lifting of frames, pit wood roof, filling and other work, and reduce the speed of cutting coal, slow passage. After the empty lane is exposed, it is necessary to follow up the chain wooden stack above the support pit wood in time and to protect the top with the guard plate. When the working surface piece sits seriously, measures such as slurping reinforcement can be taken. A protective net is laid between the brackets to prevent strings and protect personnel and equipment.

3) Other safeguards
(1) It is necessary to discharge the toxic and harmful gases and accumulated water in the empty road ahead of time and thoroughly clean up the sundries in advance to prevent the iron cutters from injuring people when the coal mining machine passes through the empty alley;
(2) complete the overhaul of the mechanical and electrical equipment on the working surface in advance to ensure that the working condition of the equipment is in good condition;
(3) Ensure that the initial support force of the working face bracket reaches the standard and keep the bracket strong;

(4) Strengthen special measures for workers to learn, and hang up empty road layout maps on site to facilitate workers' on-site construction;

(5) Using wind cannons and hydraulic shears to retreat and cut in time;

(6) A safety net is placed on the front pillar of the bracket to prevent the iron from smashing and injuring people.

4) Analysis of recovery effect.

6212 work surface in the process of advancing over the empty lane, in the empty lane rock reinforcement and ensure the initial support of the bracket on the basis of the measures of the bracket and empty lane between the tight top, the work surface large-scale piece help, the phenomenon of the roof has been improved, the work surface bracket pressure only increased by 5%, after the empty lane bracket pressure returned to normal, Improve the speed of progress of the work surface, achieve safe recovery, successfully extract 530,000 t coal resources, and good economic benefits have been achieved.

6. Conclusions

Combined with the 6212 scrap work surface to face through the multi-layer multi-angle empty alley technical difficulties,

(1) Analysis of 6212 residual work surface empty lane spatial distribution characteristics, through numerical simulation to obtain the work surface over the top coal slope empty lane, bottom coal oblique empty alley and intersection of the surrounding rock deformation law, of which the intersection stress concentration is the highest degree.

(2) For the space location of empty alleys, different over-the-air lane key technology prevention, to ensure the safety of the salvage work surface.

(3) In the course of working surface over empty alleys, safety measures such as coal release control and roof management have been developed.

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