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Studies on the Material Characteristics of Bolt†

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In order to study how to improve the overall performance of the operational metal bolt, based on the production process of an ordinary bolt used in understructure engineering, this paper focuses on the existing problems of ordinary metal bolt identified by some survey and analysis. The results show that the structure of operational metal bolts is so unreasonable that the bolt tail is easy to fracture with low load capacity. Besides, it also introduces a new type of strong metal bolt and its heat treatment and roughing processing technology. Through bolt tensile and metallographic test, the property of the new bolt is analyzed. The new findings indicate that after special processing technology, the overall strength and plastic of the bolt has been greatly improved and the grain of bolt tail structure refined ,which would help build up favorable working conditions for bolt tail.

Keywords: New bolt, Processing technology, Mechanical test, Microscopic test.

INTRODUCTION

Tunnel support is a key technique in coal mining since reasonable, safe and reliable tunnel support technology is essential for keeping high yield and high efficiency of mineral well. As an active form of support, bolt support carries many advantages, such as good effects but low costs. It represents the development trend of tunnel support and has been widely employed at both home and abroad, which makes it one of the principal support forms in sinking and driving engineering[1,2].

The intensity of the bolt has a direct impact on the strength of the surrounding rock and the supporting resistance pressure that the bolt does to the surrounding rock, which furthermore affects bearing capacity of surrounding rock where the whole bolts support and the supporting effectiveness of the bolts. In the last few years, high and ultra-high intensity bolts have been developed and high intensity, high rigidity, high reliability have become a development trend. This kind of supporting system has great advantages in improving tunnel supporting effect, guarding safety of tunnel, reducing labor intensity of miners and simplifying maintaining technique at coal face area which will facilitate quickening the progress of coal face and realizing high efficiency and high production of mineral well. Nowadays high intensity supporting technology, which has been commonly used at home and abroad, has achieved great economic and social results[3].

Problems of ordinary bolt: Due to unreasonable structure of ordinary metal bolt used in China, it is common to find potential safety hazard and economical waste in tunnels supported by metal bolts. There are two problems: on one hand, with low extension, bolts could not adapt well to the twist of the surrounding rock, thus resulting in the shortening of life span of its tail. On the other hand, a large amount of metal materials are wasted because of low effective utilization rate. Therefore, it has become a major tough problem of manufacturing technology to design reasonable structure of bolt and make it carry economic property, which need urging solution.

At present, most of the metal bolts are made of reinforced bar: at first, the reinforced bar is divided into what is suitable for the design requirement; then put one end of the bar (100 mm long) into round; last, roll screws at the bolt-end which has been cut into round. In this way, after processing, the thread bottom of the metal bolt end is 10-14 % smaller than nominal diameter of the body of the rod and the area of section is 20-22 % smaller. Because the limit load of the bolt depends on the strength of the most unsubstantial part of the whole bolt, the material (intensity) strength of this common reinforced bar is wasted over 20 %.

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In order to solve this problem, the equal strength bolt is positively developed, that is, equaling the extreme load of the tail to that of the bolt body. There are mainly two methods: one is to use precision rolling right-reinforced bar bolt, together with specialized nuts to make equal strength bolts. However, the right-hand screw thread will affect the stir of resin bolt coagulator, the lift angle of screw is so large that it is not easy to screw down the nuts and it becomes flexible in most cases and the input is high. All these disadvantages make it unable to be used widely. Other way is to do some heat processing over the end of the common reinforced bar, making the strength of the bolt-end stronger than the body of the rod[4].

In most cases, heat processing over the bolt-end is used. It means to strength the screw thread of the bolt-end by solid quenching metastable phase, which make it stronger than the body of the rod so as to make sure the body of the rod blends first rather than the tail when the bolt bears the tensile stress. The bolts made by this way still break at its end when the distortion of the surrounding rock is great. This could not be explained by the push and pull on it, but from the mechanical property, after the heat processing, it is concluded that the internal reason for its abruption is that the metallurgical structure has changed after the quenching and heat processing over bolt-end (Table-1). Its increased strength is accompanied with declined plastic property. Although the whole extension ratio is improved, the bolt-end part is lowered so much that it causes higher brittleness and waste. (now the heat processing technique is 860-880 ºC selective heating and quenching[5].

Processing on the Caudal part of the new bolt: The new metal big-end bolt (patent No: ZL 99 2 16921.6), specially produced by laevorotatory screw-thread steal, is researched and developed by Professor Ma Nianjie from School of Resources and Safety Engineering, China University of Mining and Technology (Beijing). Besides, he also research and develop the equipment for producing this kind of metal big-end bolt. Its structure sketch map is showed in Fig. 1. The diameter of this big-end bolt screw is 3-4 mm longer than the nominal diameter of the body of the bolt[6]. The bolt-end is first treated by eddy-current heating, then overstriking treatment is done in the upset system, while in this procedure, rolled thread is put on the big-end as a assorted measure. (its specific producing technique is introduced into documentation)[7]. The heat processing over bolt-end is done by cooling down in the heated air and there is no quenching process, which will not lower the plastic property. For one hand, heat processing makes the reinforced bar improved both in its strength and extension ratio (the internal does not change in the bolt-end) for the other hand, the diameter of the bolt-end is longer than the diameter of the body of the rod. After these two procedures, the nature of the bolt is improved greatly. While the bolt reaches its limit of yield strength, the screw on the bolt-end does not break and the abruption takes places only on the body of the rod. All these make the strength and extension ratio be completely displayed[8-10].

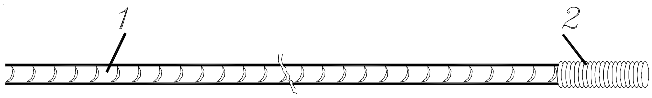

Fig. 1. Structure sketch map of new bolt. 1-Body of rod; 2-tail of rod

Experiments on new bolt material property: In order to study the internal structure changes of the material after the heart treatment corresponding manufacture and whether these changes will benefit the working conditions of the bolt, we did material big-end bolt microscopic and mechanics tests.

Mechanical property test: Tensile test, which is a common way to measure the intensity of steel is carried out on tensile testing ma-chine. Tensile test specimen is made by regulated standard. During the process of tensile, a map of relation between the stretching force F and the elongation ΔL will be recorded on papers, which is called tensile curve graph. Trough the analysis of that graph, the intensity index of metal can be worked out. After the tensile test, the body of bolt will undergo four changing phases:

Elastic phase: During this phase, if the load is removed, the specimen will recover, showing elastic deformation.

Yielding phase: When the load increases and specimen stress exceeds σ_p, the stain grows faster than the stress. At this time, stress is out of proportion to strain so that plastic deformation takes place. When the steel force reaches its yielding point, deformation will develop quickly. Although the steel is not damaged, it won't be up to requirements of use.

Strengthening phase: When the steel graduates from elastic phase to yielding phase, its property has undertaken a basic change from elasticity to plasticity, reflecting changes in the internal structure of steel (one part of a crystal lattices is opposite to the other, slipping along certain crystalline faces). After passing the yielding point, the internal structure of steel rebuild new balance, improving capability of deformation resistance.

Necking phase: When strengthening of steel reaches its highest point, the cross section of weak specimen will obviously decrease, causing necking phenomenon. Due to sharp shrink of specimen section, plastic deformation speeds up quickly so that pulling force drops correspondently and eventually fracture occurs (Fig. 2).

Specimen before and after metal big-end bolt test (Fig. 3). P-ΔL curve is made by experiments show in Fig. 4.

SEM experiment: Microscopic test is done in the Dao Jin material mechanics testing center China University of Mining and Technology. SEM was used to preserve metallic phase.

TABLE-L
HEAT TREATMENT CYCLE CURVE AND PROPERTY ABOUT BOLT END

Heat processing technique	Mechanical property			
	Yield strength (Mpa)	Ultimate strength (Mpa)	Elongation percentage (%)	Hardness (HRC)
860 ºC × 12-14 min water quench	1130	1690	10	45
880 ºC × 12-14 min water quench	1080	1650	5	46
900 ºC × 12-14 min water quench	1100	1470	4	47
Hot reduction state of supply	410	650	26	18

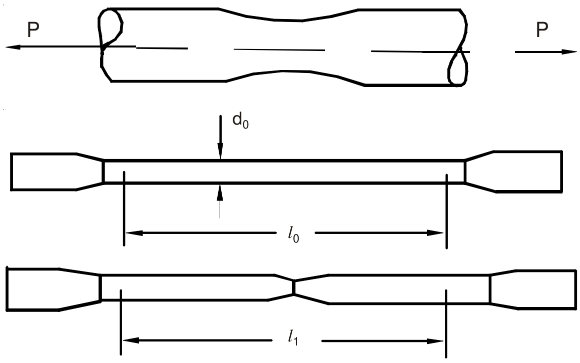

Fig. 2. Sketch map of necking phenomenon

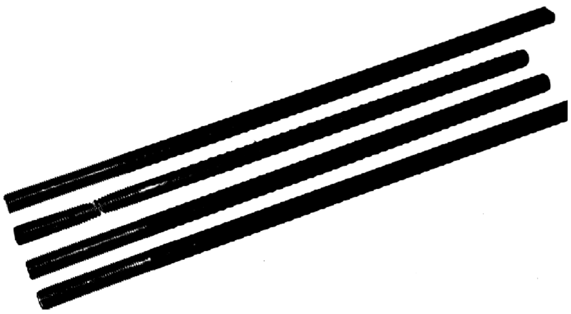

Fig. 3. Specimen before and after bolt test

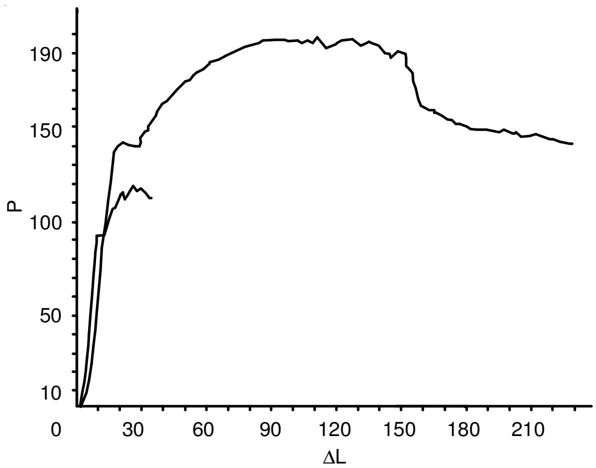

Fig. 4. P-ΔL curve of bolt

Then, the staenmchyma of the bolt is preserved be-fore and after the treatment ,which is under the enlargement factor: 750×, 1000×. The photos of the statenchyma before and after the treatment are shown in Figs. 5 and 6.

From the photos of the metallurgical, we can easily tell that the crystal grain in the bolt-end structure is refined.

Test analysis report: By comparing ordinary metal with the same specifications through tensile test of big-end bolt, it is concluded as follows: The bolt breaking strength has been raised from original 11.5 to 195 kN. Percentage of elongation has been increased from 35 to 228 mm. The crystal grain in the bolt-end structure is refined. The reason is that if the heat treatment over the bolt-end is under the phase transition temperature, the structure of the material does not change. Thus there is no chance that the bolt-end will become fragile. There is an extrusion procedure after the heat processing. During this extrusion, the bolt-end is strengthened and the geometry of

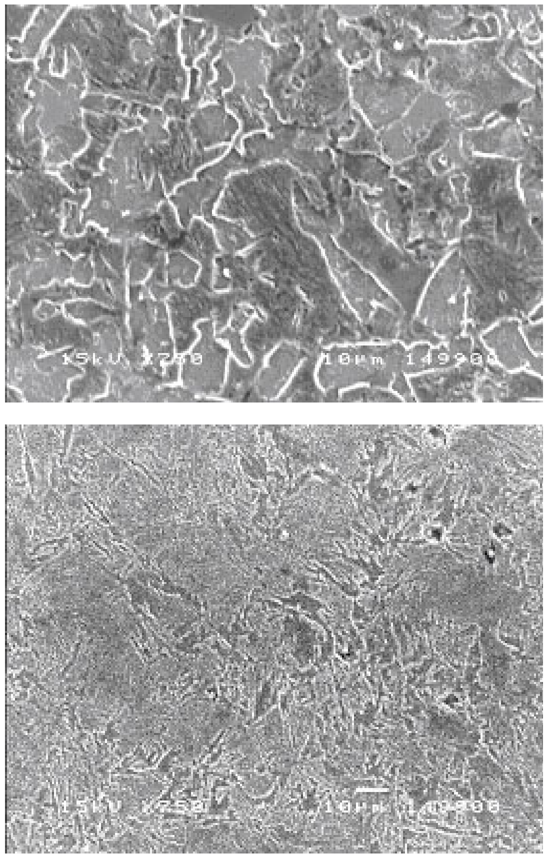

Fig. 5. Seven hundreds and fifty fold photo of metallurgical structure before and after heat treating

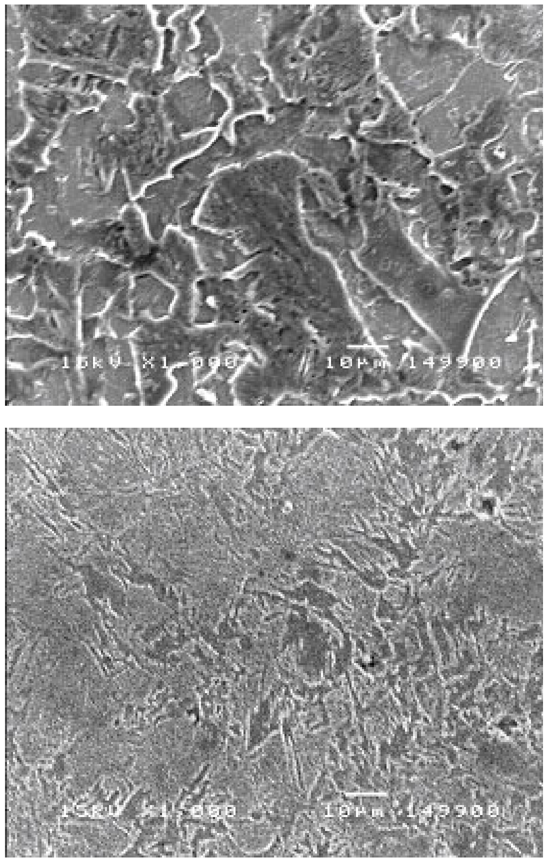

Fig. 6. One thousand fold photo of metallurgical structure before and after heat treating

the end is revised, so the strength of the bolt will be definitely improve. At the same time, crystal grain refinement will lysis the alignation of the internal components. Both the strength and the plastic nature of the bolt-end will absolutely improve after processing, which will bring great advantages to its working state.

Conclusion

Some conclusions can be drawn from the analysis and tests of common metal bolt. The manufacturing method now used in our country is causing low bearing capacity in the bolt-end, which is a potential danger in the bolt supporting tunnel and a waste of money. After heat and upset over the bolt-end bolt, the structure of the bolt-end is refined. The plastic nature and strength of the bolt-end is improved. The disadvantage is that the brittleness of bolt-end becomes larger after heat processing is overcome, so the extension ratio is able to increase. However, the disadvantage of the low strength in common bolt is conquered. The combination property method is improved after manufacturing procedure over the bolt-end.

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