Optimization Design of Circulation System for Metal Working Fluid

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Abstract

Based on a metal wire production enterprise as an example, aiming at the deficiency and shortage of original metal working fluid system, this paper put forward some improvement of system and process optimization measures. Besides, we tracked the actual running situation of the optimized processing lubrication system, and then the optimized process efficiency, stability and reliability were evaluated and studied.

Key words: METAL WORKING FLUID SYSTEM (MWFS), CIRCULATE, SYSTEM, OPTIMIZATION, DESIGN

1. Introduction

Metal processing is not only producing, but also resource consumption and waste discharging. To take full account of the production with the ecological point of view [1, 2, 3], energy consumption and environmental impact are different from each process [4, 5]. For a long time, the resource consumption and environmental pollution have caused a serious negative impact in the metal processing industry [6, 7, 8]. Therefore, green optimization of the manufacturing process has been widely concerned through the industry [9, 10]. At present, the model of metal working fluid system(MWFS) has been widely used in foreign countries. But in our country, there were always on the basic of experience and with a certain degree of blindness.

At present, the supply of metal processing fluid supply model has been widely used in foreign countries, and our country has always been on the basis of experience, with a certain degree of blindness [11,12]. As is demanded to the metal working industry of green optimization manufacturing [13], good quality and better work environment [14, 15, 16], better optimizing of MWFS are concerned [17,18]. The old design and equipments of MWFS is obsolete, the product quality problems caused by the metal working fluid system is emerge in endlessly, quality of wire such as bad glossiness, larger strength change and surface defects etc. At the same time, it also caused the serious environmental pollution which brought the serious loss to the enterprise [19].

In view of the above problems, this study combined with the requirements of energy-saving and emission-reducing, MWFS has been optimizing designed, through the analysis and comparison of the results, the optimized process appeared. Later green production and energy saving for the metal wire processing industry is proved.

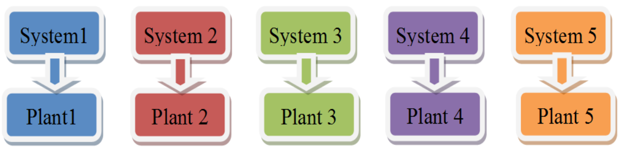

Figure 1. The original supply system of metal working fluid in use

By the figure it can be seen, the original lubricating system used tap water as water preparation, added new fluid according to the steel wire production, making the total amount of fluid lubrication constant. The system shut down 1~2 days per month for drainage works. Each shutdown 15% of the old liquid was rowed off, as a way to exclude metal chips and bad product.

2. Present situation analysis of MWFS

2.1. The original MWFS in use

MWFS is a system which can transport, cool down, store and control the lubricant [20]. It is responsible for the quality of the lubricant. In Jiangyin Fasten wire products co., LTD. (hereinafter: the plant) as an example, the factory had 5 sets of independent lubricant circulation system originally. Each system respectively controlled 1~5 wet processing fluid areas of steel wire production workshop, as shown in figure 1. For each independent system, the main equipment and technological process was shown in figure 2.

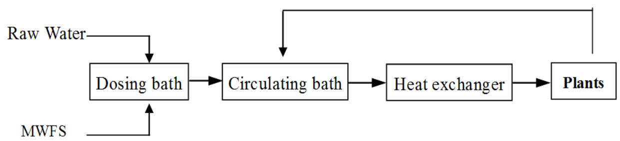

Figure 2. The operation process of lubrication system

2.2. Problem analysis of metal processing cycle system

The original lubricating system existed the following problems [21, 22, 23, 24]:

(1) The dosage of lubricant was large, which resulted in increased energy consumption such as water, electricity, etc.

(2) The equipment of lubricating fluid circulation system was obsolete, so the system running maintenance needed to consider many factors such as water quality and equipment. Besides, the labor costs were very high.

(3) Large amount of liquid waste discharged with the purification treatment effect not obvious, which led to serious pollution of the environment.

(4) Due to the above 3 points, the quality of the products declined, customer complaints increased, loss was immeasurable.

3. The optimization of drawing lubrication cycle system

To accomplish the goals of reducing in lubricants and mould consumption, prolonging the service life of lubricants, saving production cost, improving the production environment, lowering the temperature in the workshop, shortening downtime of cleaning pool, and lightening workers' labor intensity, etc., the optimization design of wire drawing lubrication system had the following several aspects.

3.1. Water softening

The quality preparation water affected the pH, conductivity and bacteria of lubrication fluid. If the hardness of lubricants was too high, it would easily to react with anionic surfactants in the emulsion, generating insoluble soap precipitation, which may destroy the stability of emulsion [25, 26]. Ion exchange technology was adopted for water softening treatment, making up the hardness of water control in 80 to125 ppm $CaCO_3$, pH 6.5 to 7.5, Cl^- concentration < 10^{-6}, SO_4^{2-} concentration < 10^{-6} (do not reduce the anti-rust), bacteria content < 10^3/mL.

$$2RNa + Ca^{2+} \rightarrow R_2Ca + 2Na^+ \tag{1}$$

$$2RNa + Mg^{2+} \rightarrow R_2Ca + 2Na^+ \tag{2}$$

3.2. Optimization of supply system structure

The original 5 sets of independent lubricant circulation supply system were changed to 2 sets of focus liquid circulation cooling system. At the same time each system was installed circulating bath and pouring bath which could switch to each other, as shown in figure 3. Circulating bath and pouring bath was connected, switching each other through the valves. When the impurities in circulating bath gathered too much, pumped the upper lubricant into the pouring bath, switched valves to connect pouring bath with workshop, the valve between the Circulating bath and table was closed. At this time pouring bath was used as circulation bath, and the original circulation bath was as a sedimentation tank. When the under layer lubricants in circulation bath was precipitated completely, strained the upper liquid into the pouring bath, the rest sediment was pumped into the waste liquid bath. After the pouring work finished, the original circulating bath and pouring bath recovered back to the original features, and so on, forming a complete cycling system.

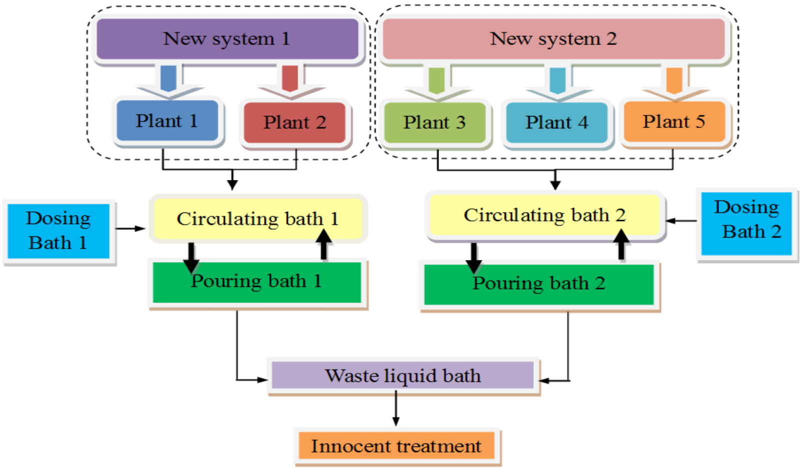

Figure 3. The optimized circulation supply system arrangement

The pouring and circulating of lubricant–natural sedimentation particles force analysis in the gravitational field

Gravity: $$F_g = \frac{\pi}{6} d^3 \rho_s g \tag{3}$$

Buoyancy: $$F_b = \frac{\pi}{6} \rho g \tag{4}$$

Resistance: $$F_d = \xi A \frac{\rho u^2}{2} \tag{5}$$

Here: $$A = \frac{\pi}{4} d^2 \tag{6}$$

According to Newton's Second Law:

$$F_g - F_b - F_d = ma \tag{7}$$

So the free settling velocity can be deduced as:

$$u_t = \sqrt{\frac{4gd(\rho_s - \rho)}{3\xi\rho}} \tag{8}$$

3.3. Lubrication cooling system upgrade

In summer, the working temperature was very high with the using of lubricant, so we increased some heat sinks in the original cooling device. In this way, the cooling area was increased, the cooling effect of lubricant was improved, the performances of lubricant grease decomposition and oil film rupture caused by high temperature were reduced. The temperature of working environment was decreased from 40-50℃ to 35℃ below, thus the workshop environment and working comfort was improved.

The selection and calculation formula of heat exchanger was as follows:

$$Q = K \cdot F \cdot \Delta t_m \tag{9}$$

In the formula, Q refers to heat flow with unit Watts; Δt_m refers to logarithmic mean temperature difference with unit ℃; F refers to heat transfer area with unit m^2.

In the actual operation of plate heat exchanger, because of the influence of dirty and unequal flow, a correction coefficient β is introduced into the formula (9). β is ordinary taken 0.7~0.9. Therefore, in the actual use, the formula is carried on:

$$Q = \beta \cdot K \cdot F \cdot \Delta t_m \tag{10}$$

3.4. Adding the pipeline cleaning

Pipeline conveying system using for a long time led to the adhesion of sticky mud, scrap metal, bacteria, and incrustation in pipe wall. It seriously influenced the fluid supply and circulation cooling effect. Adding some new dedicated pipeline cleaning equipment, selecting the appropriate pipe cleaning agents and methods, they can effectively and quickly dissolve all kinds of dirt adhesion in the tube wall, achieve the purpose of cleaning the pipe line thoroughly.

3.5. Adding the filtering facilities to remove sludge and scrap metal

Metal debris was generated in the process of dra- wing wire products, it came into being oil sludge when adhering with lubricant oil. These impurities suspended in lubricants may stick drawing die hole dirty, block die eye, and then result in line breaking, so that the mould cost and the waste wire rate increased. Metal powder and other chips and floating oil would provide breeding environment for bacteria, which would accelerate the deterioration of lubricant. The increasing in impurities could also affect the cleanliness of wire surface, causing the deterioration of the surface quality of products. So we designed a multi-stage filtration device combined of coarse filtration and fine filtration technology, as shown in figure 4. Stage 1 was precipitation and separation of coarse particle, water climbed after the ladder, coarse particle precipitated at each step and clean water flew into the next stage. In stage 2 of fine particles got preci- pitation and separation, fluid of phase 2 flew through the slope, and grain sediment would be deposited at each step with clean water into the next stage. Stage 3 was set as sterilization area, which had the effect of inhibiting bacteria and microbial. At regular intervals of pouring liquid, clean water was used to rinse the ladder, then the sludge would be pumped out for further disposal.

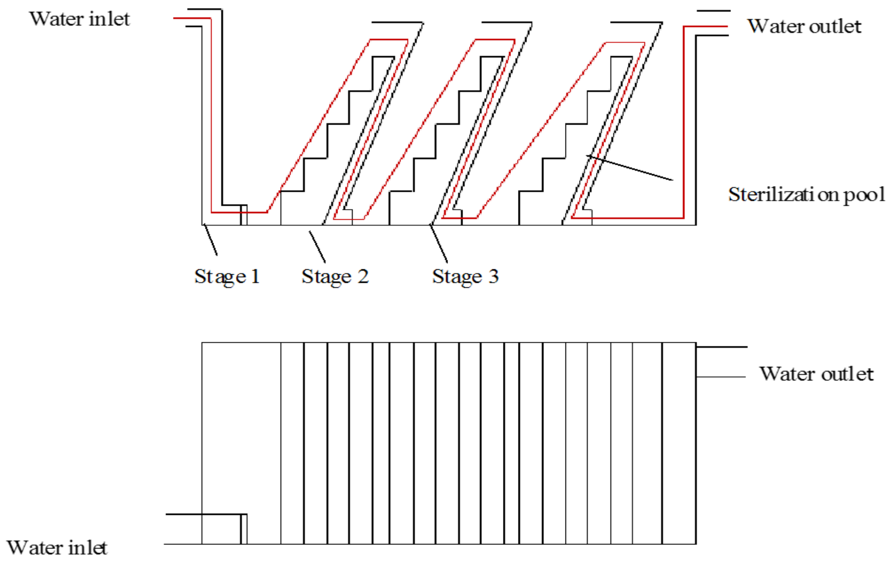

Figure 4. A coarse filtration and fine filtration technology combination of multi-stage filtration device

4. Results and discussion

4.1. Effect of temperature changes in MWFS circulation system

In this study, temperature of MWFS circulation system was measured and analyzed before and after the optimization, through recording monthly average temperature of the circular groove, it can be observe the temperature of the circulation system before and after optimization. To get the best performance, temperature of MWFS should be controlled in 35℃~45℃. Figure 5 showed that before optimizing. Circular groove in the average temperature changes over the environment temperature. Usually from January to April of every year and at the end of the year, in month November and December, environment temperature would be lower than 35℃, while at the month from May to October of every year, it would be higher than 45℃. Daily highest temperature would beyond 60℃, some of oily substances dissolved out and accelerated aging of MWFS. After optimizing, temperature throughout the year have been excellent controlled in 35℃~45℃ in the circular groove.

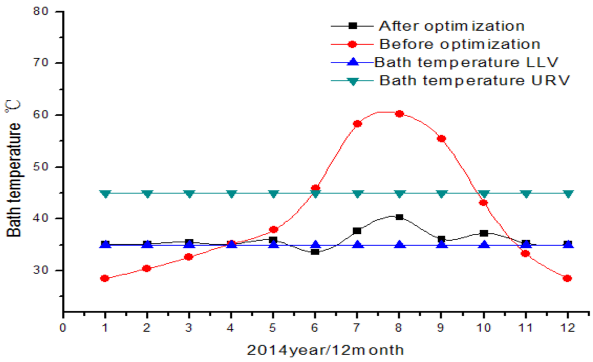

Figure 5. Temperature of MWFS circulation system

4.2 Effect of environment temperature changes of plant

In this study, through measuring the environment temperature of plant under system optimization. Figure 6 showed that variety of environment temperature in average in one year. When weather changed, did the temperature of plant. It can be clearly seen that after system optimization, the environment temperature of plant 5℃~20℃ lower than before. When optimizing, workers' gain a more comfortable surrounding and fatigue reduced. The same time, heat of machine was carried away quickly, equipment running to reduce energy consumption. Finally, artificial cost is reduced, equipment operation efficiency improvement, product qualification rate of increase, it may directly or indirectly influence the cost of production.

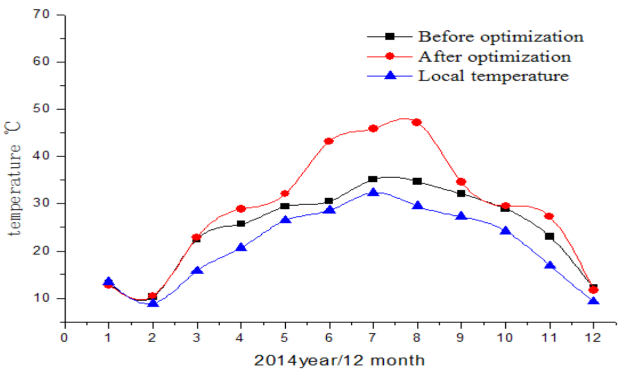

Figure 6. Environment temperature changes of plant in a year

4.3. Effect of MWFS monthly consumption after optimization

In this study, keep the working conditions inside the water tank wire drawing machine , gave a MWFS concentration of 4.5%, the same drawing rate and steel wire production quantity, MWFS monthly consumption was counted after optimization the whole year. It can be seen monthly consumption of metalworking fluids were not identical in figure 7., after optimization, MWFS monthly consumption kept consistent, and with a totally lower consumption than former. Monthly usage of MWFS vary considerably and irregular. In order to maintain a constant concentration of MWFS and ensure production output, optimize the former consumption should be up to 150 tons per month, the lowest 100 tons, an average of 120 tons/month. While after optimization, equipment operation stably and MWFS additives are held constant, adding amount of a count of 100 tons per month. Quality of steel wire products is relatively stable, which has no obvious flaws, when the seasonal changed, adding content has a slight variations.

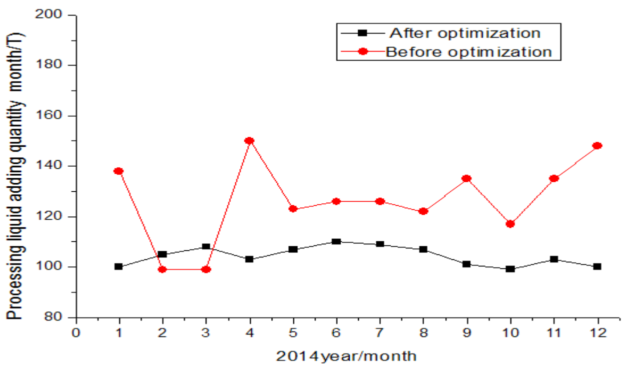

Figure 7. MWFS monthly consumption in a year

4.4. Effect of pH of MWFS after optimization

The same experiment conditions was shown in Figure 8., adding new MWFS at the same ration daily timing and keep a concentration of 4.5%. After optimization of MWFS, it had been seen that pH of MWFS had a slim range from pH 8.5~9.5. Gave six times of adding amoxicillin of 0.05 ppm/L as bactericide a year, a large number of bacteria was inhibited. Which was testified good to promoting the production efficiency and guarantee the quality of steel wires. With a long time of using of new MWFS, pH can be dramatic decrease from 9.0 to 6.5. In order to verify the validity of the test, the 0.03ppm/L of amoxicillin were sterilized. Five months later, the pH value significantly improved, but in July, and a sharp decline, and then add 0.03ppm/L of amoxicillin, the effect is not satisfactory, then add 0.05 ppm/L amoxicillin, pH value increased to 8.1. One month later, pH decline again. Respectively, with the addition of 0.05-3ppm/L amoxicillin, until the end of the year, pH decreased to 6.5.

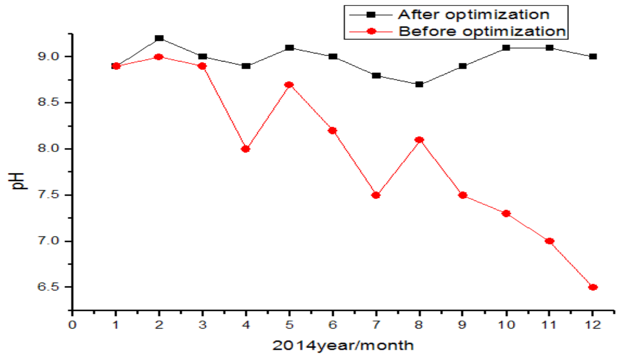

Figure 8. Effect of pH of MWFS after optimization

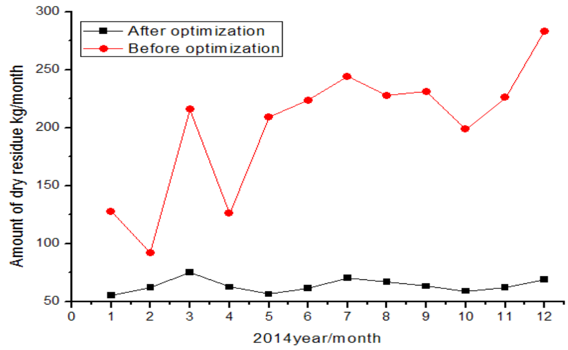

Figure 9. Quantity of waste dry slag before and after the optimization

4.5. Effect on the content of waste dry slag after optimization

In this study, quantity of waste dry slag in the MWFS of the system is discussed. Figure 9. Shows the change of waste dry slag in the MWFS system. With both the change of the environment temperature and the consumption of the MWFS , the weight of dry slag increased consumption before optimization. The higher the use time, the higher the ambient temperature, did the higher the dry slag content. This mainly apply to the more use of time which grow out the more impurities in the system. Under higher tempe- rature, the more loss of MWFS would led to the more the new liquid, and the performance of dry slag. After optimization, total weight of the dry slag reduced much, the number of dry residue is maintained constant and the quantity of the dry slag is reduced more than 4 times than before. By the optimization of the dry slag content nearly below 60 kg/ units.

4.6. Effect on the wastage of drawing die after optimization

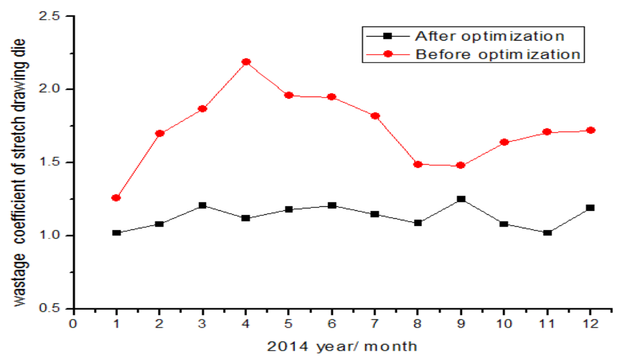

Figure 10. Wastage of drawing die in the processing of drawing steel wire making

In this study, the wastage of drawing die in the processing of drawing steel wire making is discussed. There are many factors affecting the life of drawing die, like the size of the reaction force, the way of the compression ratio, the MWFS and the surface quality of wire . Therefore, in the same steel wire production process, the wastage of the unit modulus of drawing die mirrored the drawing speed, the material of the finished steel wire and so on. To this end, a full annual consumption of drawing die coefficient has been summarized, as is shown in figure 10., in the same surface quality of steel wire and tensile rate consistent premise of the production per ton steel wire. Before optimization, the unit wastage of drawing die will increase continuously between January to April, while the next 5months decreased continuously, the annual unit wastage modulus of the drawing die at the large range of 1.3~2.3. In the case of the stable drawing process, the same stretching method is maintained, and the coefficient of unit wastage modulus of the system is maintained between 1.3 to 2.3, the process is stable and the surface quality of the product is of no defective. Coefficient of unit modulus is reduced by 1.5 times compared with the optimization.

4.7. Running cost analysis of system optimization

Table 1. Optimization of the production cost of steel wire for metal working fluid supply system

Consumption RMB/T	Before optimization	After optimization	Optimization rate
Labor	300	290	3.3%
Energy	500	600	-20%
Defective products	250	170	32%
Others	600	500	16.7%
Total price	1650	1560	5.5%

As shown in the above table1., when the system process optimized, comprehensive production cost optimization rate reached 5.5%, in which the labor cost has an optimization rate of 5.5%, the comprehensive energy consumption reduced by 20%, 32% of the cost of defective products, other cost optimized at 16.7%. This result is beneficial to the optimization of production efficiency, and indicate the advantage of the optimization of the MWFS system.

4.8. Optimization of the process flow

In this paper, the supply system of the MWFS system is optimized, and a complete and practical application of wire drawing process is proposed. Based on the whole year's comprehensive study of production test instance, new processing route of wire drawing lubrication is recommend. The process route of new parts is recommended at figure 11.:

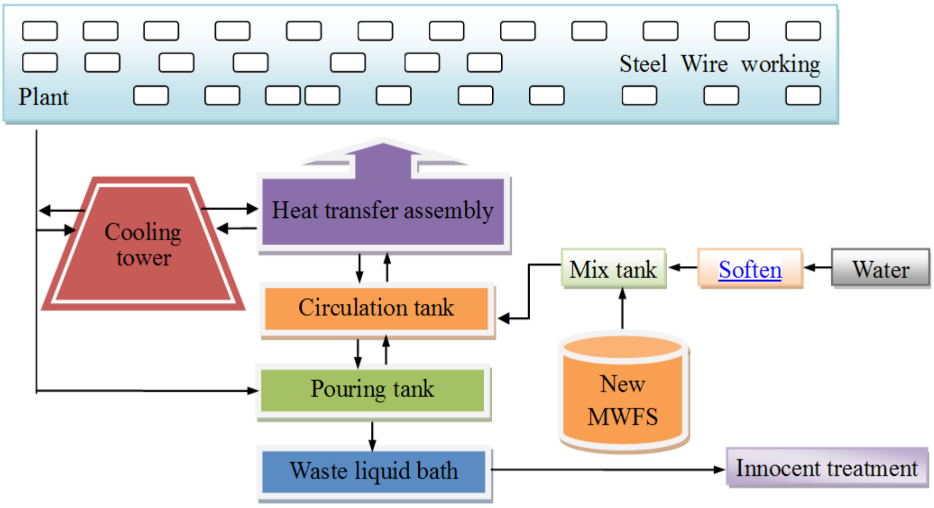

Figure 11. The flow of process route optimization of process planning for green manufacturing

5. Conclusions

(1) Through increasing water softening system, optimizing the structure of MWFS supply system, improving the function of the cooling system, deep cleaning pipeline, accelerating the sludge and metal scraps filtering and other measures, to achieve the purpose of optimization design of MWFS system.

(2) In this paper, optimization results of the MWFS system are analyzed. The influence of the system's optimization consist of the consumption of MWFS, temperature and pH, of system, quantity of dry slag, and the change of the unit modulus of drawing die are studied. And then gave a comparison validation of total cost of a whole year wire drawing working. When optimization, result show that the system can be used to optimize the processing liquid temperature can be better controlled between 35℃~45℃pH value between 8.5~9.2, dry slag weight reduced by more than 4 times, the annual MWFS consumption reduced by about 20%, according to the cost of MWFS production of 2000 RMB/tons steel wire, the annual savings of 1000 tons per year, about 400000 RMB had been economized and the overall cost savings of about 5.5%;

(3) In this paper, the MWFS circulation system is fully optimized, and a application of steel wire drawing process is constructed completely and practically. According to the practical example, it proves that the maintenance cost of the MWFS is reduced, the labor cost and equipment maintenance time were saved. At the same time, impurities and the amount of waste liquid emission load were reduced in MWFS system, prolong the service life of the lubricating fluid. Meanwhile , the depth of the steel wire production process for the production of green manufacturing process has been optimized, which has created favorable conditions.

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