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Method for Controlling Production Cost of Nano Ti-based Materials based on DMAIC

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In order to reduce the production cost of nano titanium based functional materials, a production cost control method of nano titanium based functional materials based on DMAIC is proposed in this paper. The DMAIC (Define, Measure, Analyze, Improve, Control) model was used to analyze the production of nanoTi-based functional materials and define the main factors affecting the production cost of nanoTi-based functional materials. The indicators for measuring the quali. The regression model was established to determine the main factors affecting the rod content and yield of nanoTi-based functional materials. The appropriate experiments were used to determine the best control conditions and to improve the technical parameters. Through the control methods of monitoring, coordination and improvement, the phased results are consolidated and improved. The experimental results show that the quality and yield of nanoTi-based functional materials are significantly improved after using this method, and the cost reduction of each production link is also significantly higher than that of the comparison method.

Keywords: DMAIC, Atom-Economy, Ti-based, Functional Materials, Controlling Production Cost

1 Introduction

The emergence of nanoscience in the 1990s has greatly broadened the field of chemistry research, and has attracted the interest of many chemists and has become a research hotspot. The so-called nanoscience refers to the study of the properties and interactions of matter (including the manipulation of atoms and molecules) at the nanoscale (between 1 nm and 100 nm), as well as the multidisciplinary science and technology that utilizes these properties [1, 2]. The basic units of nanomaterials can be divided into three categories according to spatial dimension [3, 4]: Zero-dimensional, which means that the spatial three-dimensional scale is within the nanometer size range, such as nanoscale particles, atomic clusters, artificial superatoms, and nano-sized holes. One-dimensional means that there are two dimensions in the space, such as nanowires, nanorods, nanotubes, and nanobelts. Two-dimensional means that there is one dimension in the three-dimensional space in the nanometer scale, such as ultra-thin film, multilayer film, and superlattice. In this definition, spatial dimension refers to the degree of freedom that is not constrained. According to its aggregation state, nanomaterials can be roughly divided into nano-powder (zero-dimensional material), nano-fiber (one-dimensional material), nano-film (two-dimensional material), nano-block (three-dimensional material), nanocomposite, nanostructure [5]. Among them, the nano powder is also called ultrafine powder or ultrafine powder, generally refers to a powder or particle with a particle size below 100 nm, and is a solid particulate material in a transition region between the atomic cluster and the macroscopic object. Nano-powder has the longest research and development time and the most mature technology, which is the basis for the preparation of other nano-materials [6-9].

Titanium (TiO_2) is rich in compounds. Nano-titanium is commonly known as titanium dioxide. It is a non-toxic white powder, tasteless, non-irritating, and has excellent thermal stability and chemical stability [10, 11]. Because nanoTi-based functional materials have excellent catalytic, electrical, magnetic and optical properties, they have broad application prospects in many fields, such as UV-resistant materials, textiles, photocatalytic catalysts, self-cleaning glass, sunscreen, paint, ink, food packaging, paper, aerospace, solar cells and lithium batteries [12]. Nano-TiO_2 has a well-known photocatalytic effect [13, 14]. In addition, a variety of ways to modify the TiO_2 photocatalyst have been carried out, and a series of nano-titanium dioxide composites have also been synthesized. The hydrogen form of titanate $H_2Ti_3O_7$ is a potential electrolyte for proton transport fuel cells. Barium titanate and lead titanate are excellent ferroelectric materials [15]. Alkali metal titanates such as potassium titanate and sodium titanate have high catalytic activity and ion exchange properties, which attract more and more attention in photo-purifying water, photocatalysis and fuel cell electrolytes. Before the 1980s, the research and development of nanoTi-based functional materials was mainly used as fine ceramic raw materials, catalysts, sensors, etc. [16], and the demand was small. Since the 1980s, due to its broad application prospects in photocatalysis and environmental protection, the production and demand for nanoTi-based functional materials has increased greatly. At present, developed countries such as Japan, the United Kingdom, the United States, Germany and Italy have conducted in-depth research on nanoTi-based functional materials and have realized the industrial production of nanonanoTi-based functional materials. More than a dozen companies around the world produce nanoTi-based functional materials, with a total production capacity estimated at 5,000-11,000 tons/year and a single-line production capacity of 500-600 tons/year. Since production cost of nanoTi-based functional materials is high, research on production cost of nanoTi-based functional materials is of great significance.

In the past, the production cost control method based on RBF neural network was used to adjust various cost drivers by analyzing the cost influencing factors and constructing the cost control model. The cost control method based on reinforcement learning pays attention to the advance control of cost, and carries out production cost management through activity-based costing. However, the control effects of the above methods have not reached the ideal state. DMAIC (Define, Measure, Analyze, Improve, Control) is an important tool for process improvement in Six Sigma management [17-19]. Six Sigma management is not only a concept, but also a set of performance breakthroughs. It turns ideas into actions and turns them into reality. DMAIC refers to the process improvement method consisting of five stages of definition, measurement, analysis, improvement and control. It is generally used to improve existing processes, including manufacturing process, service process and work process, etc. In order to reduce the cost, this paper proposes a production cost control method of nano titanium based functional materials based on DMAIC. The production situation of nano titanium based functional materials is analyzed by using DMAIC model, and the main factors affecting the production cost of nano titanium based functional materials are determined; The indexes to measure the quality and output of nano titanium based functional materials were measured; The regression model was established, and the main factors affecting the content and yield of nano titanium based functional materials were determined; Through appropriate experiments, the optimal control conditions are determined and the technical parameters are improved; Through monitoring, coordination and improved control methods, the phased achievements have been consolidated and improved, in order to provide some help for reducing the production cost of nano titanium based functional materials.

2 Materials and methods

2.1 Enterprise characteristics of producing nano Ti-based functional materials

The production process of nanoTi-based functional materials is between discrete production and continuous production [20]. It is a hybrid production process, which is characterized by both process-oriented enterprises and discrete enterprises. The complexity of this production process in nanoTi-based functional materials has resulted in the same complexity of cost control, as shown in the following: the production of nanoTi-based functional materials is a large-scale production and management mode of multi-stage production, multi-stage transportation and multi-segment storage. There are many processes and different forms. This feature makes the cost of the place scattered [21]; and there are various raw materials and work in progress. And the finished product makes the product cost dispersion [22]. The production and operation process of nanoTi-based functional materials is the unification of the production process and the circulation process, generally including three cycles of supply, production and sales [23].

According to the material flow and product formation process of the nanoTi-based functional materials manufacturer, the costs incurred in each stage can be represented by Figure 1. Due to the complicated production process of nanoTi-based functional materials, the out of control of any one process, the uncoordinated production process, and the negligence of some people's management may cause the production cost to be out of control. Therefore, how to realize the production cost control of multiple processes and links is an important issue for nanoTi-based functional materials manufacturers.

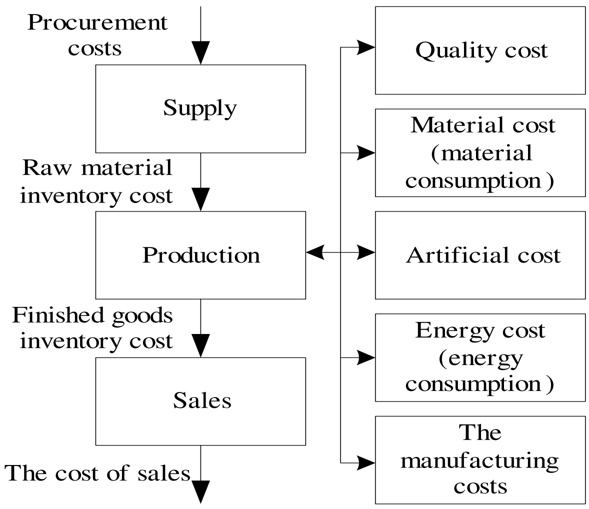

Fig. 1 *Cost at each stage in the production process of nano titanium functional materials*

2.2 DMAIC

DMAIC is the most important and classic improvement model in Six Sigma management, and it is the logically rigorous process cycle. It emphasizes the use of data language to describe product or process performance and leverages quantitative analysis and statistical thinking. By breaking old habits, DMAIC can achieve truly enhanced and innovative solutions to meet the needs of continuous improvement. At the same time, the advantage of applying the DMIAC process improvement problem is that the process conforms to the process of people's understanding and grasp of new knowledge, and provides tools at each stage to ensure that the project can be implemented correctly.

Since the establishment of standards can facilitate the follow-up process, therefore in order to achieve the Six Sigma goal, we must first set standards, track the assessment bias between operations and standards in management, and continuously improve, eventually reaching 6δ. A simple process model for continuous improvement of each link has been formed: definition, measurement, analysis, improvement, and control. The specific implementation process is as follows.

(1) Definition stage (Define): The main content of the definition phase is to identify the key needs of the customer and identify the requirements in order to improve the product or process [24]. Form the project team, develop a project plan, and determine the key cost characteristics (CTQ) for measurement, analysis, improvement, and control to define the improvement project within a reasonable range.

(2) Measure: The main content of the measurement phase is to develop the desired goals through the measurement and evaluation of existing processes [25]. Identify performance metrics to measure and weigh existing systems and data with flexible and effective metrics to understand existing cost levels. Verify the effectiveness of the measurement system, ensure that the measurement results are true and effective, and determine the original level of process improvement.

(3) Analyze: The main content of the analysis phase is to use statistical tools to analyze the entire system and find a few key factors that affect production costs.

(4) Improve: The main content of the improvement phase is the use of project management and other management tools to establish optimal improvements for key factors to minimize process deficiencies or variations.

(5) Control: The main content of the control phase is to consolidate the results achieved during the improvement phase. Through the revision of relevant documents, education and training methods, the successful experience will be institutionalized and standardized. Through effective monitoring, the results of process improvement are maintained, and continuous improvement methods that further improve the improvement are sought.

2.3 Implementation of the DMAIC process

Using the DMAIC method, according to the current production situation of nanoTi-based functional materials, the bottleneck problem first defined is to optimize the research object. The bottleneck can be improved, then the bottlenecks of the new production system are redefined, and new problems are improved, and new problems are improved to form effective continuous improvement.

2.3.1 Definition of the problem

In the production process of nanoTi-based functional materials, there are many factors affecting product quality, yield and cost in process control points, process operations, mechanical equipment, raw material quality, etc. [4, 26]. It can be seen that the main problems include the problems existing in the production process of nano titanium based functional materials, operators, machinery and equipment and raw materials.

(1) Problems in the production process of nanoTi-based functional materials: The production process of nanoTi-based functional materials is shown in Figure 2.

It can be seen from Figure 2 that ilmenite and stainless steel balls were made into ilmenite ball milling powder by ball milling under argon shielding gas, and ilmenite ball milling powder was combined with sodium hydroxide solution and hydrochloric acid solution to form the rod of the nanoTi-based functional materials. The rod of the nanoTi-based functional materials rods were treated by the combined process, and the whole process can be divided into four steps: ball milling pretreatment, carbothermal reduction, hydrochloric acid dissolution and air roasting [27]. Particles of nanoTi-based functional materials were obtained and used to make different nanoTi-based functional materials.

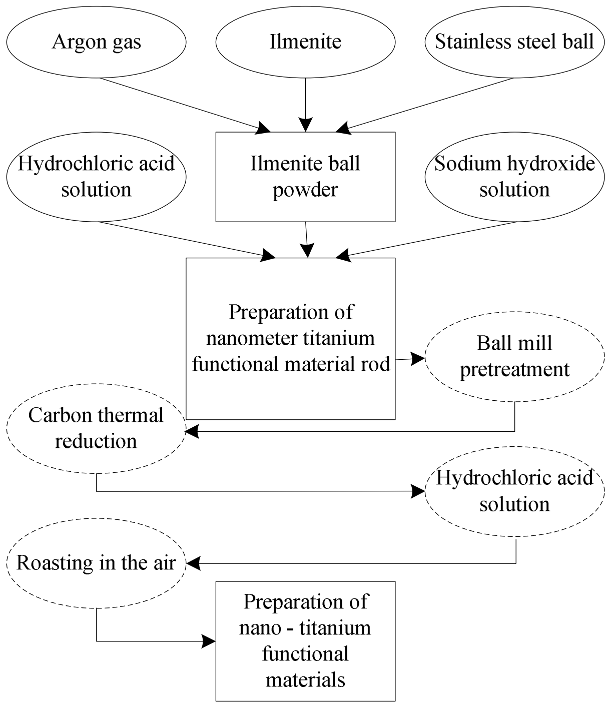

Fig. 2 *Production process of nanoTi-based functional materials*

In the above process, there are two main problems: First, in the process of producing nano titanium base rods, the drying time of the sample is insufficient, resulting in a small amount of water in the sample. During the chemical reaction with the solution reagent, impurities and the like occur due to the participation of moisture in the chemical reaction process, which affects the quality and yield of the nanoTi-based functional materials. Second, the combined process is used to treat ilmenite. During the preparation of the granule solution of the nanoTi-based functional materials with pore structure, factors such as the amount of reagent used and the dissolution temperature also affect the content of the titanium base.

The production process of nanoTi-based functional materials is the core issue of production cost control [28], and improving its quality and yield is the key to reducing the production cost of this process.

(2) Problems with operators: From the perspective of personnel structure, most of the front-line employees are young people, which are inevitably easy to be anxious, difficult to manage, and have insufficient ability to operate. Therefore, it not only affects the speed and efficiency of work, but also has a greater impact on the ability to produce safety. Due to the continuous reform of the economic system and the rapid development of the social economy in the past few years, the loyalty of employees has gradually faded, and the mobility of workers among enterprises has become strong. Not all employees have regular, comprehensive, unified systems, business training and safety education. This has resulted in no regular, comprehensive, unified, systematic business training and production safety education for all employees. In addition, employees' understanding of the changes in the system and the standard operating procedures is not fully understood and mastered. There is a large potential production risk due to the feeling of operation or frequent inquiries on the site with the squad leader.

From the perspective of personnel growth and promotion conditions, due to the influence of old and traditional employment concepts, and the lack of meticulous and complete employment mechanism, the situation of the employees being promoted or raised is too small, which will dilute the enthusiasm and self-motivation of employees.

(3) Problems with machine equipment: From the point of view of the production equipment itself, the production equipment is not used for a short time, and the production tasks are heavier and the production conditions are relatively bad. Therefore, the requirements for equipment maintenance, maintenance and repair are high. However, maintenance is limited by the production task, and sometimes it may not be done. For example, if there is a problem with the equipment during production, it cannot be repaired in time, which will lead to an increase in abnormal wear of the equipment and affect normal production.

From the point of view of the maintenance of the equipment, when the operating staff uses the equipment, the cleaning is not thorough, the maintenance is not in place, and the habit of finding the maintenance personnel is problematic.

(4) Problems with production materials: After each batch of raw materials enters the factory, it will be stored in the area to be inspected. After the inspection is passed, the qualified label will be transferred from the warehouse management personnel to the raw material qualified area for production and preparation. Workshop material receiving personnel and production operators only accept qualified raw materials for production, but there are also small quality differences in the materials that pass the inspection.

To sum up the above problems, we first find out the main factors from many factors and improve the main factors. New problems will arise during the production process, and the cause should be re-determined for improvement, gradual and continuous improvement. Among the above problems, the rods quality and yield of of nanoTi-based functional materials have an impact on the overall production cost, which is an important step and core for reducing the overall cost. Therefore, it is defined as a bottleneck problem, and it is the most scientific and reasonable to study it.

2.3.2 Quality deviation of nano Ti-based functional materials

By analyzing various factors that may affect the quality and yield of rods of nanoTi-based functional materials, the following two factors were found: raw material ratio and new process. The collection and statistics of two important factors are used to provide a basis for decision-making. The accuracy and authenticity of the data is the basis for ensuring the smooth progress of follow-up work. The improvement of raw material ratio includes the improvement of the ratio of main materials to auxiliary materials, and the improvement of the ratio of main material to solution reagent. The collection of data is a simple and time-consuming task. Under the cooperation of the quality department, according to the inspection results of the QC department, the data collection work was completed. The specific statistics are as follows:

2.3.3 Quality analysis of nano Ti-based functional materials

(1) Introducing independent and dependent variables: By measuring the data, it can be found that the ratio of the main material to the auxiliary material and the ratio of the main material to the solution reagent have a great influence on the content of the rod of the nanoTi-based functional materials. However, this judgment is based on the analysis of chemical reactions and has not undergone rigorous scientific argumentation. Therefore, the two factors are identified by the regression analysis method to determine the content of the impact indicator date.

By defining them as independent variables X1 and X2, the rod content of nanoTi-based functional materials was defined as the dependent variable Y, and the regression equation was established. The 12 sets of data in Table 1 were input into the Excel worksheet, the regression model was established, and the data was analyzed to obtain the following indicators.

Tab. 1 *Statistical table of technical parameters of supply and demand of nano-titanium functional materials*

Batch	Main and auxiliary materials ratio	Main material and solution reagent ratio	Nanometer titanium functional material rod base /%
1	0.9	9	91.2
2	0.91	9	91.8
3	0.91	15	92.6
4	0.93	15	93.8
5	0.95	9	94.4
6	0.91	12	92.2
7	0.90	15	91.8
8	0.92	12	92.9
9	0.94	12	94.1
10	0.93	9	93.2
11	0.95	12	94.7
12	0.92	15	93.2

According to the analysis results in Table 2 - Table 4, the significance test results were 0.996707, and the variance analysis result was 0.996416. This shows that the sampling data is reasonable, the independent variable has a great influence on the dependent variable, and the dependent variable has a significant linear relationship with the independent variable.

Tab. 2 *Regression statistical results*

Multiple R	R Square	Adjusted R S	Standard error of	Observations
0.997807	0.996707	0.996416	0.000562	12

Tab. 3 *Results of variance analysis*

	Regression analysis	Residual	A total of
df	2	10	12
SS	0.002141	4.92E-05	0.002146
MS	0.001015	3.18E-06	
F	3318.514		
Gnifcance F	1.00E-20		

Tab. 4 *Regression analysis results*

	Intercept	Main and auxiliary materials ratio	Main material and solution reagent ratio
Coefficient	0.322160	0.648254	0.001167
Standard error of	0.007540	0.008018	5.62E-06
t Star	42.97980	81.68818	20.25755
P-value	5.82E-11	3.26E-20	5.82E-11
Lower 95%	0.306325	0.63139	0.000949
Upper95%	0.337995	0.664008	0.001284
The lower limit of95%	0.306325	0.631399	0.000949
The 95% ceiling	0.337995	0.664079	0.0012842

The linear equation is:

$$Y = 0.648254 * X1 + 0.001167 * X2 + 0.322160. \quad (1)$$

According to the results of regression analysis, X1 and X2 have a great influence on the rod content of nanoTi-based functional materials, and there is a significant linear relationship between the two domains. The coefficients of X1 and X2 are both positive, and the rod content of nanoTi-based functional materials can be increased by increasing their values. It can be considered that the ratio of the appropriate material to the main material and the ratio of the solution reagent to the main material can ensure the quality of the nanoTi-based functional materials.

Through fish bone analysis, there are many factors affecting the rod content and yield of nanoTi-based functional materials. These include the operator's ability to work, knowledge and positive working attitude, the integrity and operation of the equipment, the quality of the material and the suitability of the production process. Combined with regression analysis, we believe that the main factors affecting the rod content and yield of nanoTi-based functional materials are the ratio of auxiliary materials to main materials, and the ratio of solution reagent to main materials.

2.3.4 Quality improvement of nano Ti-based functional materials

In this phase, the optimization process is mainly achieved by determining the optimal control conditions through appropriate experimental design.

(1) Determination of the best ratio of the main materials to auxiliary materials: According to the method of golden section and pre-experimental data, the ratio of auxiliary materials to main materials is in the range of 0.95-0.99, and the rod content of nanoTi-based functional materials has a maximum value. Therefore, the ratio of auxiliary materials to main materials is selected between 0.95-0.99. In order to ensure that the experimental data is true and effective, all experiments will be arranged under certain conditions, the reaction between the main material and the solution reagent ratio of 1:10, thereby eliminating the influence of the ratio of the main material to the solution reagent on the experimental operation. The Table 5 shows ratio and content of main and auxiliary materials.

Tab. 5 *Ratio and content of main and auxiliary materials*

Main and auxiliary materi-als ratio	Content
0.95	93.00%
0.99	92.96%

The position of the first experimental point X1 was: 0.95 + (0.99 - 0.95) * 0. 629 = 0.176, after a small test at this point, the measured content was 93.41%. The position of the second experimental point X2 was: 0. 95+(0.99-0.95) *0. 393=0. 966, after a small test at this point, the measured content was 93.26%.

Comparing the results of f(X1) and f(X2), since 92.41%>92.26%, the interval of 0.95-0.965 was deleted.

The experimental points were again selected in the range of 0.965-0.99. The position of the third experimental point X3 was: 965+ (0.99-0.965) *0. 629=0. 981, after a small test at this point, the measured content was 93.82%. After the comparison, 93.82%>92.96% can be obtained, so the interval of 0. 98-0.99 was deleted.

The fourth test point X4 was selected in the range of 0.975-0.98, and its position was: 0.975+(0.98-0.975) *0. 393=0. 978. After a small test at this point, the measured content was 93.66%.

Since the rod content of the nanoTi-based functional materials obtained at 0.975 is already lower than the measured value of 93.66 at 0.978, the interval of 0.975-0.978 should be deleted, and the new experimental points should be determined within the range of 0.978-0.980. However, in practice, the ratio of main materials and auxiliary materials is already small, and the small test values at 0.978 and 0.980 are also relatively close, so the optimum ratio of main materials and auxiliary materials can be set to 0.9979. Finally, in the actual production of nanoTi-based functional materials, the optimum ratio of main materials and auxiliary materials is set to 0.9979±0.001, which is 0.978-0.980.

(2) Determination of the optimal ratio of solution reagent to main materials: According to the golden section method and preliminary experimental data, the ratio of solution reagent to main materials was selected in the range of 15-21, and the rod yield of nanoTi-based functional materials has a maximum value. Therefore, the ratio of solution reagent to main materials was selected in the experimental range of 15-21. In order to ensure the authenticity and effectiveness of the experimental data, it is necessary to arrange all experiments under certain conditions, and carry out the experiment with the ratio of main material to auxiliary material of 1:0.98, so as to eliminate the influence of other factors on the experiment. Table 6 is ratio and yield data of solution reagent to main materials.

Tab. 6 *Ratio and yield data of solution reagent and main materials*

Solution reagent and main material ratio	Yield of nanometer titanium functional material rod
15	76.53%
21	76.51%

The position of the first experimental point X1 was: 15+ (21-15) *0. 629=17.6. After a small test at this point, the nanoTi-based functional materials rod yield was 76.59%. The position of the second experimental point X2 was: 15+ (21-15) *0. 393=16.6. After a small test at this point, the nanoTi-based functional materials rod yield was 76.71%. Comparing the results of f(X1) and f(X2), since 76.71%> 76.59%, the interval of 17.5-21 was deleted.

Select the experimental point again within the range of 15-17. The position of the third experimental point X3 was: 1:5+ (17.5-15) *0. 393=16.0. After a small test at this point, the yield of the sulphonate was measured to be 76.79%. After comparison, 76.79%>76.71% can be obtained, so the interval of 16.5-17.5 was deleted.

The fourth experimental point X4 is selected in the range of 15-16.5, and its position was: 15+ (16.5-15) *0. 393=15.7. After a small test at this point, the measured content was 76.66%.

Since the rod yield of the nanoTi-based functional materials obtained at 15.7 is 76.78%, which is equal to the measured value of 76.79% at 15.9, the interval between 15-15.6 and 15.7-16.5 should be deleted and continue. The new experimental point was determined in the range of 15.6-15.9, but in practice the range of solution reagent to main materials has been smaller, and the small test values of 15.6 and 15.9 were also relatively close. The best ratio of solution reagent to main materials is set to 15.8. In the actual production operation, the ratio of solution reagent to main materials cannot be controlled very precisely, and it remains unchanged at one point. Therefore, the reaction ratio of solution reagent to main materials was set as 15.8 ± 0.1, ie 15.7-15. 9.

2.3.5 Quality of production process of nano Ti-based functional materials

Project Control is based on good advance planning and planning, with regular or irregular surveys of all links in the project implementation process. Identify biased project activities in a timely manner, identify possible implementation options, and reduce bias. The project progresses to the final goal according to the plan. Due to the uncertainty of some work and the interference of various factors in the implementation process, the process of achieving progress often deviates from the expected path. Therefore, the project manager should compare the objectives according to the various information, find out the deviation, analyze the reasons, adjust the countermeasures and correct the measures to achieve the deviation.

Working in the control phase, the first thing to do is to have a clear goal. In this process, it achieves the achievement of the goal. The calibration objectives are based on an improvement plan and do everything possible to make progress as determined by the goals and direction. The second is to effectively use limited resources, improve the efficiency of resource use, and avoid wasting manpower, material resources and financial resources. Finally, monitor progress and improvement, properly address these issues, and ensure a smooth workflow.

3 Results

3.1 Quality improvement

The method for controlling production cost of nanoTi-based functional materials based on DMAIC was proposed in the paper. Taking the manufacturer of the nanoTi-based functional materials in China as the research object, the production cost is controlled by the method of this paper. The results are shown below.

3.1.1 Rod quality of nano Ti-based functional materials

Through the workshop hour study and the analysis of relevant data, there is a certain correlation between the ratio of main materials to auxiliary materials and the rod content of nanoTi-based functional materials. Through the workshop hour study and the analysis of relevant data, there is a certain correlation between the ratio of main and auxiliary materials and the bar content of nanoTi-based functional materials. The correlation obtained by experimental data is a function relationship similar to a parabola. A section was selected, based on experimental data, and the best ratio of primary to auxiliary materials was determined to be 0.98 by scientific analysis. Under this optimal ratio, the nanoTi-based functional materials can be improved from 91.50% to 97.73%, as shown in Figure 3.

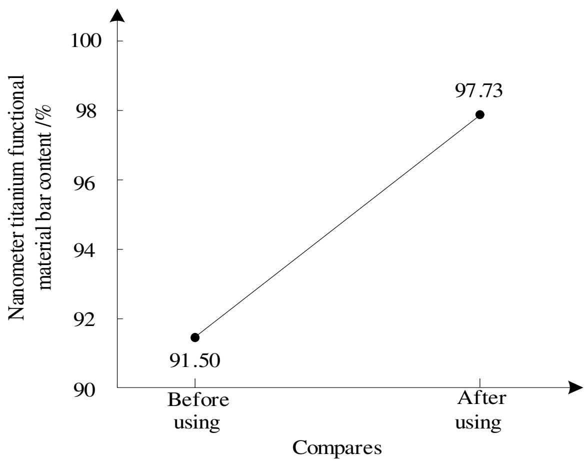

Fig. 3 *Content of nanometer titanium functional material rod*

3.1.2 Overall quality of nano Ti-based functional materials

This method not only enhances the rod content of nanoTi-based functional materials, but also reduces the by-products and other impurities, which has a positive impact on the overall quality and yield. After using this method, the content of nanoTi-based functional materials increased from 96.1% to 98.2%. As shown in Figure 4, the product quality has been greatly improved.

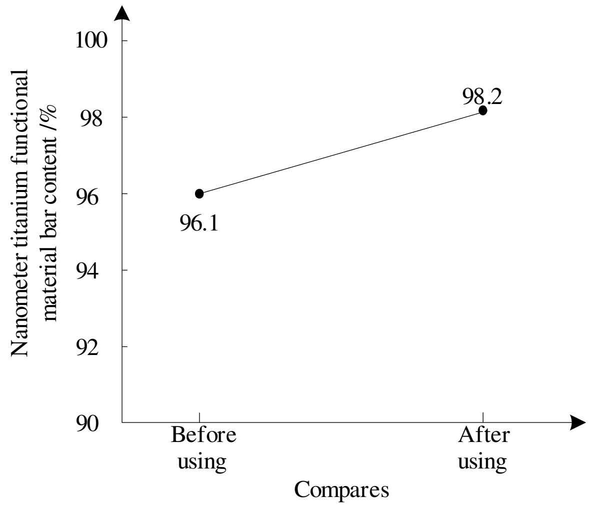

Fig. 4 *Content of nano titanium functional materials*

3.2 Yield improvement and cost analysis

3.2.1 Rod yield of nano Ti-based functional materials

Under the condition that the ratio of main and auxiliary materials is 0.98, the yield of nanoTi-based functional materials is closely related to the ratio of solution reagent to main ingredient. Through experimental data and scientific analysis methods, it can be obtained that when the ratio of the reagent to the main material is controlled at 15.8, the content of the rod of the nanoTi-based functional materials all reaches a higher value of 95. After using this method, the rod yield of nanoTi-based functional materials increased from 74.3% to 76.7, as shown in Figure 5.

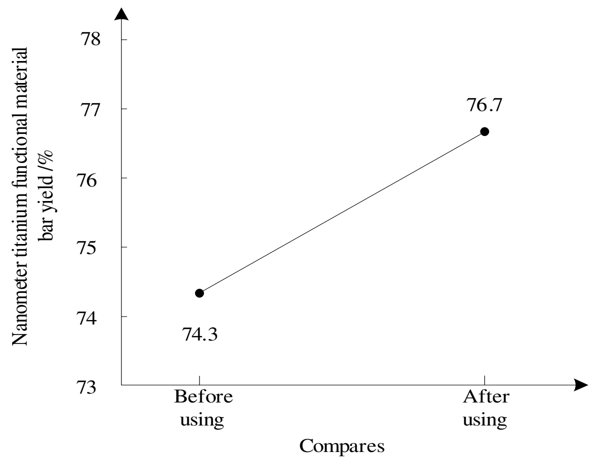

Fig. 5 *Yield of nanometer titanium functional material rod*

3.2.2 overall yield of nano Ti-based functional materials

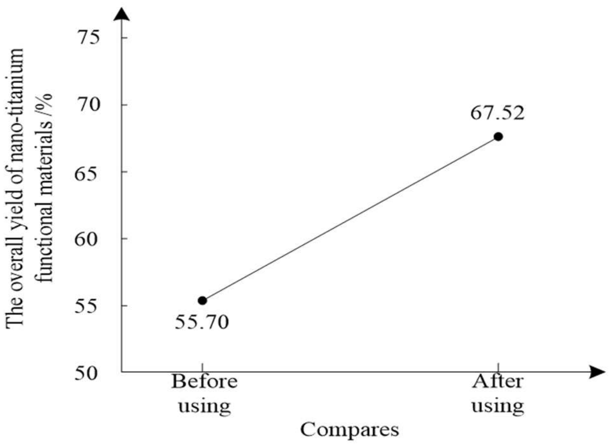

Fig. 6 *Overall yield of nano-titanium functional materials*

By using the method of the present invention to improve the ratio of the main material to the auxiliary material, and the ratio of the main material to the solution reagent, the material completion is more complete in the preparation process of the nano functional material rod. This not only increases the rod content of nanoTi-based functional materials by 3.23 percentage points (effectively reducing reactive impurities), but also improves the overall yield of nanoTi-based functional materials. As shown in Figure 6, the overall yield of nanoTi-based functional materials increased from 55.70% to 67.52%.

As the yield of nanoTi-based functional materials increases, the cost of raw materials is reduced by 68.3Yuan/kg. Calculated by the research object in December 2018, the output is about 62030kg, and the monthly savings in production is 6203×68.3=423664.9Yuan.

3.3 Control effect of production cost

In order to verify the superiority of this method in controlling production cost of nanoTi-based functional materials, the production cost of nanoTi-based functional materials was controlled by the method of this paper, the cost control method based on RBF neural network [29] and the cost control method based on reinforcement learning [30], respectively. The results obtained by the three methods were compared with those in which the production cost control was not performed. The results were shown in Table 7.

Tab. 7 *Production cost control effects of different methods*

The cost of	Before control/ (ten thousand yuan/month)	After control by this method/ (ten thousand yuan/month)	RBF neural network method after control/ (ten thousand yuan/month)	After key node control/ (ten thousand yuan/month)
Procurement costs	51.32	44.68	48.92	48.11
Raw material inventory cost	19.27	16.99	17.59	18.04
Quality cost	138.94	129.20	134.22	132.98
Material cost (material consumption)	5132.45	5089.34	5119.57	5111.46
Artificial cost	155.40	148.93	152.52	152.66
Energy cost (energy consumption)	99.71	90.06	94.84	94.44
The manufacturing cost	116.82	100.33	110.08	108.97
Finished goods inventory cost	36.51	32.10	33.65	33.08
The cost of sales	44.82	39.15	42.04	42.73

Analysis Table 7 shows that after using this method to control production cost of nanoTi-based functional materials, the cost of different production links decreased significantly. Among them, the decline in manufacturing cost was the most significant, reaching 14.16%, while the material cost was lower due to the larger base, which was 0.84%. After using the cost control method based on RBF neural network, the material cost decreased the least, at 0.25%, and the raw material inventory cost decreased the most, at 8.72%. The cost control method based on the key node has the lowest cost reduction of 0.41%, and the finished product inventory cost has the highest decline, which is 9.39%. The experimental results show that the proposed method is optimal for the production cost of nanoTi-based functional materials.

4 Discussion

Nano Ti-based functional materials have been favored by researchers all over the world for their special performance and wide range of applications, and have been successfully applied in various fields such as photocatalysis, lithiumion batteries and solar cells. Due to the shortage of mineral resources, the production cost of nanoTi-based functional materials is relatively high. Therefore, the method for controlling production cost of nanoTi-based functional materials based on DMAIC is proposed. The purpose of this paper is to reduce the production cost of nanoTi-based functional materials, but the research focuses on the improvement of product quality and yield. Through the research in this paper, the quality of nanoTi-based functional materials has been greatly improved. The increase in rod content and yield of nanoTi-based functional materials has led to a significant increase in the overall yield level of nanoTi-based functional materials, with an overall yield increase of 11.82%. The cost reduction in each production segment is also significantly higher than the comparison method.

This method has achieved certain results in improving the quality and yield of nano titanium based functional materials. After research and improvement, the quality level and yield of each process of the product are much higher than the original process, and the expectation of reducing production cost is realized to a certain extent. However, due to the limitations of various factors, there are still some deficiencies in the research method and process. For example, more methods are not selected to optimize the design method, so it needs to be further improved. After the work and study, the research can continue to deepen and improve. Perhaps using more scientific and rational research methods, experimental design and RBF neural network methods, we can find better production conditions, and the improvement should continue. In the future, efforts will be made to improve the rod quality and yield of nanoTi-based functional materials to achieve the goal of continuing to reduce production cost of nanoTi-based functional materials.

5 Conclusions

Nano Ti-based functional materials are widely used for their unique advantages. Their production costs are highly influenced by raw materials and process factors. At the same time, production cost control is one of the necessary means for enterprises to stand out in the fierce market competition under the economic reform environment. Therefore, the method for controlling production cost of nanoTi-based functional materials based on DMAIC is proposed herein. After using this method to control the production cost of nano titanium based functional materials, the cost of each production link is significantly reduced. Among them, the manufacturing cost decreased the most, reaching 14.16%, and the material cost decreased the most, reaching 0.84%. After using the cost control method based on data analysis, the material cost decreased by 0.25% and the raw material inventory cost decreased by 8.72%. For nanoTi-based functional materials manufacturers, the introduction of a new management method is, in a sense, a management revolution. The implementation process must be carried out step by step, and it cannot be rushed. It can only be effectively implemented if it is approved by all members of the company. The advanced management mode will inevitably lay a solid foundation for the rapid development of the company in the future. In order to provide some help for the realization of cost control in the whole field through this research, but because this paper does not choose more methods to optimize the design method, it needs to be further optimized in the next research process.

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