Design and research of pulsed vacuum sterilizer based on digital PID

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Abstract. The design and application of pulsed vacuum sterilizer based on digital PID can provide a certain technical support for the development of related industries. In order to make the theory and technology of pulsed vacuum sterilizer more perfect in our country, a simple design of the sterilizer was made, and the influence of air pressure on pulsed vacuum sterilizer was also compared and analyzed based on a clear overview of relevant theories in this study. The results show that the high pressure pulsed vacuum sterilizer has better sterilization effect. Compared with the traditional sterilizer, the pulsed vacuum sterilizer based on digital PID has better sterilization performance. The purpose of this study is to provide a scientific basis and reference support for further studies.

Key words. Digital PID, pulsed vacuum, sterilizer.

1. Introduction

A certain number of microbial communities live in the living environment of the human body, these microbial communities may have a damaging effect on people's bodies depending on their own skills, while some microbial communities may have some positive effects on the normal functioning of the organism and some physiological activities. These microbial communities include microbes, fungi, and other microorganisms. The quantity and kind of microorganisms existing in the human organism's living environment may be closely related to human health and disease, which have a certain impact on the health of the human body. For example, they may cause certain damage to the human immune system, and allow more bacteria or fungi to stimulate the human organism, thereby reducing the body's own immune levels and increasing the recurrence and severity of the disease. Therefore, the elimination of some harmful microorganisms has gradually been paid attention to by some countries. More timely measures have begun to be gradually applied to the actual sterilization process, which has provided a guarantee for human beings to

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create a better living environment. This research will study and discuss the design of pulsed vacuum sterilizer based on digital PID technology. The purpose of this research is to provide a theoretical basis and reference for the follow-up research and technical improvement and development.

2. State of the art

In the production and life of people, some microorganisms always affect people's normal life more or less. Many medical researchers believe that the presence of harmful bacteria in the environment for a long time may have an impact on people's health and may be an increase in people's disease outbreaks [1]. In recent years, the relevant international medical organizations and biological organizations have fully realized the negative impact of harmful microorganisms on human health and stability. And some western developed countries have been gradually carry out the relevant work and human body micro-biome research through some related techniques and methods, and obtained some achievements [2]. The sterile environment, especially the environment without harmful bacteria is necessary in many industries. In some hospital systems, some premature neonate can't complete its invasion of the external bacteria through its own immunity because of its relatively weak immune capacity. A sterile environment can help them go through this difficult period [3]. In some biological industries, a sterile environment is extremely important for the design and operation of industry related biological experiments. Only in a sterile environment can the process of the experiment be smoother and the results obtained are more reliable [4]. There are many researches on sterilization instruments, and the gradual improvement of sterilization instruments has made more industries develop. Under this trend, pulsed vacuum sterilizer based on digital PID technology has been studied more and achieved more achievements [5].

3. Methodology

In the present era, the economic level of our country has been greatly improved. However, our country's economic development model is more extensive mode of development, which has caused great damage to the relevant environment of our country to a certain extent. The harmful microorganisms in our environment have been increasing. And it does harm to the survival of people and other organisms [6]. It can be found in more reports in our country that with the development of the times, the physical quality of our citizens has declined. This trend is not only due to the lack of a certain amount of physical exercise, but also partly because of the gradual deterioration of people's living environment [7]. Many reports indicate that the harmful microorganisms in the soil and water bodies in our country are showing a gradual trend with the accumulation, which may have a great negative impact on our national health in the future to a certain extent. Under this trend, the research on killing some harmful bacteria in our country began to increase in the selection of better technology and theory. And in the development of some

industries, the creation of a sterile environment is also extremely demanding. To some extent, it may promote the development and progress of some industries in our country, and obtains more research results directly or indirectly. Especially in the development of the medical and biological industries in China, the use and operation of these industries may require the use of certain sterile environments, which can promote the human body to obtain a greater degree of health. Especially in the development of the biological industry, due to the operation of some pathological experiments, it may cause the relevant researchers to adhere to the harmful bacteria during the experiment. If it is not possible to sterilize the body or related tools and clothes in time, it may cause some harm to its health. The development of the food industry in our country also attaches great importance to the sterilization of related raw materials so that more healthy foods have been developed and put into market production [8]. Under this trend, sterilizer has been gradually applied to the development of various industries in our country (see Fig. 1).

Fig. 1. Development and application of sterilizer

Under this kind of demand, the related profession in our country has begun to increase for the sterilizer research. The sterilizers with different sterilization properties have been gradually put into practical industrial application, and have provided certain technical guarantee for the safety production and the safe use of products in related industries. However, due to lack of knowledge about sterilization theory in some industries or fields in our country, this makes the development and application of sterilization equipment still have certain limitations, and has laid a certain security risk for subsequent development. Nowadays, the design and research of pulsed vacuum sterilizer based on PID technology have provided certain positive impetus for the demand of sterilization treatment in various industries [9] (Fig. 2).

However, because of the high production cost of the sterilization technology, and the lack of mastery of the technology in some sectors of our country, it makes it impossible to better integrate the technology with the actual demand of the industry. This limits the further development of some industries to a certain extent [10]. Therefore, a clear overview of the design theory of digital PID based pulsed vacuum sterilizer was given and the feasibility of its practical application was analyzed in this study. The purpose of this study is to provide theoretical support for the gradual improvement of this technology, and to provide technical support for the integration of this technology with other industries.

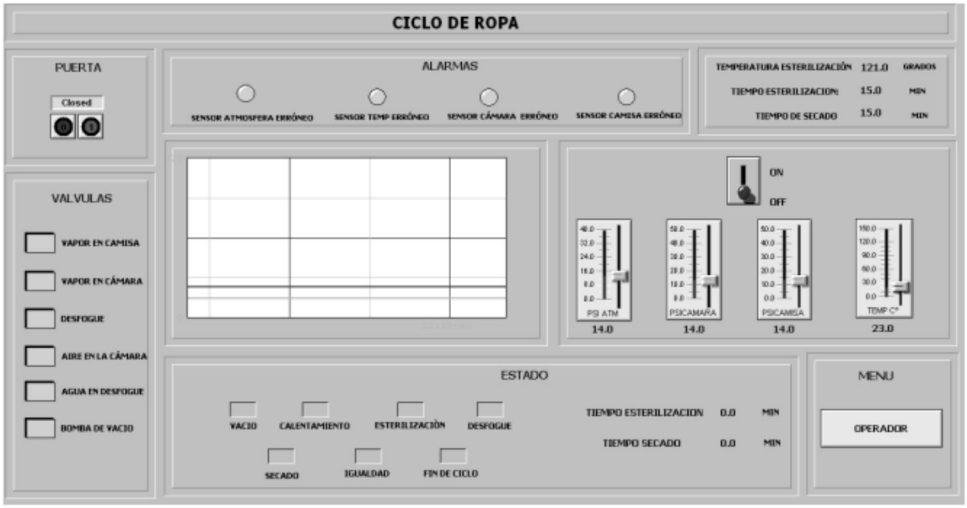

Fig. 2. The use of digital PID technology in the development of sterilizers

In order to obtain more accurate and reliable analysis results, the study was further carried out by the following related research analysis. The detailed methods of study are as follows:

First of all, the relevant information was read and summarized in this study. On this basis, the relevant theories were clarified, and the main deficiencies of the commonly used sterilization system in our country were explained and analyzed. Then, the sterilizer was designed and optimized on the basis of the cognition of the design principles of the sterilizer.

In view of the pressure and temperature detecting system of sterilizer, the control algorithms of steam generator and temperature in the sterilization cavity were studied and discussed. The algorithm model of PID was introduced in the design concept of pulsed vacuum sterilizer [11]. The related formulas of the algorithm model were introduced as follows in this study.

(1) The deviation between the preset value of the pulsed vacuum sterilizer and the actual output value of the sterilizer was calculated. The formula model is

$$e(t) = r(t) - c(t)\,, \tag{1}$$

where $r(t)$ and $c(t)$ represent the set value and actual output value respectively.

(2) The control expression of PID was analyzed. Because this kind of control is composed by many different links, the model equation is constructed as follows:

$$u(t) = K_{\mathrm{p}} \left[e(t) + \frac{1}{T_1} \int_0^1 \mathrm{e}(\tau)\, \mathrm{d}\tau + T_{\mathrm{D}} \frac{\mathrm{d}e(t)}{\mathrm{d}t} \right], \tag{2}$$

where K_{p}, T_1 and T_{D} represent the proportion of each link, integral time and differential time, respectively.

(3) In order to better reduce the static error in the PID control process, the stability of the vacuum sterilizer was higher. The study further optimized the above formula so that the system could maintain the maximum output value and speed up the control. The model equation is

$$u(k) = K_{\mathrm{p}} \left\{ e(k) + \frac{T_{\mathrm{D}}}{T} \left[e(k) - e(k-1) \right] \right\}. \tag{3}$$

Finally, the actual case was introduced, and the sterilization efficiency and performance of pulsed vacuum sterilizer based on digital PID were analyzed and compared under different pulse modes. The comparative study was mainly based on the current international standard of ISO11140-4/5, and the judgments and measurements of final elimination effect (BD) of steam sterilizer on air pre-vacuum pressure of pulsed vacuum sterilizer at high and low atmospheric pressure and whether all links can meet the anticipated conditions (PCD) of the sterilizer in the process of recycling were conducted. A common sterilizer was introduced as a negative control. Thus, a better condition for the application of the pressure of the pulsed vacuum sterilizer based on digital PID technology was determined. Furthermore, the advantages of this technology were summarized and analyzed. The research aimed at providing a theoretical basis for further improvement and development of sterilizer technology and providing technical support for the development of other subsidiary industries.

4. Result analysis and discussion

Nowadays, with the increasing attention of science and technology, various new technologies begin to appear constantly. Computer technology is one of the most influential sciences and technologies in the development of various industries in the world [12]. Many fields have begun to apply this technology to the development of themselves field. In recent years, the demand for aseptic conditions has increased gradually in some industries. Many fields in the world begin to develop the traditional disinfection equipment into the pre-vacuum and fully automatic way. In particular, researchers have a better understanding of the structure and properties of certain microorganisms. This provides some positive effects on the research and development of some disinfection and sterilization instruments [13]. Under this background, pulsed vacuum sterilizer based on digital PID has been developed and applied in actual industry or field (Fig. 3). The sterilizer combines with the digital

PID technology of computer technology, so it has more advanced R & D technology. It can achieve better disinfection effect in the absence of unattended, so it begins to be popularized gradually (Fu et al. 2011) [14]. The performance advantage of pulsed vacuum sterilizer based on PID technology in our country is mainly manifested in the vacuum validity. Thus, a plurality of bacteria and viruses can be killed so as to achieve better sterilization effect. And because of the more pre-vacuum validity, the sterilization equipment has relatively high validity and efficiency. Its system structure is relatively simple and the system function is more perfect, which can be used by more industries [15].

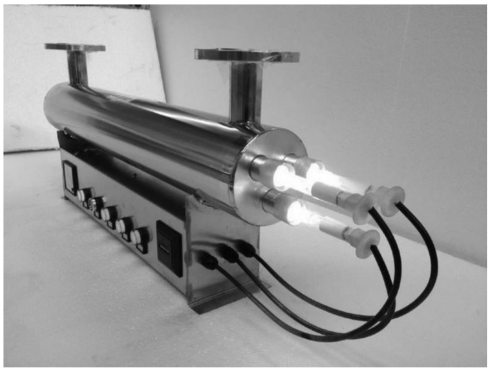

Fig. 3. The use and development of pulsed vacuum sterilizer

On the basis of understanding the relevant theories, the author studied and designed the pulsed vacuum sterilizer used in this research. The control system of the pulsed vacuum sterilizer designed in this paper is mainly composed of a single-chip microcomputer based on PIC technology and a generator that can control the steam and integrate it. In the design process of the sterilizer, the perfection of the circuit has a very important influence on the normal use of the pulsed vacuum sterilizer with digital PID technology. The utility model can further improve the service life and time of the sterilizer on the basis of ensuring that the sterilization process of the sterilizer is more reliable. Therefore, more attention should be paid to the scientificality and the systematicness of the pulsed vacuum sterilizer so that the final instrument sterilization effect is better. According to reading relevant information, the circuit of this sterilizer was summarized and perfected, so as to provide the basis for the performance of the sterilizer. The circuit design of the sterilizer in this study is shown in Fig. 4.

Based on the relevant theories and the basic design of sterilizer, the judgments and measurements of final elimination effect (BD) of steam sterilizer on air pre vacuum pressure of pulsed vacuum sterilizer at high and low atmospheric pressure and whether all links meet the anticipated conditions (PCD) of the sterilizer in the process of recycling were conducted in this study. The results of the measurements are shown in Table 1 and Table 2. The results show that the rate of BD negative test of pulsed vacuum sterilizer at high pressure is as high as 99.34 % and 95.18 % at low pressure. Therefore, the evacuation efficiency of the pulse sterilizer at high

pressure for cold air is obviously higher than that at low pressure. When the cold air is not completely discharged, the steam in the sterilizer can not penetrate more effectively, which may affect the sterilization effect. In order to verify the BD effect of autoclave under different pressure, further validation was carried out by positive experiments. The results show that the autoclave with high pressure has a higher pass rate that 46.38 %, which has better penetrating effect.

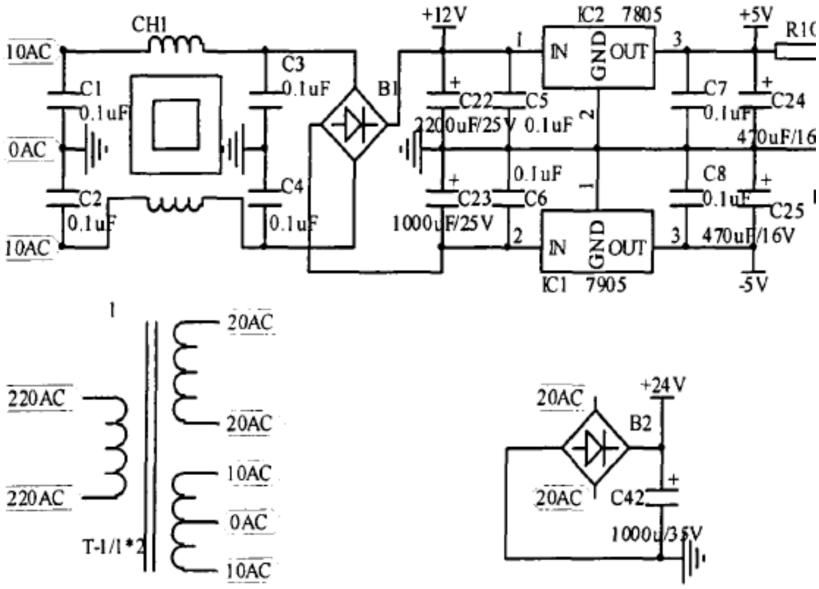

Fig. 4. The circuit operation flow of the sterilizer used in this study

Table 1. Comparison of BD test results of pulse sterilizer at low atmospheric pressure and high pressure

Test cycle negative	Experiment times	Low atmospheric pressure pulse BD test		High pressure pulse BD test	
		Qualified number	Qualified rate (%)	Qualified number	Qualified rate (%)
Positive	457	435	95.18	454	99.34
Test cycle	457	25	5.47	212	46.38

The effects of different pulse modes on PCD in sterilization pot were analyzed in this study. The results show when the negative test is carried out, the sterilization effect of the pulse sterilization pot is higher than that in the low pressure air, and its qualification is up to 99.76 %. However, the risk of sterilization may still be incomplete under qualified sterilization conditions. Therefore, positive detection was further carried out in this study. The results show that the qualified rate of pulse sterilization is higher in high pressure, which can reach 42.49 %.

Table 2. Comparison of BD test results of pulse sterilizer at low atmospheric pressure and high pressure

Test cycle negative	Experiment times	Low atmospheric pressure pulse PCD test		High pressure pulse PCD test	
		Qualified number	Qualified rate (%)	Qualified number	Qualified rate (%)
Positive	859	850	98.95	857	99.76
Test cycle	859	12	1.39	365	42.49

The experiment confirmed that the PID vacuum pulse sterilizer with high pressure has better effect. Then, the disadvantage reasons of the pulsed vacuum sterilizer for PID technology at low atmospheric pressure were analyzed. The analysis results are shown in Table 3.

Table 2. Comparison of BD test results of pulse sterilizer at low atmospheric pressure and high pressure

	Low atmospheric pressure pulse negative				High pressure pulse negative			
	Failure times	Improper handling of staff	Sterilizer leak	Poor performance of vacuum pump	Failure times	Improper handling of staff	Sterilizer leak	Poor performance of vacuum pump
BD	22	11	7	4	3	1	1	1
PCD	9	2	3	4	2	2	0	0

Finally, the performance of pulsed vacuum sterilizer based on digital PID technology and traditional sterilizer was analyzed in the study. The analysis results are shown in Fig. 5. The results show that the sterilization efficiency of this kind of sterilization pot is high, and the sterilization is more thorough. And the operation is simple, so it is more suitable for the application of related industries.

5. Conclusion

With the development of the times, the demands for aseptic conditions have gradually increased in the development of many industries, so that the research of sterilizer has gradually become one of the necessary needs for the development of the industry. In this trend, more sterilizers have been developed and applied to the actual industry development. Because the traditional sterilizer is difficult to operate and the sterilization efficiency is low, which cannot meet the actual needs of the industry. The research of pulsed vacuum sterilizer based on PID technology can provide some technical support for solving this problem. However, the research of pulsed vacuum sterilizer in our country is still few, and the related theories and techniques are

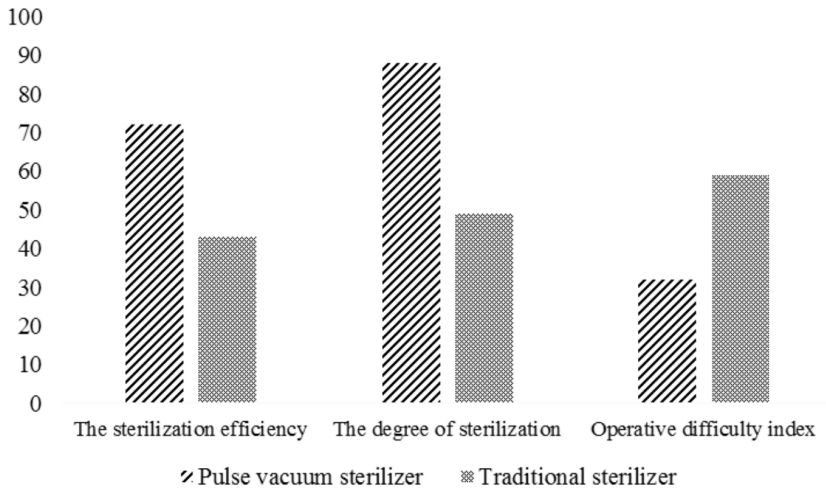

Fig. 5. Performance comparison between a pulsed vacuum sterilizer and a conventional autoclave based on digital PID technology

not perfect enough. In view of this deficiency, relevant concepts were defined and outlined by reading relevant data in this study. On this basis, the simple design of pulsed vacuum sterilizer based on digital PID technology was studied, and the performance of the sterilizer under different conditions was compared and analyzed. The results show that the pulsed vacuum sterilizer based on digital PID technology has better sterilization effect. Only the influence factor of air pressure has been studied in this study, which makes the research have certain deficiency. But this study still can provide the theoretical basis and support for the follow-up research.

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