THE EFFECT OF MOISTURE OF COTTON FABRICS ON STEAM STERILIZATION

by

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Original scientific paper
https://doi.org/10.2298/TSCI191212089S

This paper is to study the effect of cotton fabric's moisture on steam sterilization process. An experiment is designed to measure the thermal equilibrium time under different moisture concentrations. The results show that a higher moisture concentration leads to a longer thermal equilibrium time, and it does not affect the wet pack's penetration efficiency when the moisture concentration is below the threshold value of 30%. The paper concludes that a higher humidity is unfavorable for the thermal conduction during the sterilization process.

Key words: *pressure steam sterilization, moisture, thermal equilibrium time, thermal conduction*

Introduction

It is well-known that a saturated steam has a potent antibacterial property due to fast penetration of the steam into an interior of a sterilized product under a certain pressure during the sterilization process. When the steam is condensed into water, latent thermal can be released simultaneously, so that the temperature of the sterilized product increases rapidly, which is beneficial for sterilization. In order to improve the sterilization efficiency, the hot and humid steam is often used to make the bacteria protein coagulative, denaturalized, and necrotic, so that the bacillus can be finally killed. Thermal sterilization is suitable for the cases when the products have good heat and moisture resistance, this sterilization is the most reliable, and widely used in the world. There are mainly three factors affecting the pressure steam sterilization, they are work period, work temperature and saturated steam. Nowadays, pressure steam sterilizers are widely used in medical institutions, and the saturated steam plays an important role in sterilization quality [1-3]. According to the international standards and China's standards, the products are sterilized and packaged after desiccation, and the packaging materials and sterilization equipment should follow what is requested by the standards (EN867-5, US-ANSI, GB 8599-1988, WS310, and GBT 19633). Up to now, the researches on sterilization mainly focus on management, drying process and equipment operation, in the light of the authors' best knowledge, it has not been studied effect of the cotton fabrics' moisture on the thermal conduction of sterilizer package during sterilization pro-

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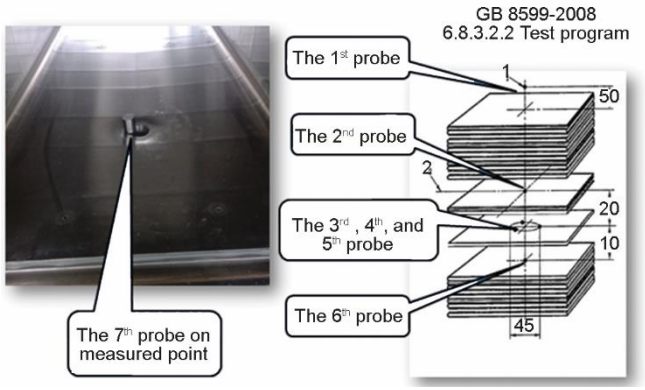

Figure 1. Experimental system with fixed probes;
1 – sensor point and 2 – middle level

cess. The biological indicator evaluation resistometers are used to obtain the experimental data to verify our theoretical results.

The effect of moisture on the inner temperature of sterilizer package

Based on the heat calculation formula, the sterilized products need to absorb a certain amount of heat from the heat reservoir when heating from the normal temperature to the sterilized temperature.

The absorbed heat can be calculated:

$$Q = cm\Delta t \tag{1}$$

where Q is the absorbed heat, c – the specific heat capacity, m – the mass, and Δt – the temperature increment of the products.

Suppose that the mass of dry cotton fabric package is m_1 (7 kg for usual), the specific heat capacity is c_1, the temperature increase of the sterilization temperature is Δt_1, the heat supplied by steam is Q_1, thus the absorbed heat from the normal temperature to the sterilized temperature of the dry cotton fabric package is:

$$Q_1 = c_1 m_1 \Delta t_1 \tag{2}$$

The mass of cotton fabric package with a certain water moisture is $m_1 + m_2$ (the mass of cotton fabric m_1 is 7 kg while m_2 is the mass of the water), the specific heat capacity of the moisture is c_2, the heat supplied by steam, Q_2, can be calculated:

$$Q_2 = c_1 m_1 \Delta t_1 + c_2 m_2 \Delta t_1 \tag{3}$$

It is obvious that the cotton fabric package with moisture requires much heat to reach the same temperature.

Based on the micro-structure analysis, the water in moist cotton fabric package may be obstacles for the steam penetration, which generates a thermal resistance. The steam penetrates and heats the cotton fabric package from outside to inside, because of the thermal resistance, the temperature in the package cannot reach the sterilization temperature when the water content reaches a certain point.

Experimental design

The weight of dry cotton fabric package was 7 kg in the experiment, different moisture concentrations were prepared. The outside temperature of pre-sterilization package was measured by an electronic infrared scanning temperature gun, then the package was put into a sterilizer, the MAST-A-1200 pulsating vacuum sterilizer was used as a test machine, the leakage rate of equipment was 0.10 kPa per minute, the inner chamber boost rate was set as 100 kPa per minute, fig. 1. After sterilization, the temperature was measured just after the

door of the sterilizer was opened, and the mass was package was weighted after it was taken out of the sterilizer. The warm pressing probes were used to collect experimental data. The 13 samples were prepared for the clinical cotton fabric package with different moisture concentrations, fig. 2 showed the sterilization process with 30% moisture concentration, the thermal equilibrium time was recorded as 93 seconds. Other samples' data were listed in tab. 1, when the moisture concentration reached 50%, five middle temperature probes were unqualified while the temperature probe of outside and surface were qualified, the sterilization test was unqualified, see fig. 3. The experimental parameters for Sample 1 ~ Sample 8 were set as follows: three times were used for each sample for change the pre-sterilization process (*i. e.* pulsing vacuum period) to crossing pressure pulsation using the commonly used sterilizer. The sterilization temperature was 134 ℃, and the pressure was 215 kPa, the time of sterilization was 240 seconds, see fig. 4 for sterilization technology, other parameters follow what are requested by international standards.

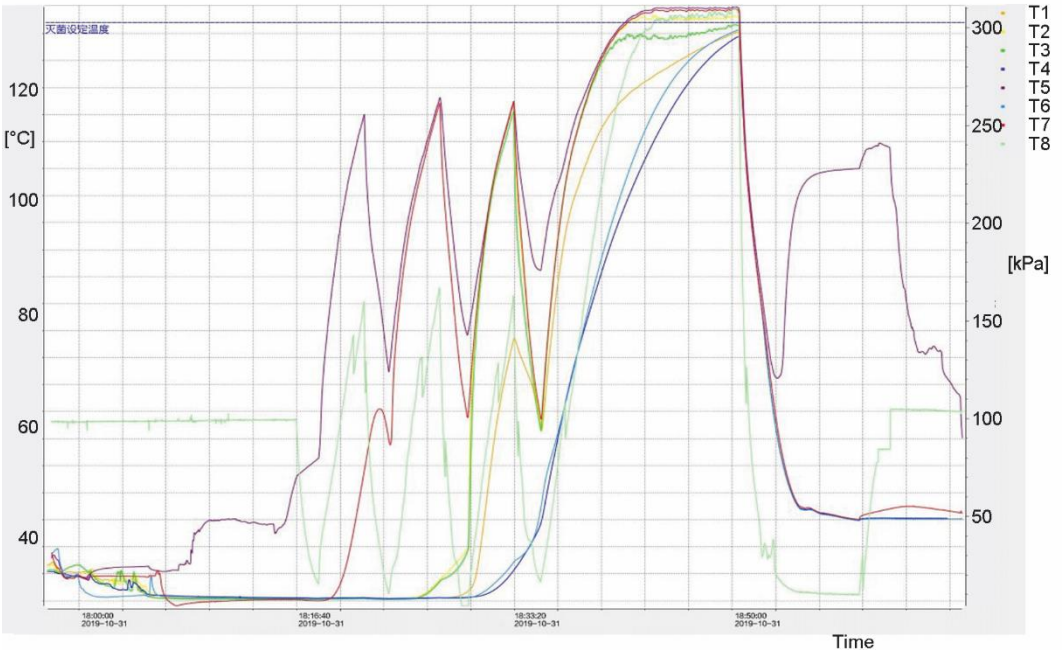

Figure 2. The sterilization process with 30% moisture concentration

The pulsating vacuum sterilizer is widely used as pressure sterilizer for hospital. However, the crossing pressure pulsation is used in pre-sterilization process for experimental sterilizer. The following formula is used to calculate the pulsating vacuum:

$$S_n = \left(\frac{P_{\text{LowerLimit}}}{P_{\text{UpperLimit}}} \right)^n \tag{4}$$

The vacuum degree (air discharge) is:

$$V_n = 1 - S_n \tag{5}$$

where $P_{\text{LowerLimit}}$ is the lower limit of pressure and $P_{\text{UpperLimit}}$ – the upper limit of pressure.

Table 1. Effect of moisture on the sterilization process and thermal conduction for Samples 1~8 (PreSTOP: pre-sterilization temperature of outside package, PostSTOP: post-sterilization temperature of outside package, Q: qualified, UQ: unqualified)

	Samples							
Items	1	2	3	4	5	6	7	8
The water content	10%	20%	30%	31.5%	30%	38.5%	50%	40%
Standard package weight, [kg]	7.005	7.015	7.009	7.025	7.013	6.916	7.000	7.025
The weight of the water, [ml]	700	1400	2100	2800	2100	2800	3500	2800
PreSTOP, [°C]	30.1	29.6	30.3	21.9	31.6	19.4	27.2	19.3
Pre-sterilization weight, [kg]	7.698	8.395	9.126	9.241	9.173	9.572	10.325	9.723
Post-sterilization weight, [kg]	7.600	8.413	9.194	9.252	9100	9.698	10.520	9.821
PostSTOP, [°C]	63	62.5	63.9	63.9	61.4	64.4	63.2	64.2
Outside surface probe 5#	Q	Q	Q	Q	Q	Q	Q	Q
Subsurface probe 7#	Q	Q	Q	Q	Q	Q	Q	Q
Upper middle surface probe 6#	Q	Q	Q	Q	Q	Q	UQ	Q
Middle surface probe 2#	Q	Q	UQ	Q	UQ	Q	UQ	Q
Middle surface probe 3#	Q	Q	Q	Q	UQ	Q	UQ	Q
Middle surface probe 4#	Q	Q	Q	Q	Q	Q	UQ	Q
Lower middle surface probe 1#	Q	Q	Q	Q	Q	Q	UQ	Q
Thermal equilibrium time, [s]	20	22	93	24.4		32.3		37.1
Sterilization test of sterilizer	Q	Q	UQ	Q	UQ	Q	UQ	Q

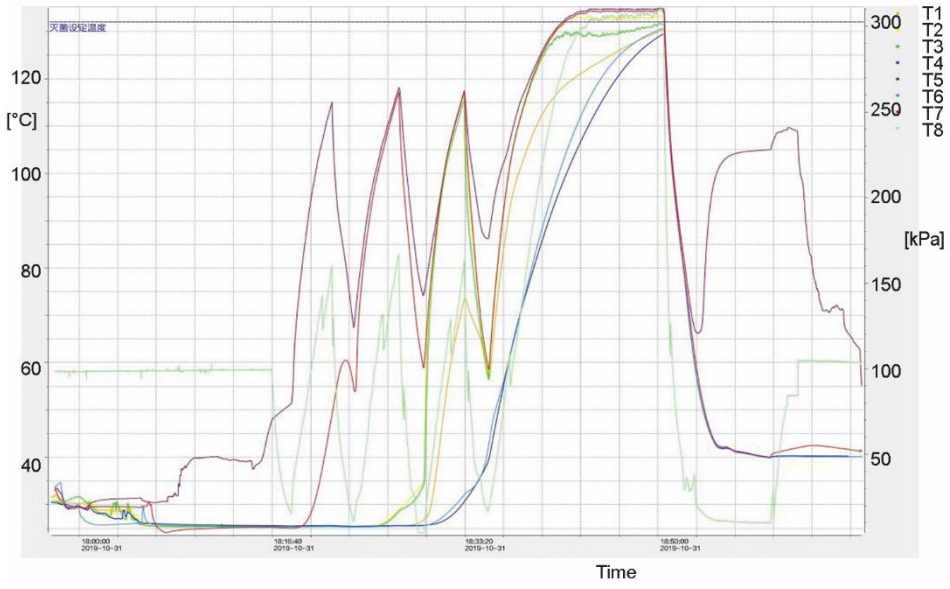

Figure 3. The sterilization process with 50% moisture concentration

The new type of sterilizer uses a mixed pulsation technology for pre-sterilization process (the sterilization technology is shown in fig. 5), during the pulsation period, the inner chamber suffers a positive pressure and a negative pressure, which has the advantages in resisting the leakage influence of positive pressure pulsation.

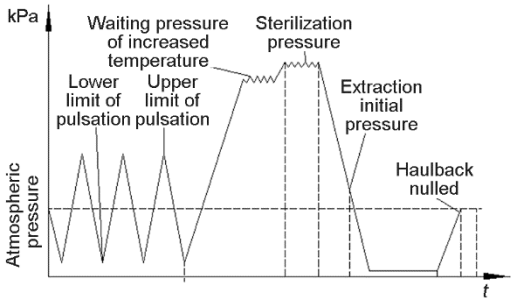

Figure 4. Crossing pressure pulsation sterilization

The experimental parameters for Sample 9 ~ Sample 13 were set as follows. Set the parameters of pre-sterilization process (*i. e.* pulsing vacuum period) to negative pressure pulsation for three times, crossing pressure pulsation for one time and positive pressure pulsation for three times using the mixed pulsation sterilizer. Set sterilization parameters in accordance with the specifications, the temperature of sterilization was 134 ℃, the pressure of sterilization was 215 kPa, the time of sterilization was 240 s, see fig. 6. The clinical cotton fabric testing packages were used to measure the moisture of 20%, 25%, 30%, 40%, and 50%, respectively, the temperature probes monitoring was all qualified and the sterilization test of sterilizer was qualified, tab. 2.

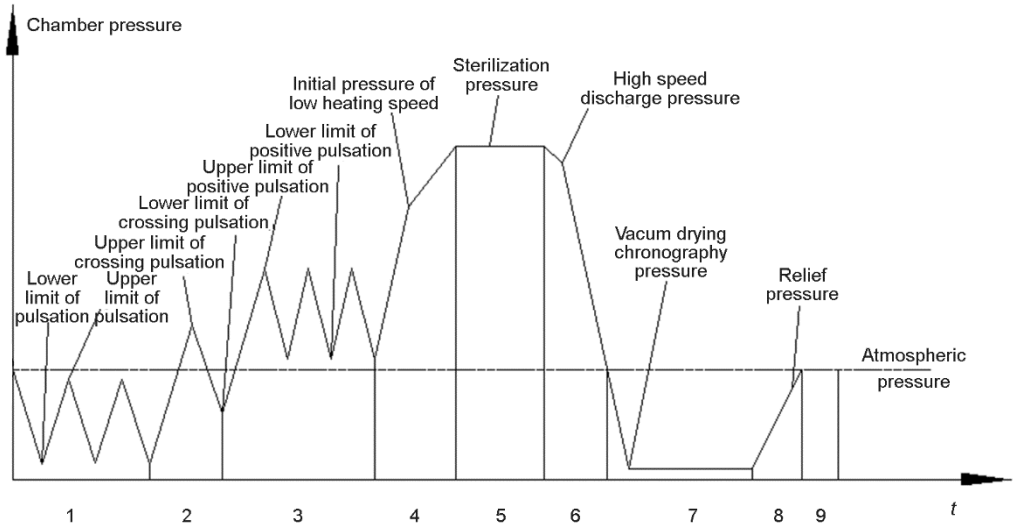

Figure 5. The mixed pulsation sterilization

Conclusions

The crossing pressure pulsation sterilizer was used in pre-sterilization process, using the laboratory standard testing package, the sterilization process with different moisture of cotton fabrics were tested, the tested probes were all qualified and met the required standard of thermal equilibrium time. Measured by the clinical cotton fabric testing package, the sterilization of cotton fabric packages were qualified when the moisture was less than 30%, however, part of the temperature probes of cotton fabric packages could not reach the sterilization parameter when the humidity was more than 30%, the thermal equilibrium time of sterilization package was above the standard requirements and the sterilization monitoring was unqualified.

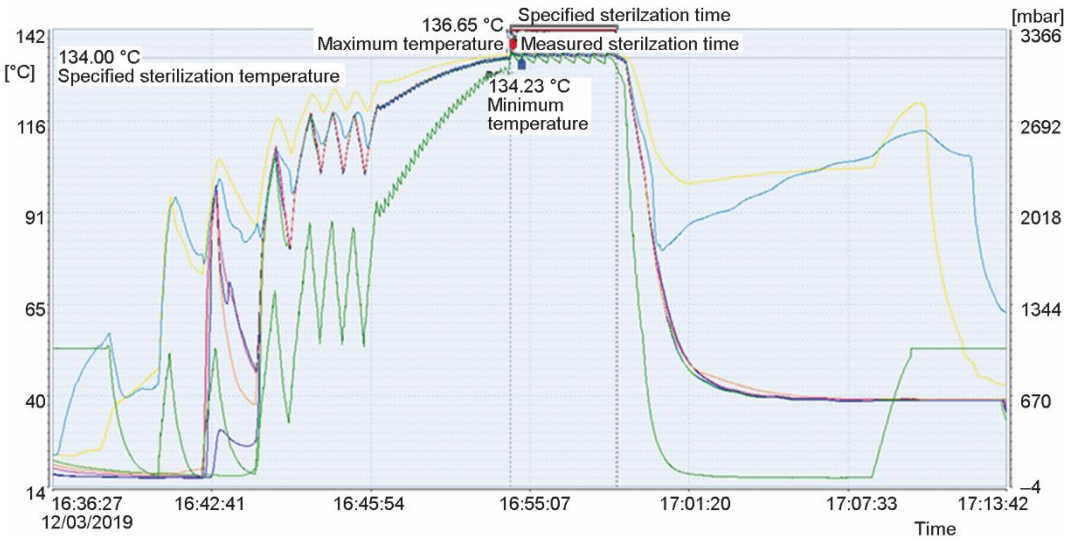

Figure 6. The diagram of mixed pulsation sterilization

Table 2. Effect of moisture on the sterilization process and thermal conduction for Samples 9~13 (PreSTOP: pre-sterilization temperature of outside package, PostSTOP: post-sterilization temperature of outside package, Q: qualified, UQ: unqualified)

Items	Sample 9	Sample 10	Sample 11	Sample 12	Sample 13
The water content	20%	25%	30%	40%	50%
Standard package weight, [kg]	7.031	6.947	6.961	6.916	6.964
The weight of the water, [ml]	1400	1750	2100	2800	3500
PreSTOP, [°C]	26.6	18.5	21.5	24.0	21.8
Pre-sterilization weight, [kg]	8.381	8.663	8.954	9.719	10.453
Post-sterilization weight, [kg]	8.500	8.744	9.000	9.753	10.493
PostSTOP, [°C]	51.0	54.8	55.5	62.7	60.5
Outside surface probe 5#	Q	Q	Q	Q	Q
Subsurface probe 7#	Q	Q	Q	Q	Q
Upper middle surface probe 6#	Q	Q	Q	Q	Q
Middle surface probe 2#	Q	Q	Q	Q	Q
Middle surface probe 3#	Q	Q	Q	Q	Q
Middle surface probe 4#	Q	Q	Q	Q	Q
Lower middle surface probe 1#	Q	Q	Q	Q	Q
Thermal equilibrium time, [s]	23.9	22.8	21.8	25.5	21
Sterilization test of sterilizer	Q	Q	Q	Q	Q

The mixed pulsation sterilizer was used in pre-sterilization process, there were much more input steam in the long-term pretreatment sterilization, given steam drying to the pack-

age which was original moist, thus promote the thermal conduction of sterilization process depending on the effect of original technology on moisture.

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Paper submitted: December 12, 2019
Paper revised: May 20, 2020
Paper accepted: May 20, 2020