The availability of steam waste energy generated during AAC production

Lu Jie, Chen Xin-Jiang, He Xiao-Lei, Zhang Ye-Xin, Liu Pin-De and Yu Jia-Feng,
Anhui Keda Industrial CO.,LTD, China

According to calculations and statistical considerations, the steam energy consumption (hereinafter referred to as heat consumption) of B05-sand AAC products accounts for about 84% of the total production energy consumption, based on which the main potential for energy saving and carbon reduction in the production of AAC products can be evaluated. Methods to reduce heat consumption generally include two categories - reducing energy consumption in the production process and using the waste energy generated in the production process to reduce the required external steam supply.As a consequence, one should consider two basic values. These are, firstly, the value of "theoretical production heat consumption" of AAC products, which denotes the minimum heat value required in the steam energy consuming production process, or the limiting value for energy saving and consumption reduction under consideration of "waste heat utilization". Secondly, the cut-off points for "high quality waste energy" and "low quality waste energy" generated in the production of AAC products, in order understand the limiting value for waste energy utilization.

This article primarily focusses on elaborating on these two basic values. The value of "theoretical production heat consumption" represents the value of "energy consumption required to heat up the green body/cake". Furthermore, the article focuses on the aspect of waste energy utilization. In order to simplify the calculation and test complexity, this article does not take into account some of the factors that need to be considered in actual production (such as electrical resistance, heat dissipation, actual steam dryness, etc.). Further, the production equations, steam equations and other parameters presented are of the common type without considering special circumstances or special cases.

The main energy consumption in the production of AAC products includes electrical power consumption, fuel consumption and steam consumption (hereinafter referred to as heat consumption).

Table1: The three types of energy consumption during production of AAC products, in % of the total energy consumption.

Index	Power consumption	Steam consumption	Fuel consumption	Total
Percentage	14	84	2	100

For B05-sand AAC products, the energy consumption converted from saturated water steam used in the steaming production accounts for about 84% of the total production energy consumption, as shown in Table 1.

The task of energy saving and carbon reduction in the production of AAC products should therefore primarily be implemented by reducing the heat consumption, and by developing an understanding of the methods to reduce heat consumption. Methods to reduce heat consumption roughly include two categories:

a. Reduce energy consumption in the production process.
b. Use waste energy generated in the production process to reduce the required external steam supply.

The required steam energy consumption in the production process includes the energy consumption required for the heating of the green body (dry material + batching water) and other energy consumption

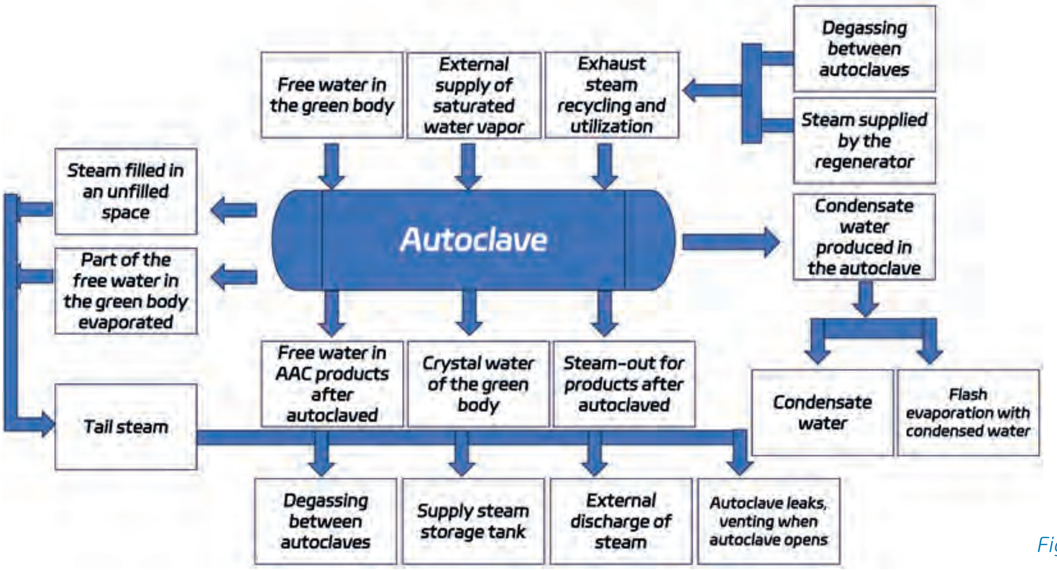

Fig.1: Water balance diagram of an autoclave process.

generated during the whole steaming process. Obviously, the energy consumption required for green body heating is the minimum limit value of energy consumption in the production process. The so-called "low-carbon product" research is concerned with reducing the energy consumption required for green body heating through process technology, that is, to reduce the minimum limit value of production energy consumption. In the production process, it is also important that producers precisely study other sources of energy consumption and take measures to reduce these as much as possible.

Practical experience indicates that full utilization of the waste energy generated during the steam curing process, namely the heat energy of condensate water and the heat energy of discharged steam (hereafter referred to as "exhaust steam"), is an effective method for reducing the required supply of external steam, that is, the consumption of steam for autoclaving.

Not all waste energy is usable. When the energy gained is less than the energy consumed in the process, the energy is not usable. The available waste energy is called high-quality waste energy, while unusable waste energy is called low-quality waste energy. With the development of science and technology, the current low-quality waste energy may become high-quality waste energy in the future.

All the water entering the autoclave in the production process will participate in the heat exchange and may participate in the transformation of the liquid to the steam phase. Therefore, the analysis of steam energy consumption cannot simply be considered from the steam heat energy alone, and a more systematic analysis is needed.

From the autoclave water balance, it can be deducted that the water entering the autoclave during the production process includes the free water of the green body, the saturated water vapor supplied externally and the exhaust steam reused. The water discharged from the autoclave includes crystalline water of the product, free water of the product exiting the autoclave, condensate water on the autoclave body, exhaust steam, steam venting at the autoclave door, and product venting when the product exits the autoclave, as shown in Fig. 1.

From the above, one needs to understand two basic values when studying ways to reduce heat consumption and determining whether they are meaningful:

1. The value of the theoretical heat consumption in the production of AAC products is the minimum heat value required in the production process. It can also be considered as the limit for energy saving and consumption reduction, except for waste heat utilization.
2. The demarcation point of high-quality versus low-quality waste energy of the entire waste energy produced in the steaming process of AAC products provides an understanding of the limit value of waste energy utilization.

The first value (1) is relatively fixed under certain products and processes, while the second value (2) will change with technological progress.

Waste energy utilization

Exhaust steam emission

In the production process, the exhaust steam discharged from the autoclave (including the venting of the autoclave product and the venting when the autoclave door is opened) includes two aspects:

a. Steam that fills the unfilled space of the autoclave.
b. The free water stored in the green body, which partially evaporates during the cooling process.

For the first aspect (a), the quantity and heat energy of the exhaust steam are relatively fixed. For the second aspect (b), when the cooling time is long, the free water in the green body has enough time to evaporate, and the quantity of exhaust steam increases. Conversely, when the cooling time is short, the water content of the product is high and the steam increases.

The ideal exhaust steam emission, that is, the exhaust steam emission limit value, is achieved when the free water in the green body is fully volatilized at each cooling stage and discharged to 0 MPa pressure.

Table 2 shows the calculation of the maximum exhaust steam emission in the autoclaving process of a series of products of the company Keda. The exhaust steam dryness (i.e., the ratio of gaseous water to exhaust steam volume) is set to 0.9.

Table 2 does not consider resistance factors such as pipeline and evaporation, which cause the free water of the green body to evaporate and prevent it from exiting the autoclave, turning it back to condensed water flowing away from the condensate discharge pipe of the autoclave body. The table shows that as the dry density of the product decreases, the free water exhaust evaporation rate of the green body increases (ratio to the weight of the product), and the total emission decreases.

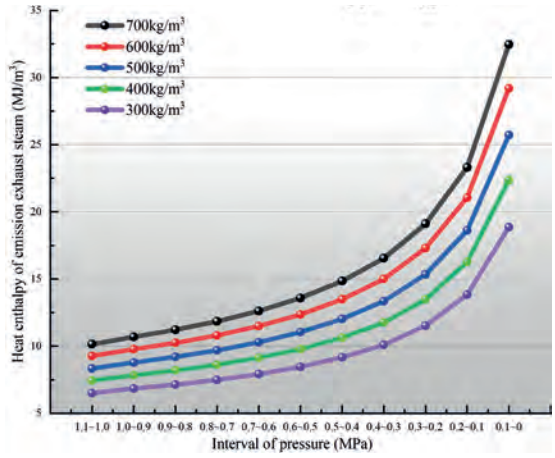

Fig. 2: Exhaust steam heat enthalpy discharged from each pressure segment.

Exhaust emission energy

Fig. 2 shows the calculated curve of exhaust steam enthalpy emission in each pressure segment during the step-down stage of the autoclave process, considering of a series of products of Keda. Table 3 shows the calculated maximum heat of the autoclave cooling exhaust steam of this series of products.

Figure 2 and Table 3 show that as long as there is enough time, the amount of exhaust steam can be discharged to the same pressure as the outside atmosphere, and the enthalpic energy contained in it is about more than 50% of the theoretical production heat consumption. It is of great significance to make full use of the heat enthalpy of exhaust gas.

Furthermore, Fig. 2 shows that as the pressure decreases, the exhaust enthalpy energy of the emissions increases, and the upward trend increases. This is because the temperature difference per 0.1 MPa in the high pressure segment is smaller than that in the low pressure segment, thus making the energy

Table 2: Exhaust steam emissions of AAC products (to 0 MPa).

Product dry density, kg/m³	700	600	500	400	300
The amount of exhaust steam evaporated from free water (y) in the green body, kg/m³	59.00	52.60	45.73	39.13	32.24
The evaporation rate of the free water in the body; tail gas (ratio to dry density of the product)	0.084	0.088	0.091	0.098	0.108
Non-filled space saturated steam from exhaust emissions, kg/m³	8.96	8.96	8.96	8.96	8.96
Exhaust steam emission, kg/m³	67.96	61.56	54.69	48.09	41.20

Table 3: Maximum heat enthalpy of autoclave cooling exhaust steam emission.

Dry density, kg/m³	700	600	500	400	300
Maximum exhaust energy content, MJ/m³	176.34	159.98	142.39	125.48	107.84
Equivalent steam volume, kg/m³	63.37	57.49	51.17	45.09	38.76

自动化控制
AUTOMATIC CONTROL
信息化管理
数字化生产
KEDA SureMaker

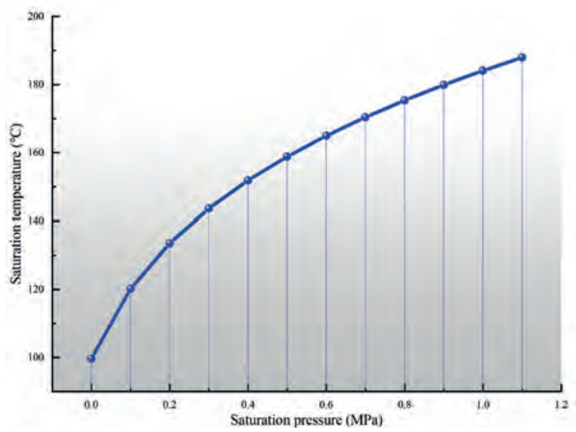

Fig. 3: Relationship between saturated water vapor pressure and temperature.

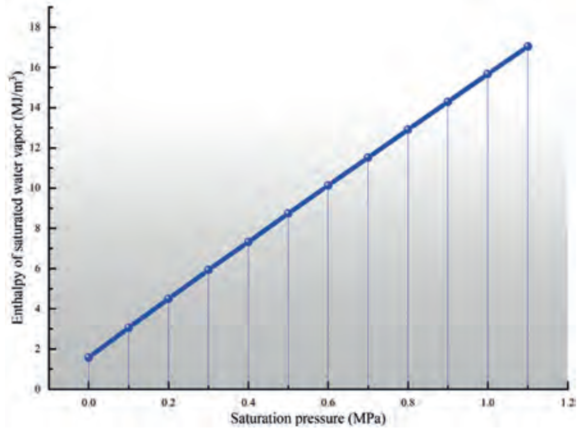

Fig. 4: Relationship between pressure and enthalpy of saturated water vapor.

value different. Fig. 3 shows that the temperature difference from 0 MPa saturation pressure to 0.1 MPa saturation pressure is 20.6°C, while the temperature difference from 1.0 MPa saturation pressure to 1.1 MPa saturation pressure is 3.9°C. As shown in Fig. 2, the enthalpy energy of the exhaust steam discharged from the pressure drop from 1.1 MPa to 0.4 MPa (152°C) is similar to the enthalpy energy of the pressure drop from 0.4 MPa to 0.0 MPa.

Fig. 4 shows that the heat enthalpy of saturated water vapor increases rapidly with the increase of pressure, and the heat enthalpy of vapor at 0.0 MPa is 1.58 MJ/m³. The heat enthalpy of steam at 0.4 MPa is 7.33 MJ/m³. The heat enthalpy of steam at 1.1 MPa was 17.05 MJ/m³. It can be seen that although the total amount of exhaust energy discharged under low pressure is large, the energy per unit volume is very low, the pressure is low, and it is difficult to overcome the flow resistance. The application is therefore difficult, and further technology improvement is needed in the future.

Reverse steam

At present, the direct reversing between the autoclaves is a more effective way to use the exhaust steam energy. Fig. 5 shows the enthalpy energy (MJ/m³) of exhaust steam discharged from a series of Keda products when the two autoclaves are released to each pressure section (MPa). Fig. 6 shows the pressure change of the autoclaves after accepting the heat enthalpy of the exhaust steam.

Fig. 6 shows that even though the pressure of the releasing autoclave decreased to 0.1 MPa, the pressure

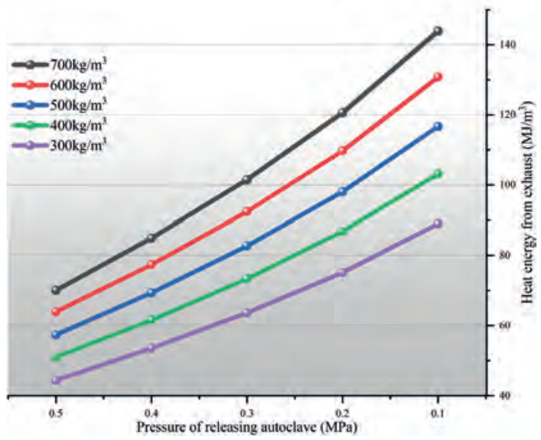

Fig. 5:
Two autoclaves: reversing steam and released energy.

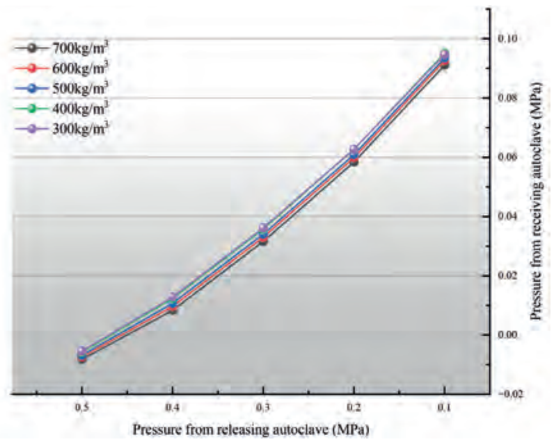

Fig. 6: Two autoclaves reverse steam, the pressure of the releasing autoclave, and the pressure of the accepting autoclave.

of the accepting autoclave did not exceed 0.1 MPa, and there was a pressure difference. The calculation of the above two figures does not consider the resistance loss and heat dissipation loss of the inverted steam process. If the resistance and heat dissipation loss are taken into account, the pressure of the accepting autoclave will be lower.

In actual production, when the pressure of the releasing autoclave is very small, the steam flow is almost stopped. This is because the low-pressure kinetic energy is weak, and the pressure in the releasing autoclave cannot overcome the friction resistance and heat dissipation loss between the two autoclaves.

In actual production, it is often seen that the pressure of the accepting autoclave exceeds the pressure data shown in Fig. 6, even greater than 0.1 MPa. This is because the initial pressure of the releasing autoclave is very high, the exhaust steam flow speed is very fast, and the steam flow into the accepting autoclave is significant. The heat accepting speed of the green body in the accepting autoclave cannot keep up with the heat flow of the steam entering the autoclave, resulting in a temporary increase in the temperature and pressure in the autoclave.

Table 4 is based on the condition that the accepting autoclave is set as an empty autoclave (without the green body), considering a degassing condition of the autoclave exhaust gas when the releasing autoclave drops to 0.5 MPa. In the absence of the green body, the pressure of the accepting autoclave rises rapidly.

Therefore, it is recommended that the pressure of the releasing autoclave be reduced to 0.4~0.5 MPa.

Condensed water availability

Source of condensed water

The condensed water source composition is shown in Fig. 7.

Quantity and heat energy of condensed water

The following data calculation is based on 1.1 MPa (gauge pressure) saturated water vapor operation, such as exhausting steam, reversing steam and other heat sources, and the condensed water will change.

Table 5 shows the maximum value of condensed water discharge during steaming of a series of products of Keda.

Table 5 shows that the total amount of condensed water contains discharged water from the autoclave body and the exhaust steam discharged to form condensed water, accounting for more than 35% of the total water consumption. Full utilization is of great

Table 4: Steam transfer into an empty autoclave and the accepting autoclave pressure (the pressure of the releasing autoclave is lowered to 0.5 MPa)

Dry density, kg/m³	700	600	500	400	300
Accepting autoclave pressure, MPa	0.362	0.299	0.240	0.185	0.136

Table 5: Discharge of condensed water.

Dry density of product, kg/m³	700	600	500	400	300
Condensate discharge of autoclave body, kg/m³	123.62	112.29	100.65	89.21	78.25
Maximum exhaust steam emissions, kg/m³	67.96	61.56	54.69	48.09	41.20
Total, kg/m³	191.57	173.85	155.34	137.30	119.44

Table 6: the heat energy discharged by condensate water in the autoclave body.

Dry density of product, kg/m³	700	600	500	400	300
The heat energy of condensed water in the autoclave body, MJ/m³	69.94	63.65	57.18	50.83	44.74

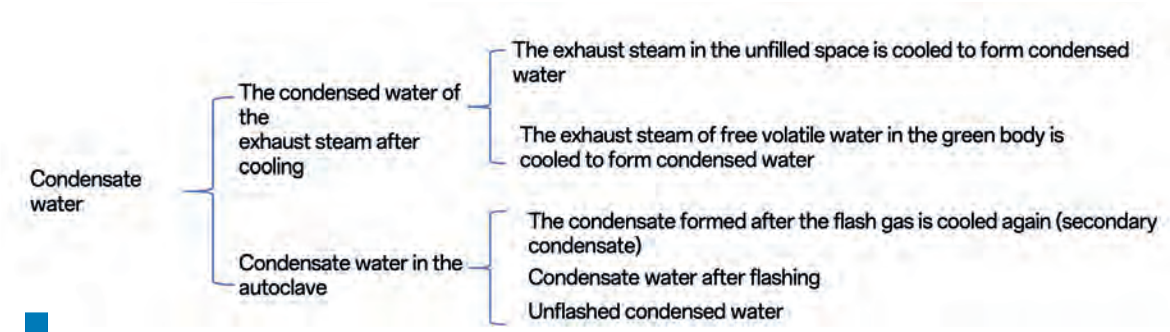

Fig. 7: Condensate source composition.

significance for saving water and energy. Furthermore, if the exhaust steam (the exhaust steam between the autoclaves or the steam directed to the steam storage tank) finally condensates into water that can be collected, the corresponding collected exhaust steam water is considerable, up to 67.96 kg/m³ for 700kg/m³ of products.

Table 6 shows that the heat energy taken away by the condensed water of the autoclave body exceeds the theoretical production energy consumption by more than 65%, and the energy content of the condensed water of the exhaust steam depends on the utilization rate of the heat energy of the exhaust steam in the production process. Making full use of the heat energy of condensed water is of great significance in order to reduce heat consumption.

Figures 8 and 9 show the pressure increase interval of a series of products in a Keda production line, the relationship between the pressure in the autoclave and the condensed water in the autoclave body, and the relationship between the pressure in the autoclave and the heat energy contained in the condensed water in the autoclave body. Because the temperature difference of the low-pressure section is larger than that of the high-temperature section, the heat energy required for boosting the pressure is high, the condensed water volume is large in the production process, and the total heat energy of the condensed water is high.

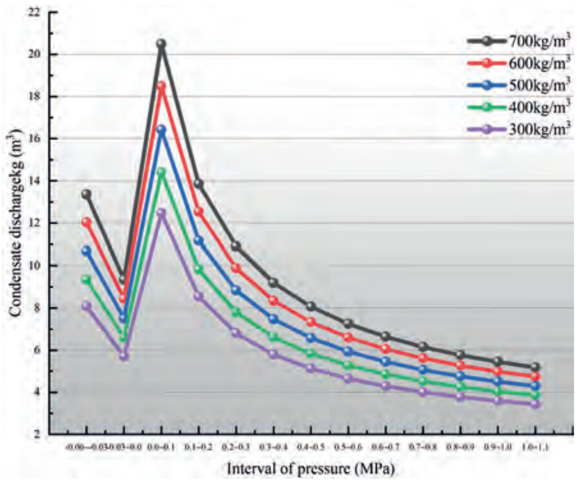

Fig. 8: Pressure boost interval and condensate discharge.

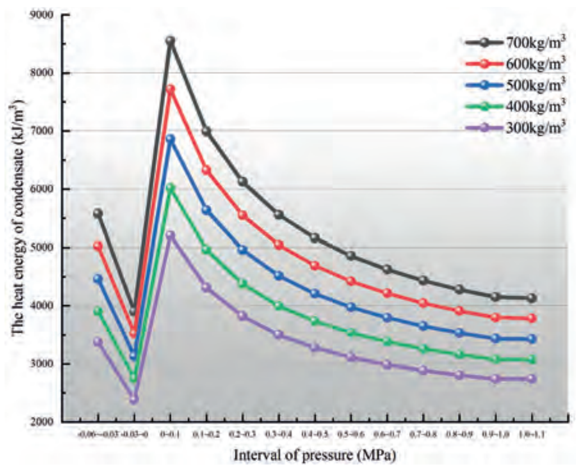

Fig. 9: Pressure boost interval and discharge condensate heat energy.

Keda Suremaker
2887, Tianmen Rd
Economic and Technological Development Zone
Maanshan City, Anhui Province, China
T +86 0555 2113600
www.keda-suremaker.com.cn

Anhui KEDA Industrial Co.Ltd
No.555, Linxiao Rd, Economic and Technolog
243041 Ma'anshan City,
China
T +86 0555 211 3600
www.keda-suremaker.com.cn