



IJEAST

INTERNATIONAL JOURNAL
OF ENGINEERING APPLIED SCIENCE
AND TECHNOLOGY



VOLUME : 4 ISSUE : 07 Print / Issue Publication Date: 07-Jan-2020



ISSN : 2455-2143



DOI : 10.33564/IJEAST.2019.v04i07.009

Indexed In



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DESIGN OF WOOD CHIPS AND ASSOCIATED VOCs TREATMENT EQUIPMENT FOR WOOD PROCESSING

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Abstract—Wood chips and associated volatile organic compounds (VOCs) generated during wood processing need to be separated and treated before they can be discharged into the atmosphere. However, the pressure drop of existing equipment such as bag-type dust remover is large, short service life, large energy consumption and high maintenance cost, a set of wood chips and accompanying VOCs processing equipment is designed. The device consists of sieve tower, multi-tube guide vane cyclone and VOCs waste gas treatment equipment arranged in series. The dust-containing air flows through the primary screen and then passes through the dust removal of multi-tube guide vane cyclone into the VOCs waste gas treatment equipment to complete the waste gas treatment of wood processing. Based on the combination of theoretical calculation and field investigation, the structural design of a large number of components and the selection of VOCs waste gas treatment equipment were carried out, and the strength of key components was also checked and analyzed. It can provide reference for the design and development of dust removal and gas cleaning technology equipment in wood processing industry.

Keywords— Sawdust treatment; VOCs treatment; Multi-tube cyclone

I. INTRODUCTION

The pollution of wood industry dust particles and VOCs (Volatile Organic Compounds), volatile organic compounds, is particularly prominent in air pollution^[1], especially in the process of machine tool processing, producing fine wood strips, thin wood chips, shavings, wood flour, etc. At the same time, various types of wood chips of various sizes can be used in the production of wood products, such as paints, organic solvents, which generate a large amount of volatile organic compounds. Improper handling can cause serious air pollution and cause great harm to human health^[2]. Therefore, how to solve the problems of large difference in the size of wood chip waste and a large number of volatile organic compounds in the processing of wood processing waste gas has become a key

link in the sustainable development of wood processing^[3]. To this end, the design of a device capable of efficiently separating and dissolving all kinds of wood chips while purifying the exhaust gas of VOCs is of great significance to the green development of the wood processing industry.

At present, there are two methods commonly used for the treatment of wood chips^[4]: one is cyclone dust collector, which uses a dust-containing gas stream to change the direction of the fluid, so that the solid particles in the gas stream are separated by centrifugal force and gravity. Although the method is compact and low in cost, it generally has a dust removing effect on wood chips having a particle diameter of 10 μm or more, and dust removal efficiency of dust particles of 10 μm or less, particularly 5 μm or less is low, and has almost no effect. Another method is to use a bag filter. The bag is made of textile filter cloth or felt cloth, uses the size of the mesh of the bag to filter the wood chips, which has high efficiency and simple structure, but the filter type dust removal mechanism leads to the modification mode. The working pressure drop is large and the energy consumption is high. The wind speed can not be very high for the treatment of high concentration dusty gas, and the bag has a short service life and high maintenance cost. It is necessary to design a more convenient and quick cleaning device to improve the working efficiency of the equipment, less maintenance cost and save maintenance time^[5]. In the application of VOCs waste gas treatment, there are mainly activated carbon adsorption technology, condensation recovery technology, thermal incineration technology, photo catalytic degradation technology^[6]. In summary, the author designed a set of high-efficiency and energy-saving wood chip separation equipment integrated with exhaust gas treatment for wood processing wood chips and associated VOCs processing equipment.

II. STRUCTURAL DESIGN AND WORKING PRINCIPLE

1.1 Structural composition and connection

Figure 2 shows the overall structure of the wood chips and associated VOCs treatment equipment. It consists of three parts: the screen tower, the multi-tube vane cyclone and the VOCs exhaust gas treatment equipment.

The front end of the screen tower is connected to the wood production and processing workshop, which is the inlet of the dusty airflow, and the rear end is connected with a multi-tube vane type cyclone dust collector. The upper tower of the screen tower is installed with a three-sided v-shaped hole screen to carry out the dusty airflow. The primary screen is used to separate the large-sized sawdust waste; the lower tower is the ash bucket, which is used to store the sawdust waste that is screened by the sieve.

Multi-tube vane type cyclone dust collector for separating small-sized wood chips and dust in dusty airflow. It consists of 21 single-tube cyclones ^[7] connected in parallel. It is divided into three parts: the inlet chamber, the dust collection chamber and the gas collection chamber through two partitions welded with the main tube and the riser tube of the single tube. The inlet chamber and the front end screen The net tower is connected, and the ash hopper is arranged at the lower end of the dust collecting chamber, and the upper end of the plenum is connected to the VOCs processing equipment through the external pipeline. The single-tube cyclone is the main separation component of the dust collector. It consists of four parts: the main cylinder, the guide vane, the riser pipe and the guide cone. The main cylinder is connected to the inlet chamber, and the guide vane has the guidance and acceleration of the air flow. The upper and lower ends of the riser pipe are respectively connected with the gas collecting chamber and the dust collecting chamber, and the guiding cone is installed in the lower end of the main cylinder in the dust collecting chamber.

The VOCs exhaust gas treatment equipment is installed at the tail end of the whole device for treating volatile organic compounds in the gas after dust removal. The flow plate is placed at the gas inlet to make the gas flow evenly after entering the equipment, which is beneficial to improve gas treatment efficiency; The ultraviolet lamp tube group emits a special band of ultraviolet rays to degrade the volatile organic compounds in the gas; a gas component safety monitoring system is installed at the gas outlet end passage, and the gas that meets the discharge standard is directly discharged into the atmosphere.

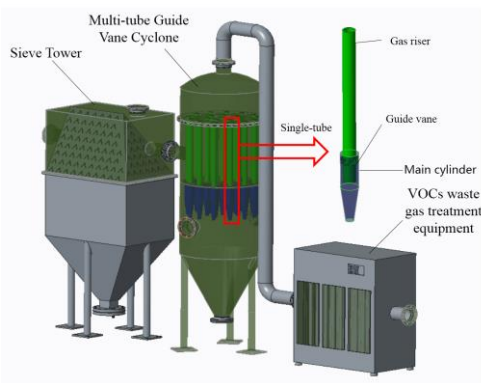


Fig. 1. Overall structure model of wood chips and associated VOCs processing equipment

1.2 Working principle

After the dust flow of wood processing is discharged, the airflow enters the screen tower. The larger particle size cannot pass through the three-sided V-shaped screen, and falls into the lower tower of the screen tower under the action of gravity potential energy. The gas is sieved and the sieve is sieved. The gas enters the inlet chamber of the multi-tube vane cyclone from the side inlet, gathers and squeezes in the inlet chamber and flows into each single-tube cyclone, and the airflow moves linearly downward along the axis under the action of the guide vanes. It is converted into tangential motion, and then the wood chips in the airflow are smashed to the wall surface by the density difference of the gas-solid two phases, and the falling cone wall is dropped to the dust collecting chamber, and the purified gas reaches the bottom of the main cylinder and enters the guiding cone to form a reversal. Swirl upward, and the gas pipe enters the gas collection chamber. At this time, the solid phase particles in the gas are extremely low, and the wood chips in the exhaust gas are processed. Furthermore, the gas enters the VOCs processing equipment, and the gas is smoothly and uniformly reacted with the ultraviolet rays of the special band emitted by the UV ultraviolet lamp tube under the action of the current equalizing plate, so that the volatile organic substances in the exhaust gas are sufficiently degraded. Finally, the gas component safety monitoring system at the exit end of the equipment monitors the composition index of the external exhaust body in real time, and completes the processing of wood chips and associated VOCs in wood processing.

III. DESIGN OF EACH COMPONENT

2.1 Working condition analysis

Through on-the-spot investigation of the wood processing plant, the treatment air volume of the factory exhaust gas treatment device reaches 60,000 m³/h-80000 m³/h. The main solid phase composition in the gas stream to be treated is shown in Table 1, and the VOCs content in the gas stream is ≤ 200 mg/ M³, the overall operating pressure is ≤ 1.32 MPa, so the processing device housing made of general 10mm steel plate can meet the strength requirement.

Table -1 Statistics of airflow composition to be treated

Main composition	Particle size	content	Approach
Wood shavings, etc.	1000 μ m or more	60%	Screen, multi-tube cyclone
Sawdust	100 μ m-1000 μ m	30%	Multi-tube cyclone
Dust	5 μ m-100 μ m	10%	Multi-tube cyclone separator

2.2 Design of large particle size treatment equipment

According to the above-mentioned on-the-spot investigation of wood processing factories, large-scale particle shavings and the like are occupied, and the processing volume is huge. In order to ensure the working efficiency of subsequent

processing devices such as small-size wood chips, solid-phase shavings, wood chips, etc. The superposition and separation are designed according to the particle size, and the sieve tower is designed at the entrance to screen the large-size shavings. The overall structure is shown in Figure 2.

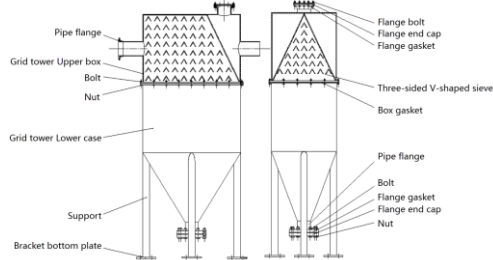


Fig. 2. Overall structure of the sieve tower

2.2.1 Screen design

By designing a three-sided V-shaped screen to increase the gas flow area to meet the processing air volume requirements, as shown in Figure 3 (a), the overall size of the screen is length $\times$ width $\times$ height: 1500 mm $\times$ 1000 mm $\times$ 800 mm. The common steel wire mesh is easy to block, easy to deform, and has a short life. It is connected to the tower body by means of the bottom of the 3mm steel plate material. The screen is used for the separation of light and large shavings and wood chips. Combined with the actual situation of the wood processing factory, wood chips above 10mm will reduce the dust removal efficiency of the subsequent dust removal device. Therefore, the mesh hole is designed to be 60°V to increase the flow area. As shown in Fig. 3(b), the hole diameter is 10mm and the span is 120mm. It is machined by milling. The screen structure is simple and easy to process. In order to ensure the pressure drop of the large air volume processing conditions and reduce the risk of clogging, the V-shaped mesh holes should be distributed on as many as three sides of the screen.

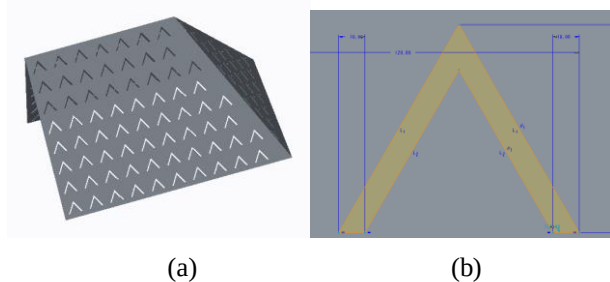


Fig. 3. Schematic diagram of the size structure of the screen

2.2.2 Sieve tower design

The screen tower is divided into upper and lower towers as shown in Fig. 3. The screen is installed in the upper tower body, and the airflow is screened through the upper tower body. The internal dimensions are matched with the size of the screen. The design of the pressure vessel is calculated to have a wall thickness of 10 mm. It not only saves material space, but

also meets the needs of pressure intensity. For the intake and exhaust pipes, a standard pipe with a diameter of 200 mm and a wall thickness of 6 mm can be used to meet the requirements of handling air volume and strength. An operating hole [8] is opened above the tower body to facilitate inspection of the inside of the device and to deal with problems such as blockage of wood shavings.

The lower tower body is mainly used to support the upper tower body and store the separated wood chips and shavings. It is connected with the upper box by bolts, and the bottom opening and unloading port. The internal space is determined according to the length of the unloading cycle.

2.3 Design of multi-tube vane type cyclone dust collector

2.3.1 Design of cyclone guide vanes

The single-tube cyclone is an important component of the multi-tube vane-type cyclone dust collector. The parameters of the guide vane have a direct influence on the separation efficiency. For the separation of sawdust dust, multi-tube arrangement is adopted, the intake air is relatively uniform, and the separation is thorough, the bottom of the cyclone. The use of the guiding cone structure can greatly reduce the occurrence of cross-flow back mixing. The curved blade structure is reasonable, the risk of being blocked is small [9], and the processing and manufacturing are convenient. The common specifications of the cyclone [10] are ϕ 100mm、 ϕ 150mm、 ϕ three kinds of 250mm. Choose here ϕ 108/76mm cyclone, the outer tube diameter is $108\text{mm} \times 2 = 54\text{mm}$, the inner tube diameter is $76\text{mm} \times 1 = 38\text{mm}$, the inlet angle α is 90° , the exit angle β is 30° , the number of blades n is 8, the thickness of the blade δ take 4.5mm, the two adjacent blade coincidence degree γ takes 33%, as shown in Figure 4.



Fig. 4. Schematic diagram of the guide vane structure

Table -2 Main dimensions of the guide vanes

Name	Number of blades (a)	Blade thickness (mm)	Distance between blade and inlet section (mm)	Blade exit angle (mm)	Blade package arc length (mm)	Blade height (mm)
Symbol	n	s	f	β	L	h
Size	8	4.5	25	30	45	47

2.3.2 Design of inner and outer tube structure of cyclone

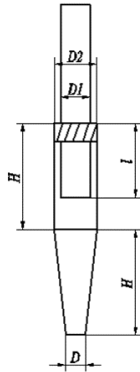


Fig. 5. Cyclone main size chart

(1) Determination of the length of the outer tube cylinder section:

The long inner tube insertion depth can improve the dust removal efficiency of the cyclone, but the excessively long outer tube will increase the pressure drop of the precipitator, so the length to diameter ratio of the outer tube is generally selected:

$$\hat{H} = H/D_2 = 2.5 \quad (2.1)$$

Substituting $D_2 = 108\text{mm}$ into equation (2.1): outer tube cylinder length $H = 270\text{mm}$. The length of the cone section is similar to the length of the cylinder section, and the length of the cone section is taken. $H_2 = 270\text{mm}$.

(2) Determination of the insertion depth of the inner tube:

The ratio of the depth of the inserted person to the length of the outer tube barrel:

$$l/H = 0.7 \quad (2.2)$$

Substituting $h = 270\text{mm}$ into equation (2.2): inner tube insertion depth $l = 189\text{mm}$.

(3) Determination of the diameter of the ash outlet at the bottom of the cone:

The diameter of the ash outlet at the bottom of the long cone is similar to the diameter of the inner tube. If it is too small, cross-flow back mixing [11-12] may occur. If it is too small, the internal swirl will be unstable, which will affect the internal rotation of the airflow [13]. The diameter of the ash outlet at the bottom of the cone = 50mm.

In summary, the main dimensions of the inner and outer tube structures of the cyclone are shown in Table 3.

Table -3 Main dimensions of the inner and outer tube structures of the cyclone

Name	Outer	Outer cone	Inner tube	The diameter
------	-------	------------	------------	--------------

	cylinder length (mm)	length (mm)	insertion depth (mm)	of the ash outlet at the bottom of the cone (mm)
Symbol	H	H ₂	l	D
Size	270	270	189	50

2.3.3 Design of other parameters of multi-tube vane type cyclone dust collector

(1) Determination of the diameter of the precipitator:

The spacing of adjacent cyclones cannot be too small, and the inconvenience of installation will not affect the flow field state at the ash discharge port, so the center distance is generally 1.4-1.5 times the diameter of the outer diameter of the cyclone. D_2 . The distance between the outermost cyclone center and the dust collector wall is desirable D_2 . The cyclone can be arranged in a concentric circle [7]. Here, in the case of a cyclone in the center, the diameter of the precipitator:

$$D = (3n+2) D_2 \quad (2.3)$$

Where n is the number of turns of the cyclone, substituting $n=3$, $D_2 = 108\text{mm}$ into equation (2.3): dust collector diameter $D = 1180\text{mm}$.

From the size of D , the number of cyclones n is preferably 21. The specific arrangement is shown in the figure below.

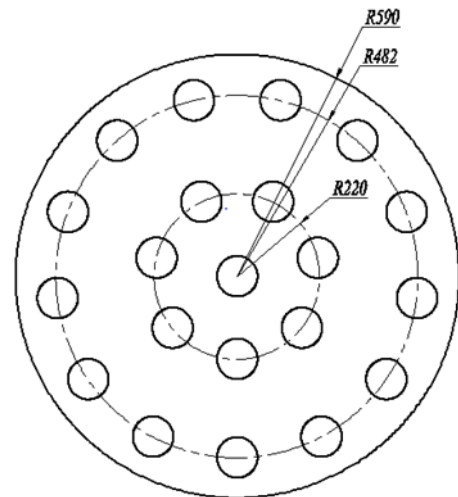


Fig. 6. Layout of the cyclone in the lower partition

(2) Determination of operating pressure:

$$Q = 1.1 \times 10^6 N F_i p \quad (2.4)$$

In this formula:

Q - Multi-tube cyclone treatment capacity, Nm^3/day .

F_i - The axial air intake area of a single cyclone, m^2 .

p- The operating pressure of the multi-cyclone dust collector, kg/cm².

Axial air intake area of a single cyclone:

$$F_i = \pi(r_2^2 - r_1^2) \quad (2.5)$$

In this formula:

r₂- the outer diameter of the cyclone outer tube, m.

r₁- the radius of the inner diameter of the cyclone, m.

Substituting q=60000×24 Nm³/day, N =21, formula (2.5) into equation (2.4): operating pressure of multi-tube cyclone p ≈ 13.49 kg/cm² = 1.32Mpa.

(3) Determination of the axial flow velocity of the cyclone:

$$C_i = TQ / (2.4 \times 10^6 N F_i p) \quad (2.6)$$

In this formula, T- working temperature, take 40 ° C.

Substituting q=60000×24 Nm³/day, N =21, Equation (2.6) into equation (2.4): Cyclone axial airflow velocity C_i ≈ 18.3m/s.

(4) Determination of the pressure drop of the precipitator:

$$\Delta p = \xi r_g C_i^2 / 2g \quad (2.7)$$

In this formula:

ξ- Cyclone drag coefficient, 12.7.

r_g- the severity of the treatment gas, kg/m³.

g- Gravity acceleration, 9.8m/s².

Substituting ξ=12.7, r_g=2×10-3kg/m³, g=9.8m/s² into equation (2.7): Dust collector pressure drop Δp ≈ 0.43 kg/m²=0.042Mpa.

In summary, the design of the remaining parameters of the multi-tube vane cyclone is shown in Table 4.

Table -4 Design of the remaining parameters of multi-tube vane type cyclone

Name	Dust collector diameter (mm)	Cyclone number (a)	Operating pressure (MPa)	Axial air flow rate (m/s)	Pressure drop (MPa)
Symbol	D	N	p	C _i	Δp
Size	1180	21	1.32	18.3	0.042

2.3.4 Design of multi-tube vane type cyclone dust collector

Main design parameters:

(1) Upper cylinder size: length 1200mm, height 820mm, width 1200mm

(2) Lower cylinder size: length 1200mm, height 820mm, width 3500mm

As shown in Fig. 7, the cylinder is mainly used for discharging the gas treated by the dust collector. As shown in Fig. 8, the cylinder is mainly used for supporting the dust collector and storing the separated wood chips and dust. Calculated by the above formula, the operating pressure is 1.32 MPa, which can meet the strength requirement by using the commonly used 10 mm steel plate. The upper and lower cylinders are bolted. In addition, the upper partition of the precipitator should be installed in the bottom of the upper cylinder in the form of welding; there are two operating holes on both sides of the cylinder for checking the working condition of the cyclone inside the separator to facilitate the daily maintenance of the cyclone.

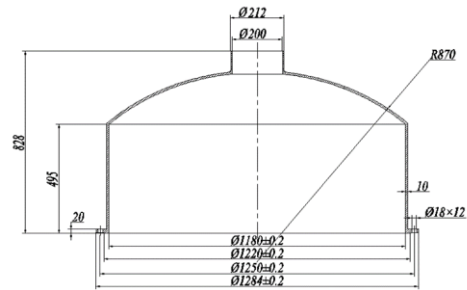


Fig. 7. Multi-tube dust collector upper cylinder

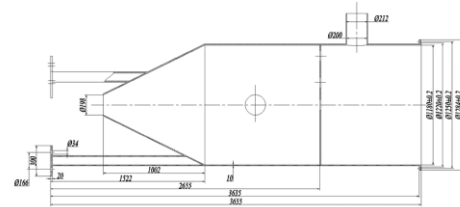


Fig. 8. Multi-tube dust collector lower cylinder

2.4 Selection of VOCs waste gas treatment equipment

In view of the fact that the research and production of photo catalytic catalytic processing equipment [14] on the market has been relatively perfect, many manufacturers in the country can manufacture and manufacture. Therefore, the equipment used in the processing of wood is selected from Botou City Xianglu Environmental Protection. The JHRRCO-6000 Photo Oxygen Catalytic Equipment manufactured by Equipment Co., Ltd. is used to process VOCs exhaust gas. The specific parameters are as follows. In addition, a gas composition safety monitoring system can be installed at the gas outlet end.

Product indicators	Parameter
Product number	JHRRCO-6000
Dimensions (mm)	3600×1650×2100
Handling air volume (m ³ /h)	60000
Treatment of exhaust gas concentration (mg/m ³)	≤400

Processable exhaust type	Hydrogen sulfide, lipids, alcohols, aldehydes, benzenes, alkanes, etc.
Installation method	Flange connection

2.5 Part strength check analysis

2.5.1 Pipe compression strength check

The gas transportation of the whole device adopts the pipeline shown in Fig. 9. The outer diameter is $D=212\text{mm}$, the wall thickness is $t=6\text{mm}$, the material is alloy steel, the tensile strength is 980MPa , and the shear strength is 490MPa .

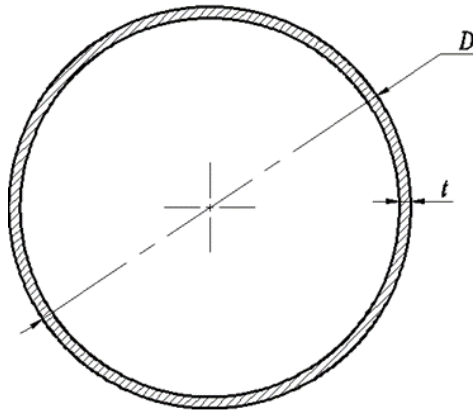


Fig. 9. Schematic diagram of pipe size

2.5.2 Analysis of tensile strength of cyclone inner tube

The uppermost end of the single-tube cyclone inner tube was set as a fixed constraint, and the operating pressure on the blade was 1.3MPa . Figure 10 shows the Von-Mises stress cloud diagram of the cyclone inner tube. Under this pressure, the stress is about 10MPa , which is much smaller than the yield stress of 620MPa . Figure 11 is its displacement cloud diagram, its deformation is very small, the maximum displacement is 0.00003mm negligible, it can be concluded that the strength and performance of the single-tube cyclone guide vane and the riser meet the design requirements.

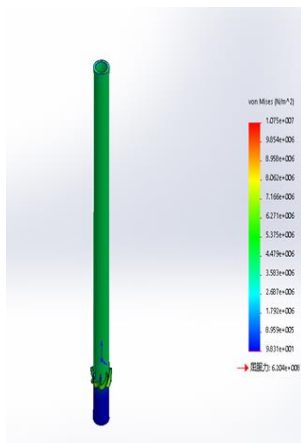


Fig. 10. Stress cloud diagram of cyclone inner tube

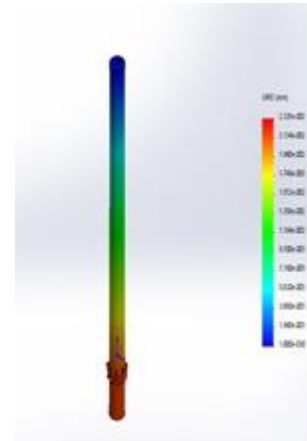


Fig. 11. Displacement cloud diagram of cyclone

2.5.3 Strength analysis of the upper cylinder of the cyclone separator

The lower edge of the upper body of the cyclone separator is set as a fixed constraint, and the operating pressure on the inner wall is 1.3MPa . Figure 12 shows the Von-Mises stress cloud diagram of the upper cylinder. Under this pressure, the stress is about 200MPa , which is close to the yield stress of 282MPa . There is stress concentration at the junction between the circular arc surface and the straight section. Therefore, it should be chamfered here. Figure 13 is a displacement cloud diagram with a small amount of deformation and a maximum displacement of 0.69mm within the allowable range of strength.

In summary, the strength and performance of the upper cylinder meet the design requirements, and the sharp corners of the detail should be chamfered to prevent stress concentration.

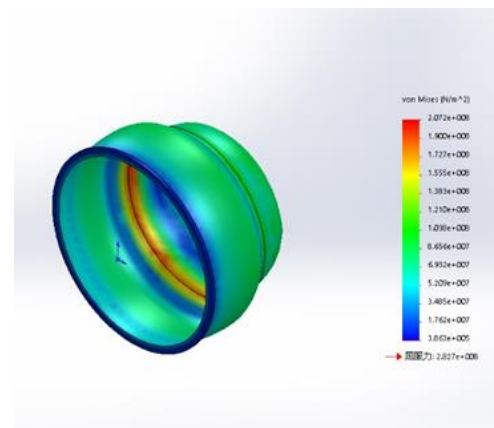


Fig. 12. Upper cylinder stress cloud diagram

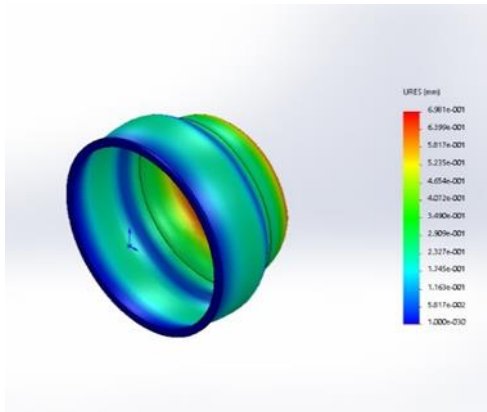


Fig. 13. Upper cylinder displacement cloud diagram

IV. CONCLUSION

Starting from the practical problems of waste gas treatment in wood processing plants, combined with theoretical calculations and research methods, the device adopts the method of superposition and separation according to the particle size of wood shavings and wood chips, which can more effectively separate solid phase impurities in exhaust gas, and creatively design three-sided v-type. The hole screen and the multi-tube vane type cyclone dust collector make the overall pressure drop of the device low, the structure is simple, the installation is convenient, the stability is good, the maintenance cost is reduced, the energy consumption is saved, and the device realizes the exhaust gas. One-stop treatment, the treated gas can be directly discharged into the atmosphere, providing reference for the design and development of dust removal and gas purification technology equipment in the wood processing industry.

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