A NOVEL GREASE REMOVAL SYSTEM FOR KITCHEN VENTILATION

TIETEELLINEN JULKAISU TURBOSWINGIN TOIMINNASTA

Tutkimustulos

Jeven

Top ventilation for top chefs

A NOVEL GREASE REMOVAL SYSTEM FOR KITCHEN VENTILATION

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Abstract

A novel kitchen hood filtration system has been developed, modelled and studied. The solution is based on a rotating filter technology and it provides many desired properties for kitchen ventilation, such as the ability to use heat recovery technology and significant reductions in maintenance costs. The main idea is to improve the separation efficiency by enhancing the inertial mechanism with centrifugal force. It can be done by rotating the filter material at high speed. The rotation causes velocity differences between particles and the collection surface. The filtration efficiency is increased due to higher collision probability between the particles and the filter media.

In the laboratory test the separation efficiency of the prototype was high starting from particle size 2-3 µm while the current kitchen grease separators are efficient only from 5-7 µm upwards. The higher efficiency is achieved with the same pressure drop level as the current solutions. The rotating movement induces a tangential flow component, which can be utilized in non-touch sealing of the rotating filter plate. The rotation also enables a self-cleaning property for the filter material as the collected particles accumulate to big dendrites or droplets which are transported to the outer edge and finally released due to their high inertia. The released particles are conducted to the container, where the collected material is removed during maintenance.

The first commercial application of the rotating filter technology is the kitchen grease separator TurboSwing launched by a Finnish company Jeven Ltd. The separators have been installed in several restaurant kitchens in Finland, and the user experiences have been promising; the system is easy to use and the separator operates reliably and efficiently keeping the exhaust ducts clean. The new product also enables efficient energy recovery by preventing the heat exchangers from clogging.

Keywords: rotating filter, grease removal system, kitchen ventilation, air filtration, indoor air quality

1 Introduction

In restaurant kitchens food preparation processes like grilling and frying can produce remarkable amount of grease aerosols. In kitchen ventilation systems the exhaust hoods are designed to remove the contaminated air from the kitchen to keep up high indoor air quality. The exhaust air duct can become heavily contaminated due to high particle concentrations causing possible fire risks in the ducts. Therefore efficient grease extractors must be used to prevent the grease particles to enter the exhaust ducting. The conventional baffle filters and multi cyclones consist of different air slots where the particle separation is done by bending the direction of air flow sharply. This system is suitable for removing large particles but the efficiency is usually rather low for smallest grease particles due to their lower inertia. Increasing the separation efficiency would require higher air velocities which in turn cause too excessive pressure drop and energy consumption for the system. In some cases also the noise level can be a limiting factor.

A new interesting approach to improve the efficiency is to create velocity difference between particles and collection surface by rotating the filter material at high speed. The rotating movement of the separator plate enhances the inertial impaction phenomena and therefore increases the separation efficiency (Heinonen et al 2006). In this study the rotating filter technology was applied to kitchen hood ventilation system.

2 Methods

The methods include modelling, prototype construction, measurements in laboratory and field testing. Modelling was used to get better understanding how the rotating filter operates and what are the most important parameters for the separation efficiency. The prototypes were built based on the experience gained from the modelling work. The performance of the rotating filter prototype was measured in laboratory with particle analysers. The long-term operation in real operation conditions was studied by assembling the developed grease separators in restaurant kitchens.

2.1 Modelling

The properties of the rotating filter were studied theoretically by modelling the separation efficiency utilizing the theories created for fibrous filters (Hinds 1982). In addition to normal deposition mechanisms like interception, impaction and diffusion the inertial mechanism caused by rotating movement was introduced to the model. The effect of rotating movement was modelled analogously to single fibre efficiency caused by gravitation (Brown 1993). In this model the gravimetric acceleration was replaced with acceleration caused by the rotation. The single fibre efficiency caused by rotation E_{rot} can be expressed by

$$E_{rot} = \frac{\rho_p d_p^2 C_c \omega^2 r}{18 \mu v_{mat}} \tag{1}$$

where ρ_p is the particle density, d_p is the particle diameter, C_c is the slip correction factor, ω is the angular velocity, r is the radius of the rotation, μ is the air viscosity and v_{mat} is air velocity in material.

The single fibre efficiency caused by rotation was calculated together with other single fibre efficiencies with the expectation that the rotating mechanism is independent from other filtration mechanisms. The other parameters in the model are air flow, inner and outer diameter of the filter, rotation speed (rpm), fibre diameter, material thickness, packing density, particle density, air temperature and atmospheric pressure. An example of the calculated efficiencies (static, rotation and total) can be seen in Fig 1.

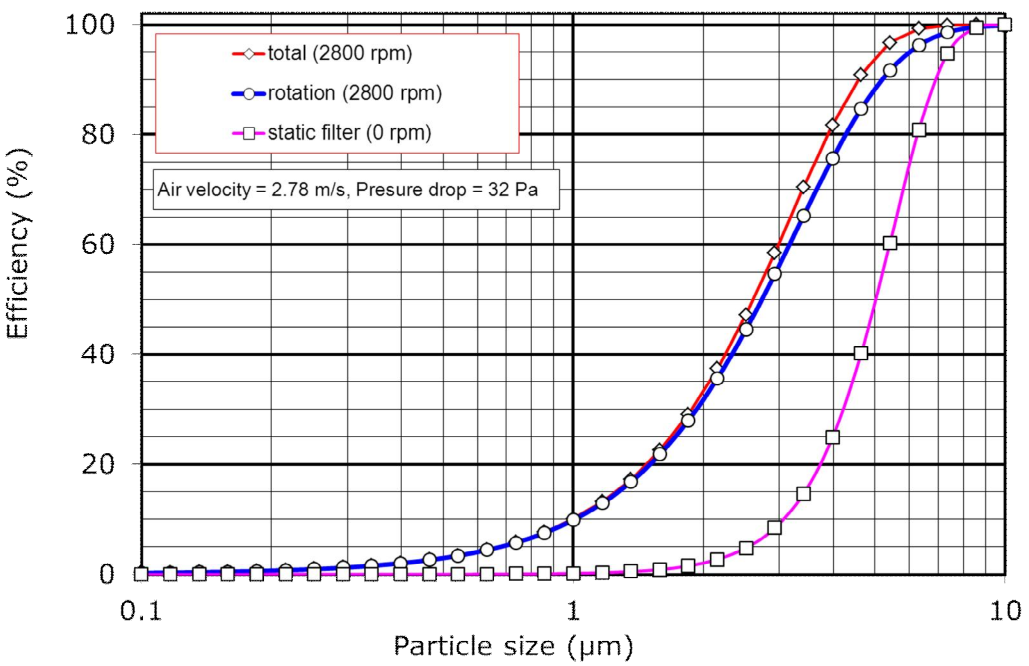

Figure 1. An example of calculated separation efficiencies.

2.2 Prototype construction

The first prototype of the rotating grease separator (Fig 2.) was designed and manufactured in co-operation between VTT and Jeven Ltd. The rotating movement is created with a conventional electric motor capable to rotate the separator disk. It can be seen that the separation plate is not mechanically sealed with the prototype body. Despite of the visible "leakage" between the separation plate and prototype body the system does not leak as the rotating separation plate induces an air flow curtain preventing the particles to pass the gap between the plate and the body (Taipale et al 2010).

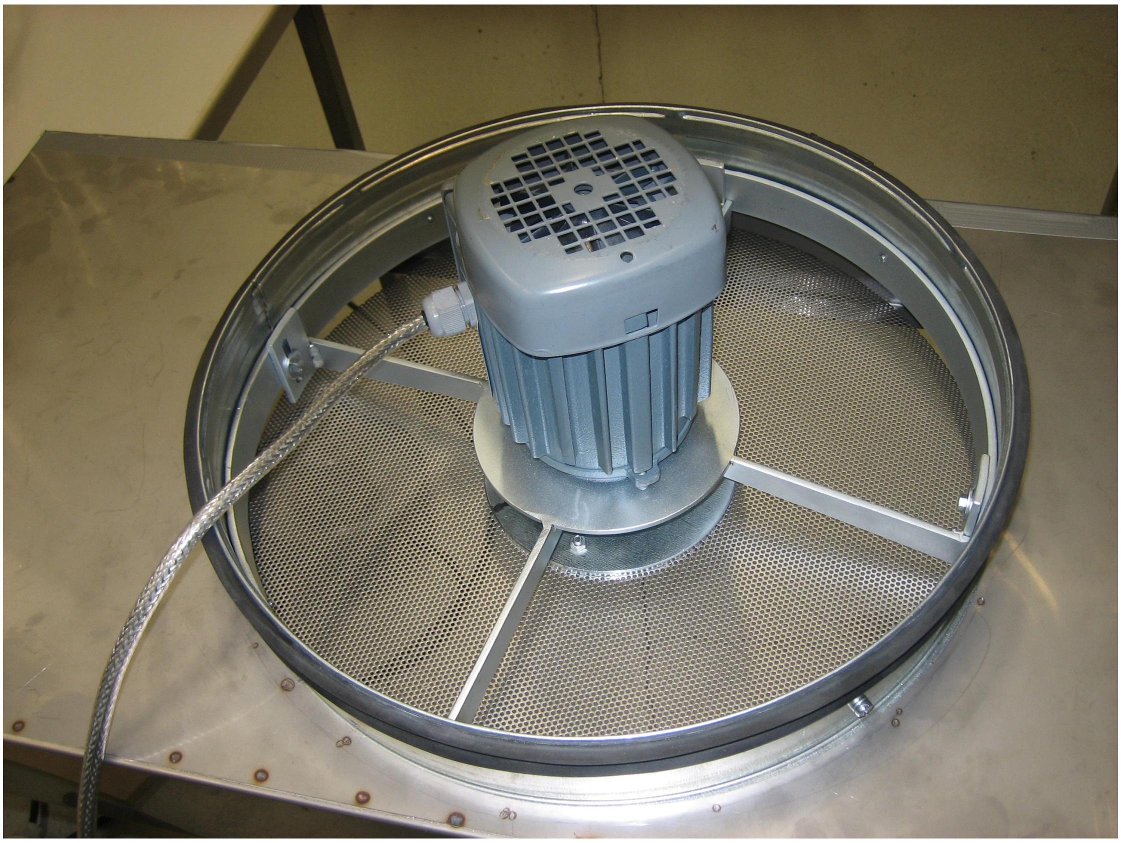

Figure 2. Grease separator prototype.

2.3 Laboratory measurements

The performance of the grease separator prototype was studied at VTT´s air filtration laboratory in Tampere, Finland. The prototype was installed in general ventilation filter test system corresponding to EN779 and ASHRAE 52.2 test benches. The separation efficiency tests were made with liquid DEHS particles generated with pneumatic nebulizer. The particle concentrations upstream and downstream of the separator were measured with an aerodynamic particle sizer (TSI APS 3321) at the particle size range 0.5 – 10 µm. The fractional filtration efficiency was calculated from the measured upstream and downstream concentrations (Taipale et al 2010).

2.4 Field tests in restaurant kitchen ventilation system

The field test in real operation conditions was arranged in two restaurants (Rosso and Amarillo) in Mikkeli, Finland. Total 18 TurboSwing rotating filter units were installed in the restaurant kitchens above grill and fryer areas which were used normally during the test. The performance of grease separators was followed for 11 months to determine their long-term performance in real operation conditions. Also the user experiences related to maintenance work were gathered during the test.

3 Results

3.1 Laboratory measurements

In the laboratory tests the efficiency measurement was repeated with different rotation speeds, air velocities, separator geometries and rotating filter materials to find the best combination for kitchen grease removal. The efficiency result of grease separator prototype with different air velocities compared to current solution can be seen in Fig 3. It is worth noticing that the higher efficiency of rotating filter increases the pressure drop only slightly.

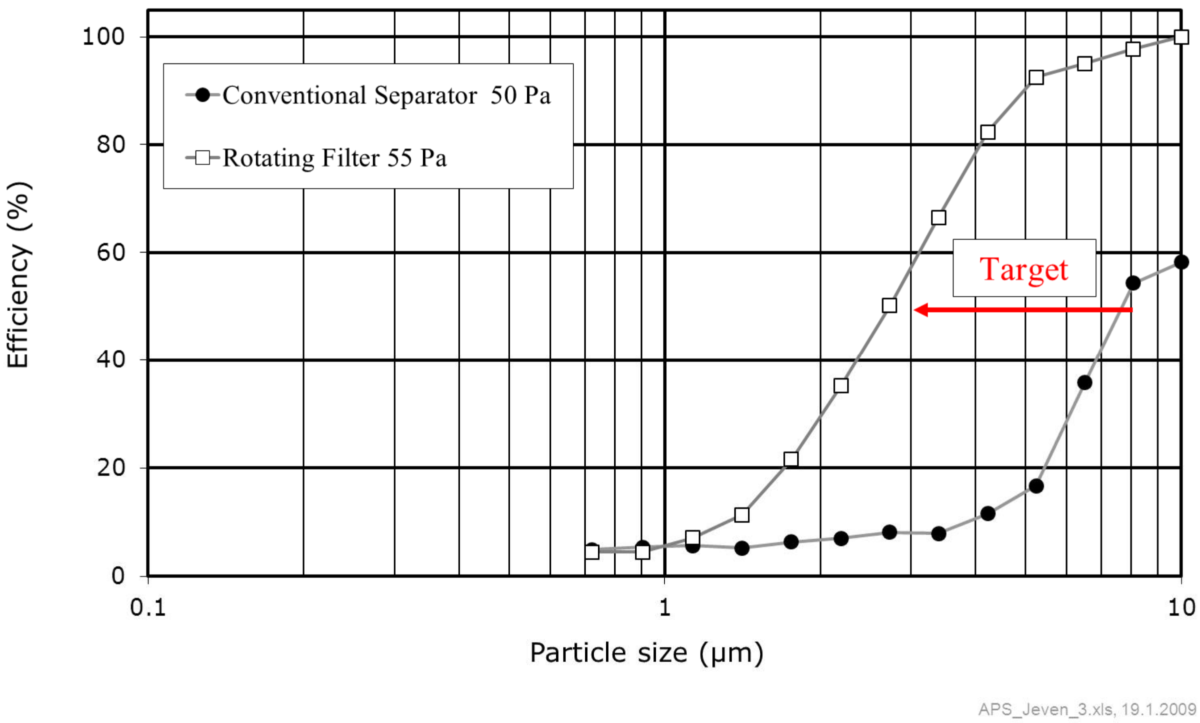

Figure 3. The fractional separation efficiency of current and new grease separators.

During the measurements it was noticed that despite of open gap between plate and body there is no remarkable leakages from the rotating filter edges. This is probably due to tangential air flow component originating from the air flow induced by the rotating filter plate.

3.2 Field test

In the field test the rotating filter units have now operated almost one year without any major problems. The filter plate made from perforated metal plate has remained clean enabling the continuous operation. Also the exhaust air ducts have remained relatively clean and the need for duct cleaning has significantly decreased. One separator unit has collected about 1 kg grease in a week, Fig. 4. and Fig. 5. Based on air flow and operation hours it can be estimated that in average the rotating filter decreases the aerosol concentration about 20mg/m^3 in the exhaust duct.

Based on the user experience TurboSwing needs less maintenance than the conventional grease extractors. The collected grease is removed from the container in average once a week depending on the usage of food preparing devises. The fluid grease can be removed simply by opening the drainage valve. Solid grease is removed manually and the dirty parts can be washed in a dishwasher.

Figure 4. Solid grease collected by TurboSwing grease separator during one week use.

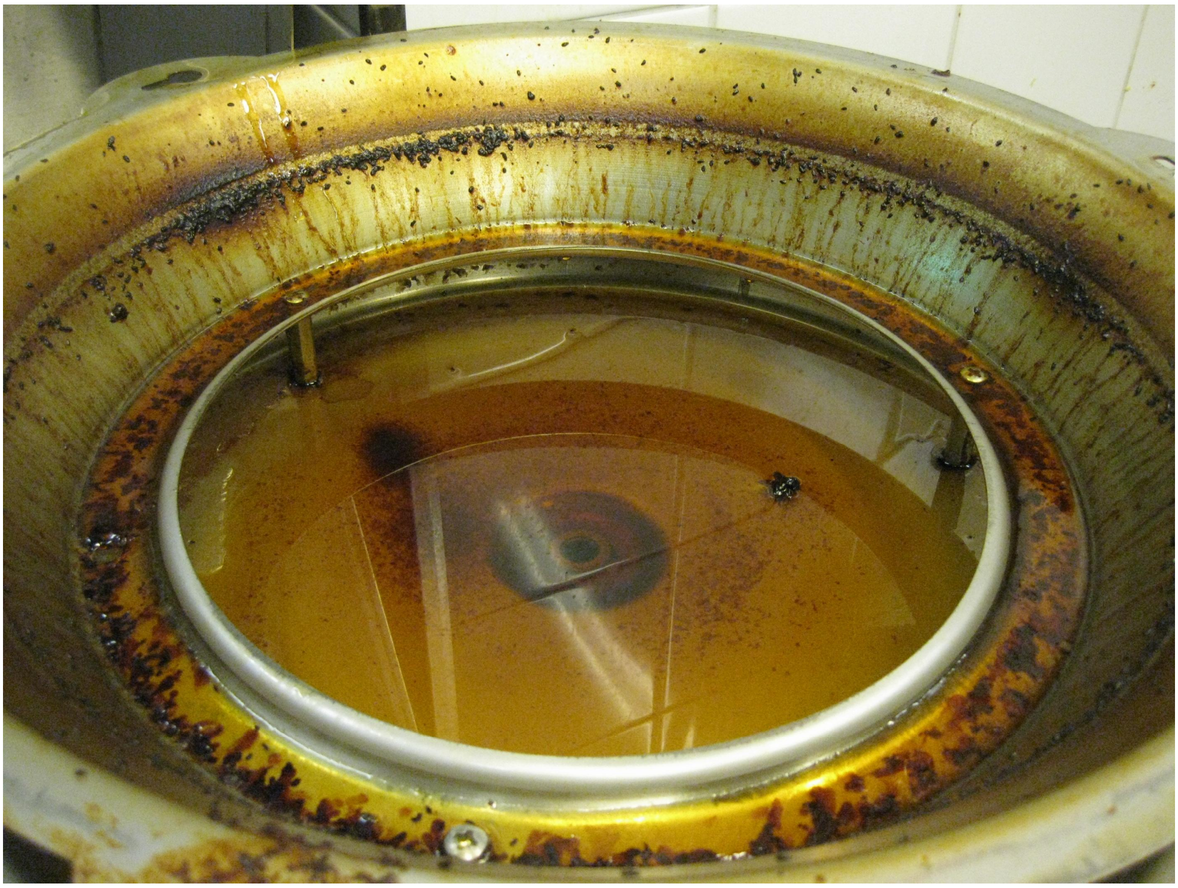

Figure 5. Liquid grease collected by TurboSwing grease separator during one week use.

4 Conclusions

Rotation of the filter material increases the separation efficiency for particle sizes >1µm where the inertial filtration mechanisms are dominating. The phenomena can be noticed both by modelling and measuring the efficiency of the rotating filter. The efficiency can be increased without excessive increase in the pressure drop. Unlike conventional grease separators the rotating filter maintains or even enhances the separation efficiency when the exhaust air flow is lowered to achieve energy savings.

The rotating filter model developed in this study was utilized in dimensioning the filter prototype. The model is an excellent tool to evaluate the importance of different parameters to the filtration efficiency. Predicting the exact fractional filtration efficiency values turned out to be more difficult as the materials used in rotating filter differ so much from the conventional filter materials.

The structure of the rotating filter enables non-touch sealing of the filter plate with the aid of induced tangential air flow. This property is significant from the practical point of view as the structure of grease separator can be simplified. Rotating the filter material at high speed causes accumulation of collected grease aerosol inside the filter material. The big droplets are transported to the outer edge and finally released due to their high inertia. In this way the filter plate remains clean enough to operate efficiently for relative long periods.

According to the user experience the maintenance of the TurboSwing is easy. The collected grease is removed from the container on average once a week and the dirty parts are washed in a dishwasher. The system is also able to keep the exhaust ducts clean and therefore reduce need for duct cleaning.

Perhaps the most important advantage of the novel system is that the high separation efficiency of the rotating filter enables installation of heat recovery system to kitchen hood exhaust system and prevents the heat exchanger from clogging. This property enables significant energy savings in kitchen ventilation systems.

5 References

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