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DESIGN OF SYSTEM FOR CENTRAL ASPIRATION OF WOOD DUST

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Abstract: A major prerequisite for the efficient operation of machineries in furniture industry is properly designed system for dust removal and collection. Inadequate dusting directly affects the life cycle of cutting tools, as well as the lubrication system, because inadequate removal of waste material from the cutting tool is cause for insufficient heat dissipation. In addition, proper design of aspiration ensures limited emissions of particles into the atmosphere, as well as dusting of a production hall. A large amount of dust in the production hall, which has accumulated on heat exchangers, significantly reduces the efficiency of heating systems. Installation of central aspiration system provides a lot of benefits, among other things, the place to collect waste. Waste material can be used for energy purposes, and that can leads to significant savings. The model of replacing the existing system of aspiration with a central one with appropriate techno-economic analysis is presented in this paper.

Key words: aspiration, dusting, wood industry, pellet production, energy saving

1. INTRODUCTION

Systems for the aspiration of wood dust are based on principles of pneumatic transport where air is used as transport fluid. For furniture factories with fewer machines "usual type of system for aspiration" are used commonly (when all machines work simultaneously), or portable devices for aspiration (when machines do not work simultaneously) [1, 2]. The problems arise when some machines in the hall work simultaneously while others machines work when it is necessary. In this case, although these systems are very uneconomical because of their working principle, there is unnecessary energy dissipations because of the amount of air coming from machines that are not currently in use.

The solution to this problem may be the installation of two parallel connected fans of which one is frequently regulated, where resistances of the network are regulated by automatic balancing valves. A model of this solution, which was applied to the real furniture factory with 7 CNC machines, will be shown in this paper. The essence of this solution is to ensure smooth and efficient aspiration of wood dust using "usual type of system for aspiration" which allows the free turn on/off of some machines.

2. SYSTEM FOR ASPIRATION

The air flow through the receiver and the minimum air flow velocity are given by the manufacturer. These conditions must be met in designing, i.e. must be ensured full suction of wood waste and safe transport of them in a floating condition through the pipeline [1]. Diameters of connecting pipe are defined by the machine manufacturers, whereby the minimum flow rate of air is prescribed, Table 1. The air velocity from the machine is determined by the conditions of effective removal of dust generated during wood processing. This is the main reason for low concentrations of mixtures during aspirations.

The list of machines, with a recommended minimum of air velocity and compatible diameters of connecting pipelines are shown in Table 1. In addition the measured air velocities in the existing system of aspiration are also shown.

Table 1. The recommended minimum of air flow and air velocities of the machine in factory

	Machine	Connections No.	Diameters of connecting pipe [mm]	Recommended minimum of air flow velocity [m/s]	Measured air flow velocity [m/s]	Recommended minimum of flow rate [m^3/s]
1	Holzma HPL 11/43/22/R	1	200	26,0	0 n.m.	1,39
		2	150	26,0	10,6	
2	Homag KAl 526/6/A3/25	1C	120	28,0	27,5	1,095
		2C	120	28,0	25,0	
		3C	120	28,0	31,0	
		4C	100	28,0	30,2	
		5C	80	28,0	34,8	
		1П	120	28,0	24,1	1,095
		2П	120	28,0	24,0	
		3П	120	28,0	29,2	
		4П	100	28,0	32,5	
		5П	80	28,0	34,2	
3	Homag Kal 310/5/A3/25	1	120	28,0	29,7	0,95
		2	120	28,0	23,2	
		3	120	28,0	13,5	
		4	120	28,0	9,0	
4	Optimat BST 503	1	160	30,0	16,0	1,21
		2	160	30,0	0	
5	Rover	1	150	28,0	23,7	0,5
6	Optimat BST 50	1	200	28,0	37,7	0,88
		2	160	28,0	23,7	

The figures presented in Table 1 show that measured values of air flow velocity and flow rate do not meet the recommended values that provide reliable operation.

The current system of aspiration was designed without previously completed project and adequate calculation. For this purpose producer used pipes that were earlier found in the hall, because the hall was exploited for wood processing prior to the privatization. Since the existing system of aspiration was not project designed, deformations on the pipeline are evident, Figure 1.

Figure 1: Deformation of pipeline

Inadequate dusting directly affects the life cycle of cutting tools, as well as the lubrication system, because inadequate removal of waste material from the cutting tool is cause for insufficient heat dissipation. A large amount of dust in the production hall, which has accumulated on heat exchangers, Figure 2, significantly reduces the efficiency of heating systems.

Figure 2: Accumulated dust on elements of the furniture and heat exchangers

2.1. Designing of new system for central aspiration of wood dust

Wood aspiration systems belong to the group the combined pneumatic transport, Figure 3. This means that air that carries wood dust must pass through the fan before it reaches the separator [3]. These systems are used in plants with fewer machines and when the number and the place of machines will not change. A centrifugal fan is commonly used for air and wood dust transport in these systems. The construction of a fan has to ensure safe passage and no sparking of transported materials [4].

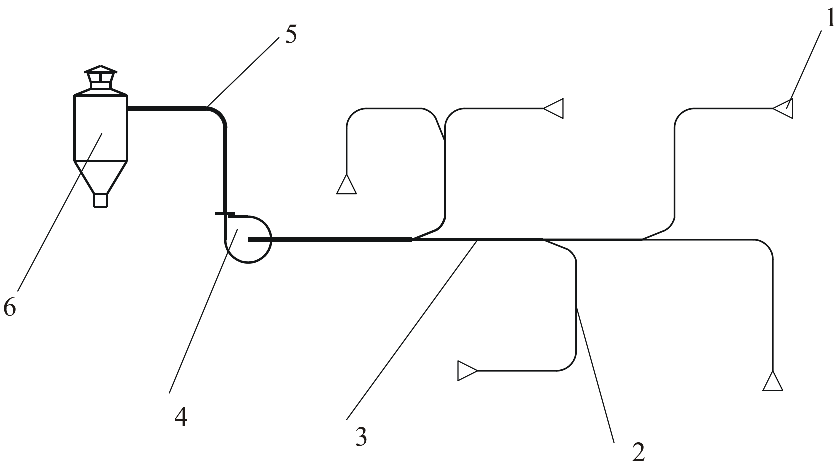

Figure 3: Scheme of usual type of system for aspiration, 1) receiver, 2) branch pipe, 3) main intake pipe (variable diameter), 4) centrifugal fan, 5) main discharge pipe (constant diameter), 6) separator

The scheme of branched pipeline is necessary before the start of calculations, Figure 4, where all elements of piping (length and diameter) as well as all input data should be denoted. Entering of the size of local resistance and pressure drop on the scheme is needed at the end [1].

Designing of pipeline is performed as to clean air transported. The calculation starts from the first machine in pipeline network that is the farthest from the fan unit. The scheme of the machine disposition in the production hall, Figure 5, shows that the farthest machine is No. 1 (11/43/22/R HOLZMA HPL). It has two receivers, Figure 6, and calculation starts from this branch.

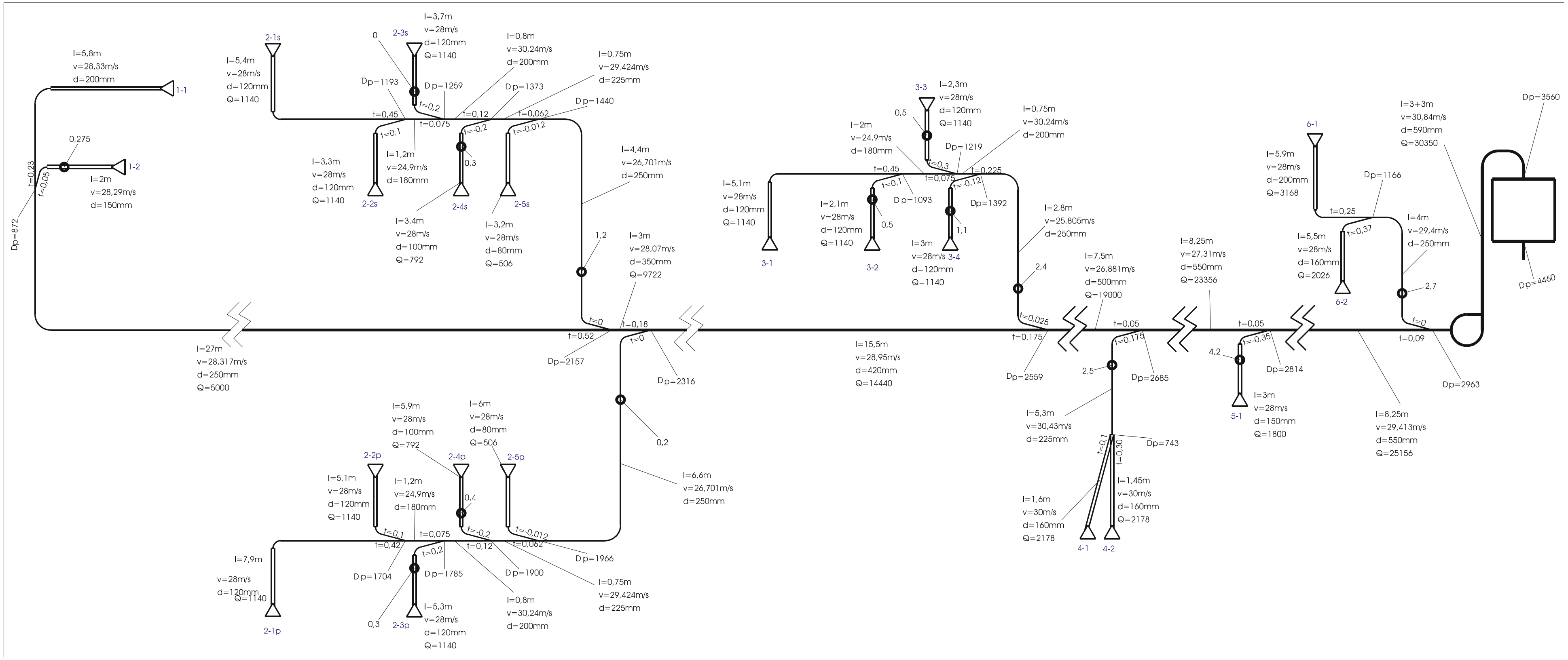

Figure 4: Scheme of branched pipeline

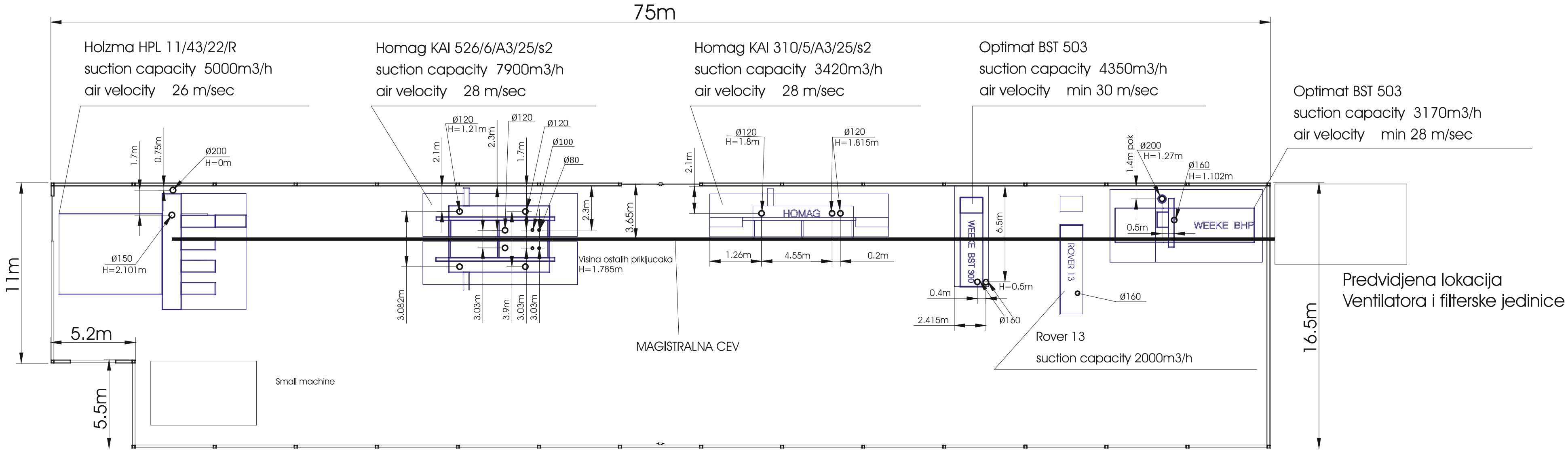

Figure 5: Scheme of the machine layout in production hall

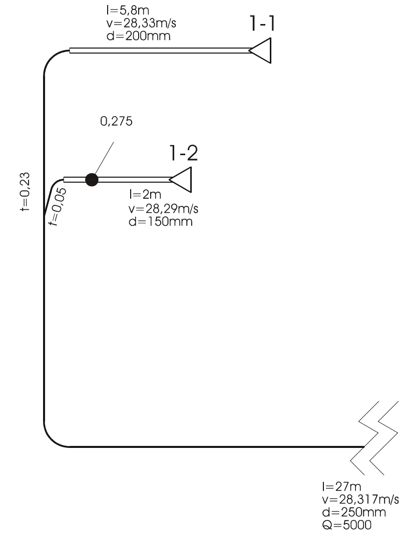

Figure 6: Scheme of pipeline from the first machine

The flow rate through each section is calculated according to the equation:

$$Q_{xy} = \frac{d_{xy}^{\ 2} \cdot \pi}{4} \cdot v_{xy} \tag{1}$$

where:

d_{xy} *[m]* - pipe diameter,
v_{xz} *[m/s]* - air flow velocity;

And pressure drop according to the equation:

$$\Delta p_{xy} = \left[l_{xy} \frac{\lambda_{xy}}{d_{xy}} + \Sigma \xi_n \right] \cdot \rho_v \cdot \frac{v_{xy}^{\ 2}}{2} \tag{2}$$

where:

l_{xy} *[m]* - pipe length,
λ_{xy} *[-]* - friction coefficient of a fluid flow,
$\sum \xi_n$ *[-]* - sum of the local resistance coefficient,
ρ_v *[kg/m³]* - air density.

Impact of material on the pressure drop in the system is taken into account at the end of the calculation for the entire network [1]:

$$\Delta p_{TM} = \Delta p_T \cdot \left(1 + \mu_p \cdot K\right) \tag{3}$$

where:

Δp_T *[Pa]* - pressure drop without material,
μ_p *[-]* - concentration of material,
K *[-]* - factor which depends on factors of pressure (usually K = 1.4).

Size and power of fans are determined from the total flow, which is determined from the continuity equation, and the total pressure drop.

2.2. Free switching on/off of a machine

Only few of machines work fulltime and they require 60% of total power for aspiration (according to the calculation the total power of the system amounts to 61.18 kW). Therefore, two fans will be installed in the system, Figure 7. One of these will meet about 60% of the needs and it will work continuously without frequency regulation. The second one that is frequency controlled will be switched on as needed. The first fan is dimensioned to meet the needs of machines that are used for the most of working time. In the case of the first fan failure, the second one provides minimum performance for production.

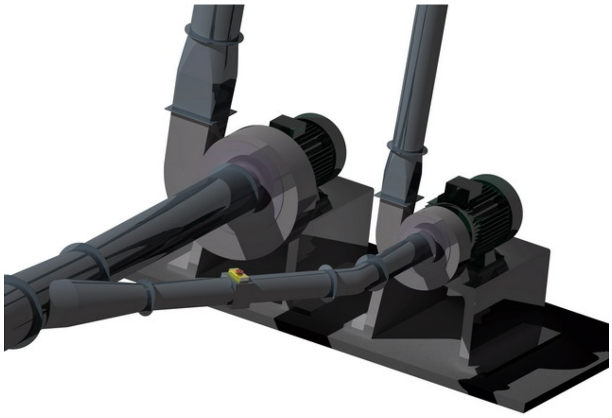

Figure 7: 3D model of fans unit

However, only the installation of the second frequency controlled fan does not provide free switching on/off of a machine. Disconnection of a machine induces air speed reduction and pressure drop in the main pipe and unbalance in the pipeline network. In order to prevent an air velocity drop below the minimum recommended speed for the horizontal pneumatic transport, slightly lower diameters were adopted in the total calculation of the network. This provides an optimal solution that will meet the minimum speed of transport after the exclusion of certain lines.

Unbalance of pipeline network is regulated by automatic balance valves, Figure 8. In addition, they are also intended for the closing of certain lines when the machine is not working [5].

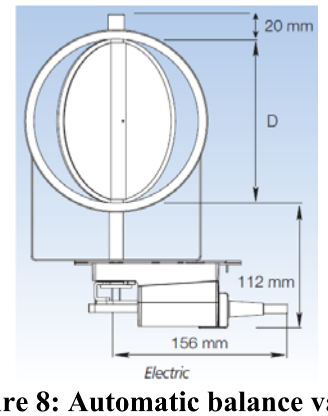

Figure 8: Automatic balance valves

3. USING OF WOOD CUTS AS ENERGY SOURCE

As fossil fuel prices continually rise, more attention is directed towards renewable energy sources. High fuel prices make those renewable fuels more financially viable because consumers seek the most economical energy source.

The furniture factory from this study uses wood waste as fuel for space heating from the beginning of production. The position of the boiler plant, which is located more than 50 m from the collection units (filter units) requires manual transferring and manual firing of the boiler as well as hiring additional workers for these jobs. In addition to the relatively large distance of the boiler, the problem is oversized boiler.

As part of designing of system for central aspirations, the building of new boiler plant which would be located a few meters from the filter unit was planned by the management in order to obtain automated insertion and burning of waste in the boiler during heating season. The amount of waste material generated during the production currently stands about 300 kg dailly (110 tons annually).

Automated insertion of material into the boiler is usually based on screw transporters, Figure 9, where the waste material directly from the silo is inserted to the boiler.

Figure 9: Screw transporters

Direct combustion of collected wood (MDF and plywood) dust is reasonable only when the boiler works throughout the year or when the thermal energy is used for purposes other than for space heating. Boiler utilisation only in winter season wears a problem with the storage of waste materials outside the heating season. In this case the most acceptable solution is the usage of a boiler with storage tank, Figure 10, where wood pellets as fuel are used.

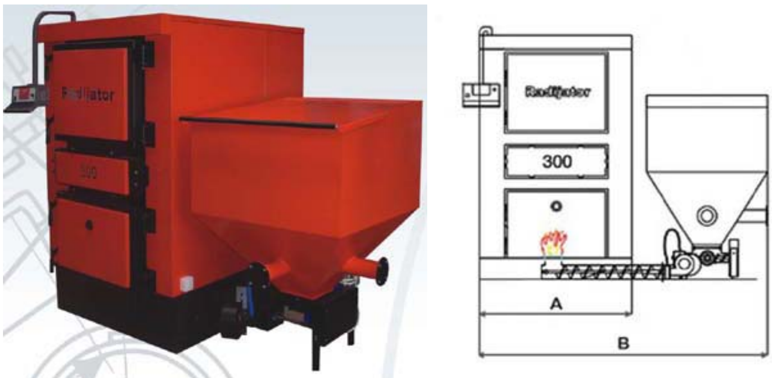

Figure 10: Boiler with tank for pellets

Combustion process is automatically controlled with two basic parameters: water temperature in boiler and the temperature of exhaust gases. Boiler firing is automatic, performed with two electric heaters while the heating power is manually regulated by user. Insertions of pellets into the tank are carried out every 5 - 15 days where the connection of a tank and a silo is possible using a screw transporter. Capacity of silo is in accordance with the thermal loads.

3.1. Pellet production

Pellets are environmentally friendly fuels that are made from wood or agricultural residues. Wood pellets are made from wood, wood wastes and sawdust. These raw materials are firstly crushed to a desired size and then are dried and pressed into cylindrical shape with a diameter of 6 to 12 mm, a length of 10 to 30 mm. The waste wood from MDF and plywood has more advantage such as powder form and large degree of dryness.

However a certain amount of waste is in the form of wood pieces that need to be grinded to 1 - 2 mm size. Grinding of material is usually performed in the crushers with hammers. In addition to the favorable characteristics of waste materials for pellet production, the advantage of using pellets as fuel is also reflected in easier storage and in a very favorable market price of pellets. The price of pellets is about 120 - 150 € per ton [6], which is much cheaper than other fuels used in Serbia, if we take into account the fact that one tone of wood pellets can replace two tons of domestic lignite, one tone of imported coal or slightly less than 500 liters of heating oil.

As amount of 300 kg per day of waste wood was generated, a mobile machine for production of pellets, which has a capacity of 100 kg per hour, will satisfy the current needs of the company, and possibly increase of production capacity. Power of electromotor is 7.5 kW, while the machine price is 2200 €. With 3 hours of daily engagement (necessary for the daily quantity of waste wood to be transformed into pellets) the payback of machine purchasing would be less than eight months while the income for the same period is amounted to more than 5700 €.

4. CONCLUSION

It is necessary to meet all of the conditions for the smooth operation of machines and workers in designing the system of aspirations. Those conditions and prerequisites were part of technical documentation of the machinery provided by manufacturers. Unhindered access to a machine by workers and unhindered passage through the production hall are also conditions that must be met during design.

The system for central aspiration has usually one filter unit for collecting waste materials, allowing automated utilization of waste materials. Filter unit should be located close to the boiler plant, pelleting plants or other plants for using waste materials. Usage of waste material for energy purposes can lead to significant savings. In addition, investments in equipment for the pelleting of wood waste would pay-back in a relatively short period.

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