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INVESTIGATION INTO REDUCTION OF FLOW RATE OF CLEANING AIR

Vladas Vekteris
Ina Tetsman
Vytautas Striška
Vadim Mokšin
Department of Machine Engineering
Faculty of Mechanics
Vilnius Gediminas Technical University
J. Basanavičiaus str. 28, LT-03224, Vilnius
Lithuania

ABSTRACT

This paper presents method for collecting polluted air that can reduce production costs (for example metal plating) and release of harmful substances. This method employs air ejection, a process where kinetic energy of a stream is transferred to another stream. Results of experimental investigations are presented as graphs of dependence of air flow rate on ejection coefficient.
Keywords: electroplating bath, ejection coefficient, local ventilation system

1. INTRODUCTION

Electroplating is a plating process in which metal ions in a solution are moved by an electric field to coat an electrode. The process uses electrical current to reduce cations of a desired material from a solution and coat a conductive object with a thin layer of the material, such as a metal. Electroplating is primarily used for depositing a layer of material to bestow a desired property (e.g., abrasion and wear resistance, corrosion protection, lubricity, aesthetic qualities, etc.) to a surface that otherwise lacks that property. Electroplating processes are becoming more and more popular each year. These technologies are increasingly being used in different industries; however air pollution control (waste management also) problem remains especially relevant for these processes. Many scientists attempt to improve the efficiency of gas collecting and cleaning equipment, i.e. to develop the methods of calculating and optimizing process parameters, create and introduce new energy-saving technologies, design advanced cleaning equipment. However, economic factors are generally decisive.

Electroplating processes are performed in electroplating baths. Bubbles of hydrogen, oxygen and other gases are formed at electrodes during electrolysis process due to electrochemical and chemical reactions. These bubbles are main source of aerosols and mist emissions during electroplating process [1, 2]. To control the maximum permissible concentration of hazardous substances in air and maintain safe working environment the local exhaust ventilation systems are used, usually side-mounted. They collect and pull the polluted air from evaporating surface through the filters. Quantity of hazardous substance released from the surface area is established depending on chemical composition of the solution, its temperature, area, evaporation period and environmental air flow conditions [3–6].

The main objective of this work is to present the Y-branch exhaust duct which has two fans and baffle installed inside. That duct can be used for two lines of electroplating baths. The baffle separates air flows from different lines and provides additional air ejection.

2. OBJECT OF INVESTIGATIONS

Object of investigation is presented in Figure 1, a. It consists of exhaust hoods, fans and ducts connected as shown in Fig. 1, b. If the cross-sectional area of the chimney is designated as *F* and baffle is attached in the middle, then $F_1 = F_2 = 0.5F$.

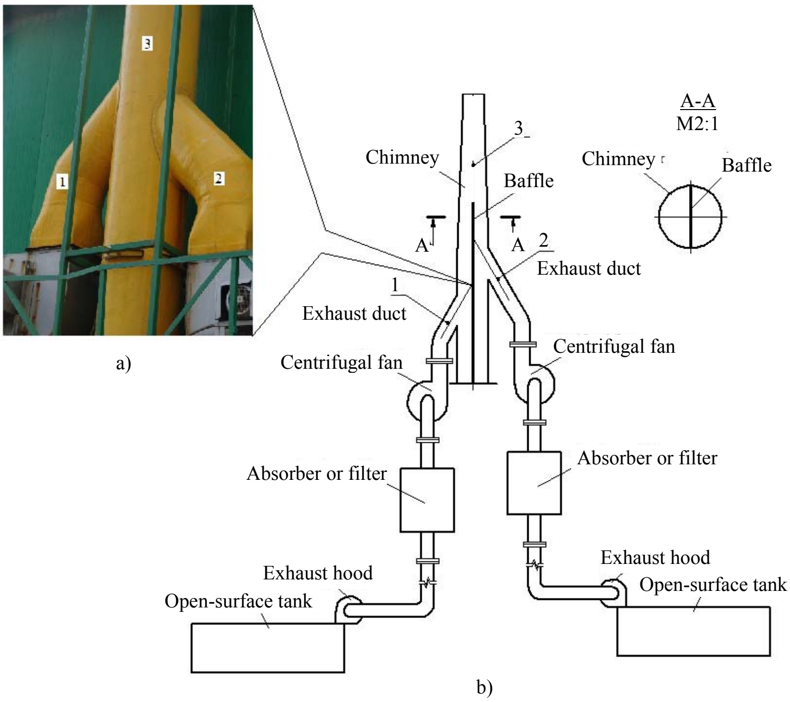

Figure 1. Object of investigation: a) – photo; b) – scheme: 1, 2, 3 – air flow rate measuring points

Exhaust hood were attached to the side of open-surface tank (electroplating bath) as it is shown in Figure 2. Their geometrical parameters are presented in Figure 2.

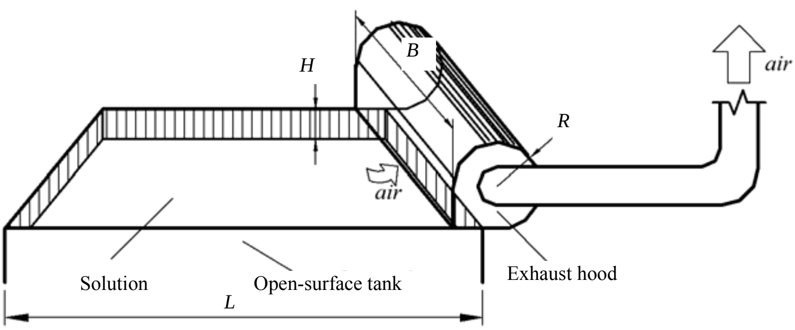

Figure 2. Hood connection scheme: B – width of the bath; H – distance from the edge of the hood to surface of the liquid; R – radius of the hood; L – length of the bath

3. ANALYSIS

The suction air flow rate (m^3/h) can be calculated using following formula [1, 7]:

$$Q = 1400\left(0.53\frac{BH}{B+H} + H\right)^{1/3} BLC_t C_{tox} C_1 C_2 C_3 C_4 . \quad (1)$$

where B is the width of the bath; H is the distance from the edge of the hood to surface of the liquid; L is the length of the bath; C_t is the coefficient for evaluating the temperature difference between air and solution (for pneumatically non-activated exhausters $C_t = 1 + 0.0157\Delta T$, for pneumatically activated exhausters $C_t = 1 + 0.003\Delta T$, where ΔT is the temperature difference); C_{tox} is the coefficient for evaluating electrolyte toxicity (in case of activated hoods $C_{tox} = 1$); C_1 is the coefficient for evaluating design of the hood; C_2 is the coefficient for evaluating environmental air flow; C_3 is the coefficient for evaluating the effect of covering of the liquid surface with polyethylene or polystyrene balls; C_4 is the coefficient for evaluating the effect of covering of the liquid surface with foam.

Values of coefficients C_1, C_2, C_3, C_4 are presented in Table 1.

Table 1. Values of coefficients C_1, C_2, C_3, C_4

Coefficient	Non-activated exhauster		Activated exhauster	
	One-sided	Two-sided	One-sided	Two-sided
C_1	1.8	1	1	0.7
C_2	1.2	1.2	1	1
C_3	0.75	0.75	1	1
C_4	0.5	0.5	1	1

It is evident from (1) that air flow rate mainly depends on temperature difference between evaporating liquid and air. Solutions used for most electroplating processes usually have a temperature of about 80ºC. In such a case C_t coefficient can be designated as C_{t80}, its value is 1.942. If electroplating process is not in progress, we can accept that temperature of the liquid equal to the temperature of environmental air (20ºC). In such a case $\Delta T = 0$ and $C_{t20} = 1$. This means that about two times less air flow rate is required if the temperature of the solution is equal to the temperature of ambient air as compared with solution heated up to 80ºC temperature.
Let's designate ratio of air flow rates as n. Then:

$$n = \frac{Q_1}{Q_2} . \quad (2)$$

where Q_1 is the air flow rate at working temperature of the solution; Q_2 is air flow rate at 20ºC temperature of the solution.

n is also called ejection coefficient. It can be seen from (2) that while initial temperature of solution increases, ejection coefficient increases too, ejected air flow rate or ejection also increase. Graph of dependence of ejection coefficient on temperature of solution is presented in Figure 3.

4. RESULTS OF EXPERIMENTS

Exhaust ducts of two lines of electroplating baths were connected as shown in Figure 1. If the both plating lines are in progress, two fans run at the same time to remove polluted air from surface of the liquid. If the cycle time of one line is greater than cycle time of the other line or one line is stopped, fan connected to the working line continues to run, second is stopped. Polluted air is removed from disconnected line due to the air ejection process only. This reduces electric energy consumption.
Removal air flow rates were measured at measuring points 1, 2 and 3 (Figure 1) during experiments. Fan of the 2nd branch of the pipeline (Figure 1) was run only. Results of experiments are presented in Figure 4.

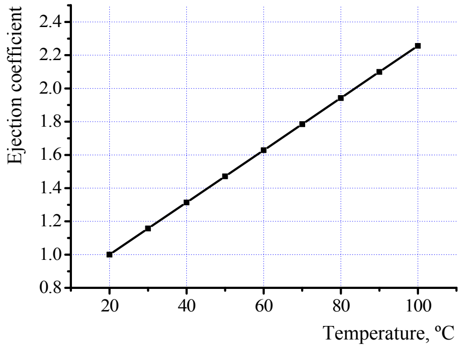

Figure 3. Ratio of air flow rates as function of the electroplating solution temperature

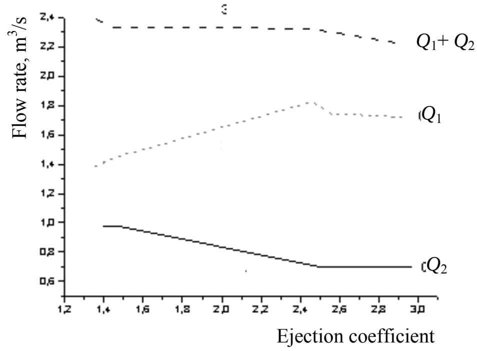

Figure 4. Air flow rate as function of ejection coefficient: Q_1 – rate of air flow created by fan; Q_2 – rate of ejected air flow; $Q_1 + Q_2$ – total air flow rate

5. CONCLUSIONS

In accordance with the results of experiments we may draw the following conclusions:

- It is established that flow rate of ejected air increases with increase of initial temperature of the solution.
- It is established that flow rate Q_1 of removal air increases with increase of ejection coefficient, Q_2 flow rate appears due to the ejection process.
- Total flow rate ($Q_1 + Q_2$) when only one fan is running significantly increases.

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