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AIR POLLUTION CONTROL IN COTTONSEED OIL INDUSTRY

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Executive Summary

The purpose of the project of the third year was development and assembling of a new experimental installation in Technion (Israel) to study the parameters that influence the pressure drop and a wide range velocity in airflow through a packed bed of cottonseeds, both bare and fuzzy. The new experimental set-up included essentially more powerful blower, a modern tool for accurate regulation of air velocities in the experimental installation, a cottonseed packed bed filter connected to the ducts, pressure transducers connected to computer with data acquisition software. The parameters varied during the experiments were the kind and the thickness of the packed cottonseeds, and the flow rate of the air. The measured data showed that pressure drop increases with increasing airflow rate, fuzziness of the cottonseed particles and thickness of the bed layer. An equation that relates the pressure drop to the airflow rate was proposed basing on the Ergun equation and coefficients that were obtained by regression analysis. Graphs plotted in accordance with this correlation equation compared favorably with most of the measured data.

A joint paper with Uzbekistan collaborators "Airflow through Granular Beds packed with Cottonseeds" based on the mentioned study was submitted for publication in scientific journal "Biosystem Engineering".

Israeli and Uzbekistan collaborators developed and designed a pilot set-up in Preparation workshop at Cottonseed Oil Mill in Uzbekistan for study of air-cleaning properties of cottonseed packed bed filters. Drawings of experimental installation were developed and preliminary works were performed. The experimental investigation using this set-up will be accomplished during the forth year of the Project. Theoretical investigation of the cottonseed packed filters was carried out for optimization of its design, for analysis of the mechanism of cotton dust removal by layer packed by cottonseed hulls and cotton seeds. Mathematical model of the mentioned process was developed in Uzbekistan.

Section I

A) **Research Objectives:** The purpose of this study is to obtain general expression for prediction of pressure drop across beds due to resistance caused by the presence of cottonseed particles in the layer, to analyze the mechanism of cotton dust removal by layer packed by cottonseed hulls and cotton seeds.

B) **Research Accomplishments:**

Research Performed in Israel

The values of the pressure drop due to the airflow through beds filled by fuzzy and bare cottonseeds obtained in experimental study are presented in *Fig. 1.* The method and procedure were described in the Annual Report for previous year of this Project.

The airflow rate per unit of filter surface perpendicular to the air stream flow, i.e., the average air velocity was varied from 0.025 ($m^3 s^{-1}$) m^{-2} to 0.22 ($m^3 s^{-1}$) m^{-2} or 0.025 m s^{-1} to 0.22 m s^{-1}. As the flow rate of air increased, the pressure drop across the filter increased for all of the particles tested. As the airflow rate increased from about 0.025 ($m^3 s^{-1}$) m^{-2} to 0.22 ($m^3 s^{-1}$) m^{-2}, the pressure drop increased from about 14 to 85 Pa for the fuzzy and to 74 Pa for bare 50 mm thickness beds. However, as seen from *Fig.3,* the pressure drop for both the 100 and 150 mm thickness fuzzy cottonseed beds considerably exceeds the pressure drop for the fuzzy 50 mm thickness cottonseed bed, with pressure drops from 15 to 182 Pa and from 20 to 257 Pa respectively.

The measured pressure drop in the 100 and 150 mm fuzzy cottonseed beds considerably exceeds the pressure drop measured in the bare cottonseed beds of the same thickness. The pressure drop increased from approximately 15 to 182 Pa in the 100 mm fuzzy cottonseed bed, and from 13 to 159 Pa in the 100 mm bare cottonseed bed, as the air flow rate increased from about 0.025 ($m^3 s^{-1}$) m^{-2} to 0.22 ($m^3 s^{-1}$) m^{-2}. As the flow rate of air increased the pressure drop

increased from about 20 to 257 Pa in 150 mm fuzzy cottonseed bed, and from 20 to 219 Pa in 150 mm bare cottonseed bed.

Increasing of the thickness of the both fuzzy and bare cottonseed bed from 50 to 100 to 150 mm leads to a relatively even increase in the pressure drop due to the airflow through the bed.

To develop expressions that needed to predict pressure drop across beds due to the resistance caused by the presence of the particles we based on equation (1) proposed by Carman and equation (2) proposed by Ergun.

Carman found that when $R_1 / \rho u_1^2$ was plotted against Re_1 using logarithmic coordinates, his data for the flow through randomly packed bed of solid particles could be correlated approximately by a single curve, whose general equation was:

$$\frac{R_1}{\rho u_1^2} = a\,\mathrm{Re}_1^b + c\,\mathrm{Re}_1^d \qquad (1)$$

Ergun has obtained a good semi-empirical correlation for pressure drop as follows:

$$\frac{R_1}{\rho u_1^2} = a\,\mathrm{Re}_1^{-b} + c \qquad (2)$$

The calculations to obtain the best-fit coefficients and the corresponding plots were carried out using Microsoft Excel; numerical values for the coefficients where $c=0$ are given in the Table 1.

The Table shows the coefficient a had values 22.72, 45.13 and 50.06 for bare seed fillers, and 44.07, 55.0 and 58.0 for fuzzy seeds, were thickness of the fillers changed from 50 to 100 and 150 mm correspondingly. The values of coefficient a for fuzzy seeds exceed values of coefficient a of bare seeds for beds with the same thickness. The possible reasons for this behavior was the presence of short fibers adhered to the cottonseed hull, called as cottonseed fuzziness. Moreover, the difference between the coefficients obtained in our research and the coefficients given by

equation (18) and (19) is probably due to the unusual morphology and surface character of the filler particles, including the fuzziness of the cotton seeds in comparison to the smoother and much more spherical shape of the particles used by other investigators. The peculiarity of the shape and surface characteristics of the cottonseed particles also leads to differences in the values of their drag coefficient (Tabak and Wolf, 1998).

Calculated values of coefficient *b* were found to vary from -1.11 to -0.91 for studied different cottonseed beds. The values of coefficient *b* were very close to the value of -1 obtained by Carman, Kozeny and Ergun using the analogy between streamline flow through a tube and streamline flow through the pores in a bed of particles.

Graphs plotted in accordance with equation (2) using the coefficients given in Table 1 compared favorably with most of the measured data for both fuzzy and bare cottonseed filter beds. *R*-squared values varied from 0.9672 to 0.9979.

Table 1: Coefficients of Equation (21) based on the experimental data.

Coefficients	Thickness of bare cottonseed filler, mm			Thickness of fuzzy cottonseed filler, mm		
	50	100	150	50	100	150
a	22.72	45.13	50.06	44.07	55.0	58.0
b	-1.07	-0.99	-1.0	-1.11	-0.91	-1.0
R-squared value	0.9959	0.9917	0.9971	0.9979	0.9702	0.9672

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Research Performed in Uzbekistan:

1. The theoretical study of a bed filter packed with cottonseeds was carried out. For development of a mathematical model of the process the mechanism of cotton dust removal by the layer of a granular material (hulls of seeds or cottonseeds) was analyzed and the physical model of the filter performance was assumed. Then, on the basis of the material balance equation and equation of kinetics of a filtration process the mathematical model of the bulk filter was performed. Taking into account of two parameters: the constant of adhesion speed and constant that describes equilibrium for the given initial dust concentration, the proper equations of bed filter functioning were obtained. The given equations were used for assessment of design characteristics of the pilot plant at workshop of Cottonseed Oil Mills in Uzbekistan.

2. Design of Pilot Plant

Drawings of the Pilot Plant that will be placed in Preparation workshop of Cottonseed Oil Mill in Uzbekistan were accomplished. The pilot plant includes an aspiration hood above shakers. The hood is equipped with bed filters included in parallelepiped spaced frame constructed with an angle bar. The cross-section of the two opposite sides of the frame exposed to the direction of airflow covered by grids. The experimental rig included the following elements: the granular bed filter filled with cottonseed, a contractor after the filter, a fan, ducts, and a damper. The filter has a width of variable value, which could be changed from 50 to 150 mm.

C) SCIENTIFIC Impact of Collaboration: The collaborating scientists of Uzbekistan have been familiarized with methods and procedures of experimental and theoretical study of granular bed filters. The Israeli collaborators participated in planning and design of pilot plant that will be placed in Preparation workshop of Cottonseed Oil Mill in Uzbekistan. This pilot plant will be built for study of air-cleaning properties of cottonseed packed bed filters. Both the experimental installations in Technion (HAIFA) and in Tashkent (Uzbekistan) were accomplished according to

the Project workplan. Accomplishing of mentioned experiments promoted for Uzbekistan collaborators to get a scientific experience in research and solution of air cleaning problems. The Uzbekistan collaborators are using the acquired experience and knowledge in scientist research and in teaching of students. TECHNION on behalf of Dr. Semion Tabak permanently rendered the advisory help in development of physical and mathematical models of performance of the bed filter, in drawings of experimental installations and solution of current problems.

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D) Description of Project Impact: The results of the research are anticipated to use in development of local exhaust ventilation systems. The acquired knowledge is expected to apply in development of aspiration and dilution ventilation systems for hulling-separation departments at Cottonseed Oil Mills. The obtained in measurements data we used for estimating the potential occupational exposure to cotton dust of workers in the hulling–separation rooms of cottonseed oil mills.

An impact was rendered in methods of air contamination control in industrial workshops with scientific and practical aims. The acquired knowledge and experience will be very useful in implementation of air pollution control in industrial, civil and agricultural buildings in Uzbekistan.

The results of the project were used in teaching process, in training of students in methods of physical and mathematical modeling of dust catching processes in bed filters.

E) Strengthening of Developing Country Institutions: Researches of Tashkent Architectural Building Institute purchased modern computer including accompanying tools like printer, scanner, etc. It makes possible to intensify the scientist research and teaching processes.

Numerical solutions of filtration problems, drawings of experimental installations, etc. were performed using the purchased computer and accompanied tools

Uzbekistan collaborators have built an experimental installation with bed filters packed by cottonseeds, used in scientist research and teaching targets.

F) Future Work: As some delay of the Project schedule we asked of Project authorities and got the extension for additional one year. During the forth year we will accomplish construction of the Pilot Plant of local exhaust ventilation system in preparation department at Cottonseed Oil Mill in Uzbekistan and perform the experiments on this pilot plant.

Section II

Managerial Issues:

1. Due to a number of problems like supplying of cottonseeds to Cottonseed Oil Mill in proper periods during a year with correspondingly periods of Oil Mill functioning, like repairing of the technological equipment, etc, occurred a delay in the Project schedule. For accomplishing the Project workplan we asked and got a permission of Project authorities for extension of the Project schedule for one additional year.

2. It took a proper time to get a special permission of Cottonseed Oil Mill authorities for installation of the Pilot Plant and performance of the experiments.

B) Budget: Not Applicable.

C) Special Concerns: Not Applicable.

D) Collaboration, Travel, Training and Publications:

Dr. S. Tabak visited Prof. Robert Pfeffer in New Jersey Institute of Technology and got help in analyzing of the research data and arrangements of future experimental and theoretical study.

We wish to thank Prof. Robert Pfeffer of the New Jersey Institute of Technology, Newark, NJ for many insightful technical discussions during the progress of this research.

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E) Request for American Embassy Tel Aviv or A.I.D. Actions. All is OK.

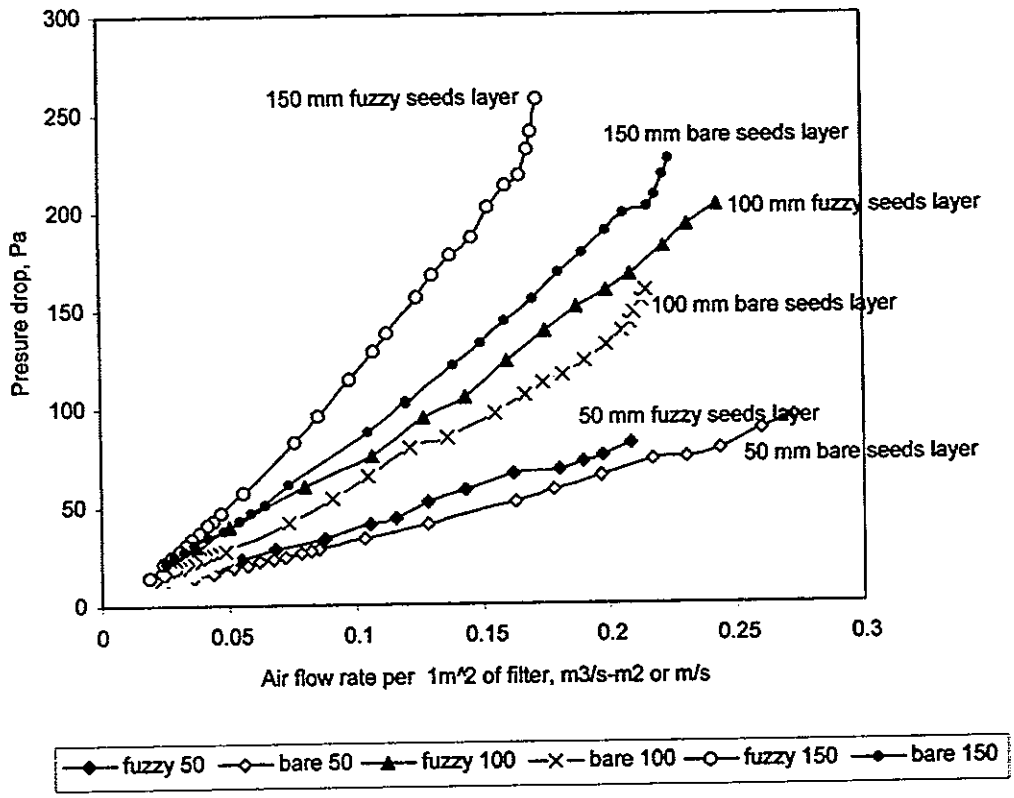

Fig. 1. Pressure drop as a function of the air flow rate through bed of fuzzy and bare cottonseed particles of different layer thickness 50, 100 and 150 mm.