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PIOTR KABSCH*, HENRYK MELOCH*, KRZYSZTOF KACZMARSKI*

NEW WET SEPARATOR OF AIRBORNE OIL-MIST DROPLETS

The type of separator described below works under industrial conditions and is a prototype unit equipped with an injection contactor to remove oil-mist droplets from the air flux leaving the casing of a spinner. The efficiency of separation has been measured by making use of a novel system which enables continuous recording of highly variable oil-mist droplet concentrations in the air flux entering and leaving the separator. The data obtained in this study give a good support to the possibility of applying and designing a typoseries of oil-mist droplet separators.

1. INTRODUCTION

Results of laboratory tests [1], [2] have revealed that a wet method may be effective (not only in a physical, but also in a technological sense) when applied for the separation of airborne oil-mist droplets entering the ambient air in the course of mechanical work. Moreover, the experimental data made it possible to determine the range of application, taking into account the type and volume of gases to be treated, the source of generation, the available local treatment systems and, last but not least, the power demand problem [2]. One question, however, has not been answered yet, namely, whether the proposed treatment method will be equally effective when scaled up to work under actual industrial conditions. Aerosol models involved in laboratory testing fail to give an adequate representation of actual aerosols. Thus, laboratory data are insufficient to provide full information on the efficiency of the method, which is a prerequisite to start any industrial-scale application.

Taking all this into account it seemed advisable to design a prototype separator and make it work under actual conditions. The prototype system was placed in an industrial plant to separate oil-mist droplets from the aerosol flux released by a machine tool, working in a normal manufacturing cycle.

* Institute of Environment Protection Engineering, Technical University of Wrocław, pl. Grunwaldzki 9, 50-377 Wrocław, Poland.

2. EXPERIMENTAL SEPARATOR

The experimental separator was designed very carefully to enable immediate industrial application (and lot production). It consisted of some parts commonly found in a commercial vacuum cleaner (blowing fan with power transmission, supporting structure and casing). Only the dust collecting part (i.e., the filter bag) was replaced by an injection contactor which had been tested under laboratory conditions [2].

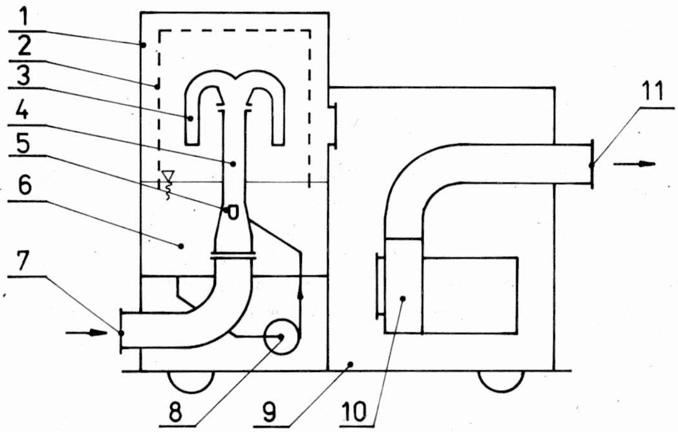

Fig. 1. Prototype separator

1 – housing, *2* – droplet separator, *3* – guide ring, *4* – throat, *5* – nozzle, *6* – tank for working liquid, *7* – inflow of polluted air, *8* – pump, *9* – movable supporting structure, *10* – blower and drive, *11* – outflow of purified air

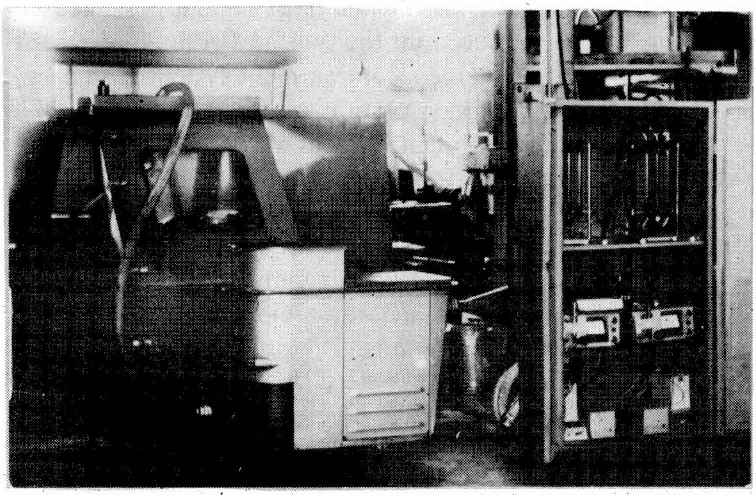

Fig. 2. Separator placed in the immediate vicinity of an actual spinner

The prototype separator is shown in fig. 1 (schematic diagram) and fig. 2 (photograph). The system has been placed in the immediate vicinity of an actual spinner (operated in a mechanical working department) and connected to a measuring device. The efficiency of the separator amounted to 400 m^3 air /h. To ensure the structural compactness desired, the inflow to the working nozzle of the separator was aided by a pump, which enabled spray intensities to approach 6×10^{-3} m^3 liquid/m^3 air. In this way, the fluid level has been decreased, thus enabling a substantial reduction of the vertical dimensions of the separator.

3. EXPERIMENTAL SYSTEM AND METHODS

The experimental system is presented in fig. 3. Air containing oil-mist droplets is drawn from the casing of the spinner *1* and sent to the separator *3* through a pipeline *2*. After the oil-mist droplets having been separated, the air flux is passed through another pipeline *4* to enter the atmosphere.

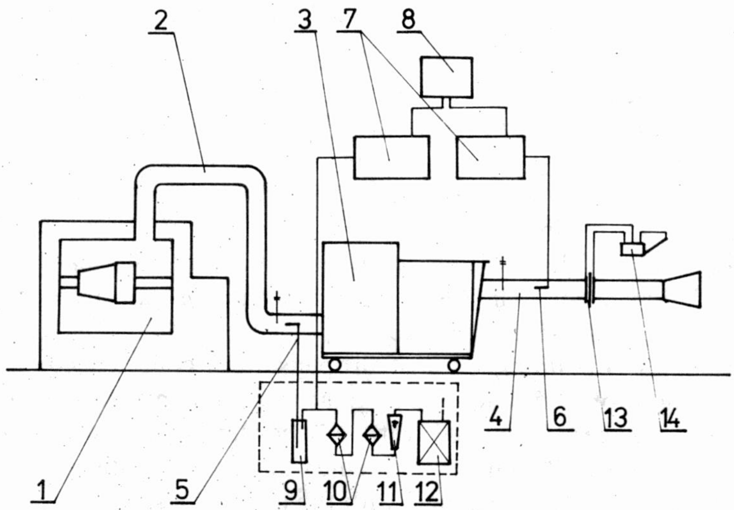

Fig. 3. Experimental system (explanation in the text)

The concentration of oil-mist droplets in the aerosol drawn from the casing of a machine tool depends on a number of factors, namely, the kind, stage and desired degree of machining, the type of the cooling medium, the intensity of cooling, and the degree of air-tight sealing. No wonder that oil-mist droplet concentration undergoes substantial fluctuations and may vary in a wide range from very low to very high values. The available laboratory measuring devices and techniques [1] failed to be workable under actual conditions; so it was necessary to develop a unique measuring system in order to meet the requirements of an industrial environment.

Influent and effluent oil-mist droplet concentrations were measured by a nephelometric method which had been tested under laboratory conditions. An electric signal coming from the photocell (which was to measure the flux of light

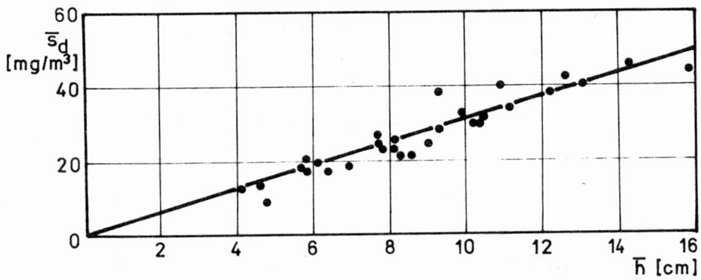

Fig. 4. Standardization curve (explanation in the text)

scattered on the oil-mist particles) was passed to an analogue meter with a small lag of indication. Two identical flumes – one before, and one after passing through the separator – were used to measure the influent and effluent concentrations. Owing to a simultaneous action, the flumes were able to indicate actual values of the highly variable separation efficiency. This two-flume recorder made it possible to determine influent and effluent concentrations by making use of the same time base.

The measuring system involved a SPECOL 10 with a FR unit (widely applied in laboratory practice), which had been equipped with a special pick-up, designed by the authors of this paper. The two nephelometric systems were coupled to a high-speed two-flume KB-5504 recorder.

Aerosol samples containing oil-mist droplets were collected continuously and isokineticly, using probes *5* and *6*, and placed in the measuring system which consisted of two gauges *7* coupled with a recorder *8*. Before receiving aerosol samples, the system was "cleaned" by removing a coarse dispersion mist (of a fragmentation "invisible" for the gauge) with the use of the separator *9*. The quantity of the mist to be removed was determined gravimetrically.

All of the indications were calibrated by the gravimetric method, using a measuring device which consisted of two unwovenfabric filters *10*, a rotameter *11*, and a suction pump *12*. In the course of calibratiom, oil-mist droplet concentration was measured on the filter *10*, and the indications of gauge *7* were recorded on the tape *8*. The time of aerosol filtration was identical to the time of indication recording. The time plots of the concentration values were integrated graphically to calculate the mean height of indications equivalent to the mean concentration of oil-mist droplets determined gravimetrically. The results of calibration are given in fig. 4. As shown by these data, the system is fit for measuring a wide range of airborne oil-mist droplet concentration, because there is a strong linear correlation between the indications of calibrated devices and the reference values. Hence

$$\bar{s}_d = 3.106 \times \bar{h} - 0.253 \tag{1}$$

where $\bar{s}_d$ is the average concentration of fine-dispersion oil-mist droplets in atmospheric air determined gravimetrically, and $\bar{h}$ is the average height of indication.

For the correlation obtained via this route, the coefficient of determination and the coefficient of correlation amounted to 0.966 and 0.983, respectively, the standard deviation being 2.87 mg/m³.

The rate of air flux through the separator was measured by the Venturi-tube method. The measuring orifice plate *13* with pressure pulse reception in the immediate vicinity of the disk was coupled to a micromanometer *14*.

4. MEASURED RESULTS AND THEIR INTERPRETATION

The oil-mist droplets under study were generated during heavy spinning which involved stainless steel, the machine oils 10 and 20 being the cooling medium.

The spinning process for a single detail lasted from ~ 120 s to 244 s, depending on the intensity of working. Thus, the shorter the time of spinning, the greater were the thermal effect and the oil-mist lift. Oil-mist lift depended on one more factor – the intensity of the cooling process. Lower rates of coolant flow brought about a more intensive lift of fine-dispersion oil-mist droplets.

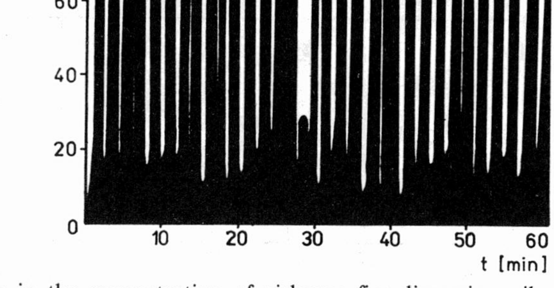

Fig. 5. Variation in the concentration of airborne fine-dispersion oil-mist droplets s_d at the inlet to the separator

t – duration of recording

It is well-known that the work arbor, the detail under working and the spinning rolls experience rotary motion in the course of the spinning process. As a result, the coolant flowing to the working spot not only evaporates and condenses, but also gives rise to oil-mist particles, which are referred to as coarse-dispersion oil-mist droplets. No significant correlation was found to occur between fine-dispersion and coarse-dispersion oil-mist droplets entrained in the aerosol which was drawn from the casing of the spinner.

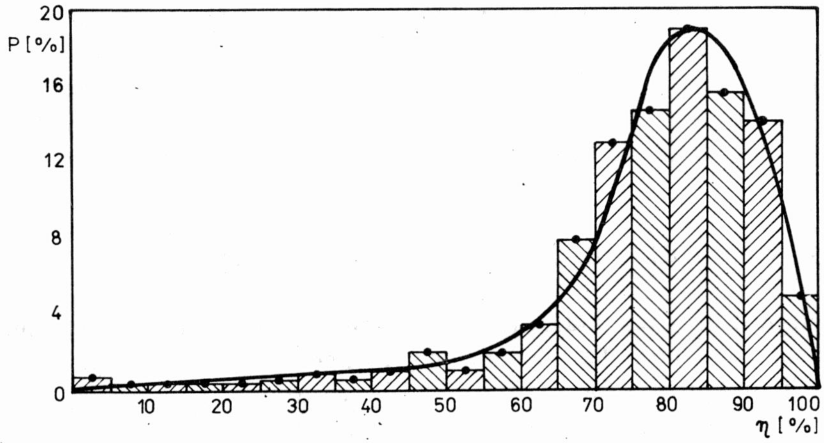

Fig. 6. Probability P of occurrence for various actual efficiencies of fine-dispersion oil-mist droplet separation η

Being independent of the temperature of the working surface, the concentration of coarse-dispersion oil-mist varied only slightly in the course of a single detail spinning cycle. It ranged from 3.5 to 6.5 g/m^3, depending on the quantity of the cooling agent used. The quantity and concentration of oil-mist droplets of fine-dispersion (condensation) were highly variable, ranging between 0 and 140 mg/m^3 in batch samples. This variability is shown in fig. 5.

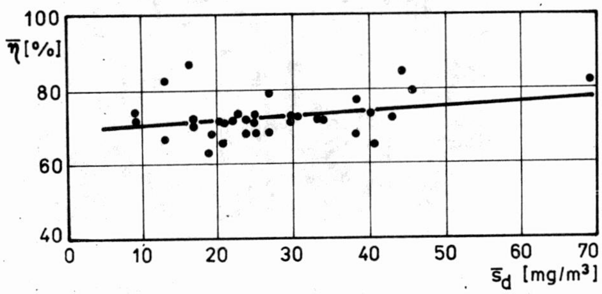

Fig. 7. Average efficiency of fine-dispersion oil-mist droplet separation $\bar{\eta}$ as a function of fine-dispersion oil-mist droplet concentration $\bar{s}_d$ in the aerosol entering the separator

Total efficiency of separation (fine-dispersion + coarse-dispersion oil-mist droplets) was found to be very high. It varied between 99.76 and 99.93%, and remained practically constant, irrespective of the process conditions involved.

The efficiency of separation of fine-dispersion oil-mist droplets measured at short time intervals (corresponding to individual cycles of mechanical working) was highly variable ranging from about 50 to 99.9%. The probability density distribution is given in fig. 6. As shown there, the maximum probability of this distribution coincides with the instantaneous separation efficiency value of approximately 83%. The average separation efficiency values vary between 65.3 and 87.0%, depending on the average fine-dispersion oil-mist droplet concentration in the aerosol entering the separator (fig. 7).

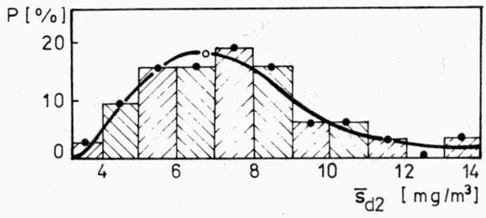

Fig. 8. Probability density distribution P for the occurrence of various average oil-mist droplet concentrations $\bar{s}_{d2}$ in the air leaving the separator

It should be pointed out that the average concentrations measured at 1-h intervals in the air flux leaving the separator ranged only between 3.5 and 13.9 mg/m^3. The probability of occurrence for these concentrations follows a log-normal distribution (fig. 8). The maximum probability corresponds with the average effluent concentration which is slightly lower than 7 mg/m^3.

5. SUMMARIZING COMMENTS

The investigations on the new method of separating airborne oil-mist droplets (entrained in the aerosol leaving the casings of machine tools) by using an injection contactor of an original design proved fruitful. Total efficiency of separation was higher than 99.7%, whereas that of fine-dispersion mist droplets amounted to 87%. The prototype separator was tested under industrial conditions for six months, and its operational reliability was confirmed. Routine maintenance is quite simple; it consists of switching on and off the aggregate and changing the working liquid (which has the consistency of a concentrated water/oil emulsion at the final stage of operation). Owing to the extraordinary turbulence of the contacting phases, the separator enables generation of high-quality emulsions, which remain homogeneous and stable even if the oil involved is a weak water-emulsifying agent. These high-quality emulsions, a by-product of the separation processes, may be reused as coolants in the process of mechanical working.

The prototype investigations have also shown that the separator may work with equal success when associated with a single machine tool. Moreover, the separator can be scaled up to an arbitrary efficiency by increasing one of the dimensions of the throat cross-section.

Owing to such a modification of design, the efficiency of the separator increases, but the separation process does not change at all; so the results of laboratory-scale [1], [2] or semi-commercial-scale investigations (like those reported in this paper) remain valid and may be a reliable starting point for the design of full-scale installations.

Separators of an efficiency amounting to 2000 m^3 of air per hour may work for single machine tools. Separators displaying efficiencies greater than 2000 m^3/h are fit for oil-mist droplet separation from aerosols leaving the casings of several machine tools which form together a machine group. It seems advisable to design typoseries of separators of 2000 to 10,000 m^3/h capacity for small machine groups involving high air-tight sealing working processes and, also separators of 10,000 to 60,000 m^3/h capacity for large machine groups. It might be interesting to apply such typoseries to the separation of oil-mist droplets produced, e.g., during rolling and quenching.

REFERENCES

[1] Kabsch P., Kaczmarski K., Meloch H., Env. Prot. Eng., Vol. 10 (1984), No. 2, pp. 47–56.
[2] Kabsch P., Kaczmarski K., Meloch H., Env. Prot. Eng., Vol. 13 (1987), No. 1.

PROTOTYPOWY SEPARATOR MGŁY OLEJOWEJ

W warunkach przemysłowych badano prototypowy separator mgły olejowej, wyposażony w iniekcyjny kontaktor, którego zadaniem jest separacja mgły olejowej z powietrza odciąganego od obudowy wyoblarki. Zmierzono skuteczność odemglania za pomocą nowego układu do ciągłych pomiarów i rejestracji szybko zmieniających się stężeń mgły w powietrzu kierowanym do separatora i w powietrzu oczyszczonym. Na podstawie otrzymanych wyników przedstawiono możliwości zaprojektowania typoszeregu separatorów i ich zastosowania.

ПЕРВООБРАЗНЫЙ РАЗДЕЛИТЕЛЬ МАСЛЯНОГО ТУМАНА

В промышленных условиях исследован первообразный разделитель масляного тумана, снабжён инъекционным контактором, задачей которого является отделение масляного тумана от воздуха оттягиваемого от корпуса давильного станка. Измерена чувствительность обестуманивания при помощи новой системы к беспрерывным измерениям и записи быстро изменяющихся концентраций тумана в воздухе, направляемом к отделению и чистом. На основе полученных результатов представлены возможности проектирования типоряда отделителей и их применения.