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SEPARATION OF OIL-MIST DROPLETS IN AN INJECTOR CONTACTOR

PART II. POSSIBLE APPLICATIONS OF INJECTION CONTACTORS – LABORATORY TESTING

Laboratory experiments were run with a model contactor. The efficiency of oil-mist droplets separation was investigated as a function of design parameters and parameters of motion. The effect of these parameters on the resistance of flow was also studied. Consideration was given to the possible application of injection contactors for separating oil-mist droplets entrained in the aerosol drawn off from machine tools.

1. PROGRAMME OF LABORATORY INVESTIGATIONS

The objective was to determine the most advantageous design parameters as well as the parameters of motion for an injection contactor when applied to the separation of airborne oil-mist droplets. The authors of this paper constructed a contactor model and modified some major elements (fig. 1). These modifications (referred to as variants I to IV) made it possible to apply different methods of breaking the working liquid into droplets and to create different forms of contact between the working liquid and gas to be treated. Thus, variant I involved the supply of working liquid to a throat through openings in the wall. In variant II the supply of working liquid was additionally provided through an axially arranged, slotted nozzle. Variant III made use of a long throat and a long diffuser. In variant IV both the throat and the diffuser were short. Variant III and variant IV involved the supply of working liquid only through the slotted nozzle which had been placed in the contactor axis. Gas flow velocity in the contactor throat varied from 48.7 to

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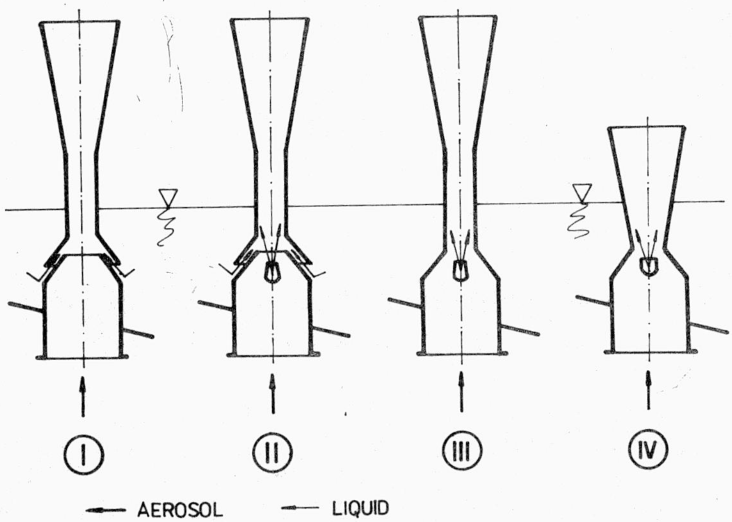

Fig. 1. Design of the injection contactor: variants I to IV

91.4 m/s, whereas the sprinkling rate ranged between 0.3 and 8.0 dm^3 of working liquid per cubic meter of air. Water or oil/water emulsion (with ES oil) were used as working liquids. Emulsions of that kind are often applied as coolants in mechanical working.

The replacement of some structural elements in the contactor on one hand, and the variation of gas flow velocity and sprinkling rate on the other hand, made it possible to achieve a wide range of variability for the hydrodynamic conditions of the filtering system. In our case this means a wide spectrum of variability in the hydrodynamic conditions of the liquid broken into droplets. In this way, various conditions of collision between the working liquid droplets and oil-mist droplets as well as various possibilities of condensation have been achieved. Changing the nature of the working liquid accounts for the change in the rate of fixation with oil-mist droplets.

Laboratory investigations involved oil-mist droplets of submicron condensation as the medium to be separated. As this aerosol displays a much greater degree of dispersion than actual industrial aerosols do, we were able to show how the design parameters and the parameters of motion may affect the separation efficiency. Airborne oil-mist droplets entering the contactor had a constant concentration of 150 mg/m^3.

The method of generating oil-mist droplets, the laboratory system for investigating the contactor model, as well as the testing methods were described in the first part of the study [1].

2. RESULTS AND INTERPRETATION

Laboratory tests gave a large set of data which were reported earlier [2]. The most characteristic results are plotted in figs. 2–7.

On analyzing the hydrodynamic properties of the contactor (fig. 2.), it became obvious that the sprinkling rate may be very high, approaching 8 dm³/m³. As the droplets of the working liquid are relatively large in size (which should be attributed to the method of injection–spraying in the contactors), the saturation of the filtering layer as well as the high relative velocities of liquid droplets and dispersed phase of the aerosol are prerequisites to ensure high separation efficiencies. A considerable disadvantage encountered here is the quite high flow resistance which varies from 7 to 8 kPa at gas velocities in the throat between 70 and 90 m/s. It has been found that the resistances occurring in the zone of injection–spraying account for 85 to 90% of the overall hydraulic resistance in the contactor. Of the investigated systems, variant IV seems to provide the most favourable energetic conditions – a high sprinkling rate (2–8 dm³/m³) at relatively low gas velocity and flow resistances (3–7.5 kPa). Variant I and II provide similar conditions at higher flow resistances (3.7–8 kPa). Variant III has the limitation of giving a rapid rise in flow resistance with increasing velocity and rate of sprinkling. Attempts to achieve sprinkling rates higher than 4.5 dm³/m³ have failed.

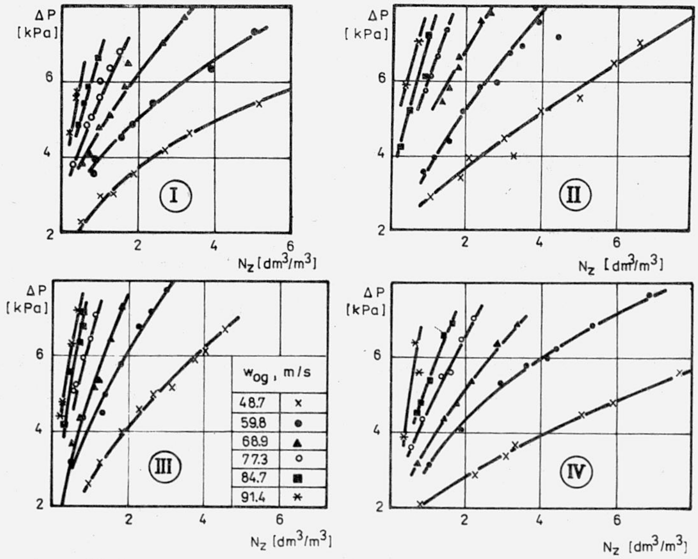

Fig. 2. Pressure drop ΔP in air flux treated in the contactor versus rate of working liquid sprinkling N_z and velocity of air flow in the contactor throat w_{og} for variants I to IV involving water as the working liquid

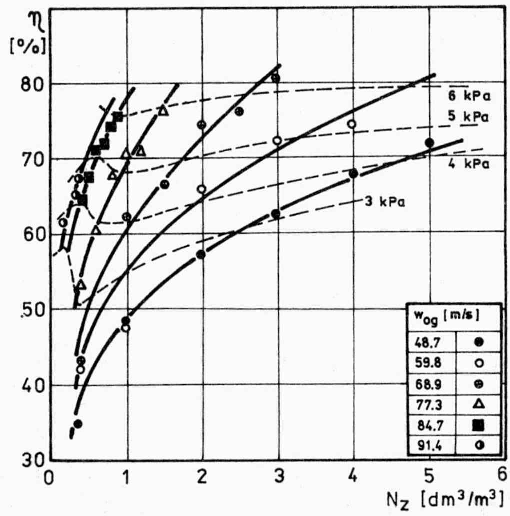

Fig. 3. Efficiency of oil-mist droplet separation η in the contactor versus rate of working liquid sprinkling N_z and velocity of air flow in the contactor throat w_{og} for variant I involving water as the working liquid

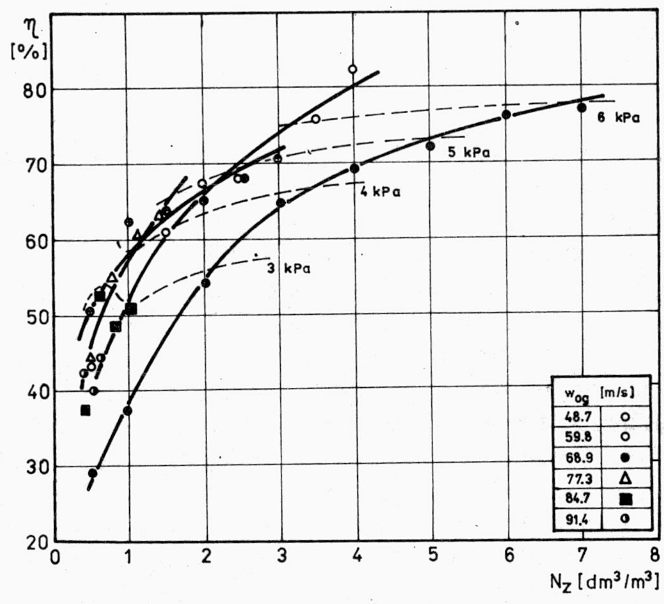

Fig. 4. Efficiency of oil-mist droplet separation η in the contactor versus rate of working liquid sprinkling N_z and velocity of air flow in the contactor throat w_{og} for variant II involving water as the working liquid

Figures 3–6 show the efficiencies of oil-mist droplet removal (separation efficiencies). The separation efficiency is defined as $\eta = (C_1 - C_2)/C_1$ where C_1 denotes the oil-mist droplet concentration in the air flux entering the contactor, and C_2 indicates the oil-mist droplet concentration in the air flux leaving the contactor. The experiments involved water as the working liquid, and a temperature of 773 K

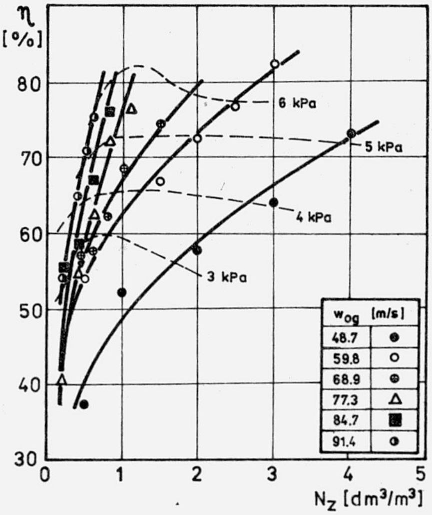

Fig. 5. Efficiency of oil-mist droplet separation η in the contactor versus rate of working liquid sprinkling N_z and velocity of air flow in the contactor throat w_{og} for variant III involving water as the working liquid

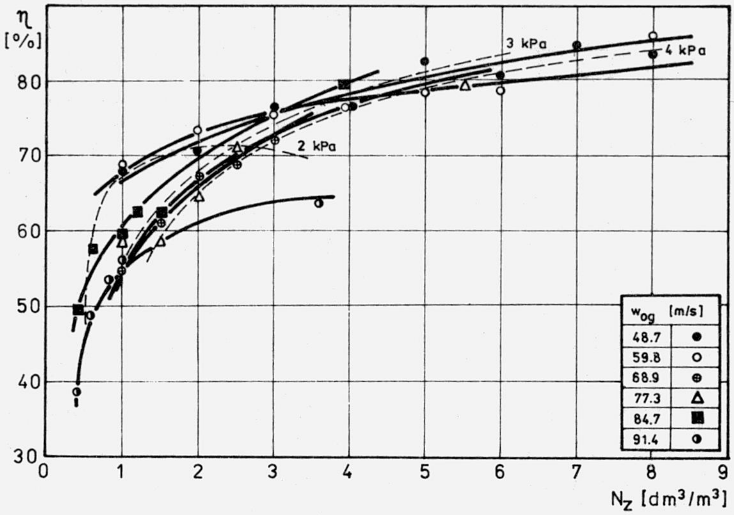

Fig. 6. Efficiency of oil-mist droplet separation η in the contactor versus rate of working liquid sprinkling N_z and velocity of air flow in the contactor throat w_{og} for variant IV involving water as the working liquid

for the generation of oil-mist droplets. Variant I and variant II failed to yield separation efficiencies higher than 80% despite the relatively high gas velocity (in the throat) and the high sprinkling rates applied (which was associated with the high flow resistance). The plot of $\eta = f(N_z, w_{og}, \Delta P)$ shows that the highest possible separation efficiencies for the two variants are achieved at gas velocities ranging from 50 to 70 m/s, and sprinkling rates falling between 2 and 5 dm^3/m^3. Variant III yielded separation efficiencies approaching 80% at lower gas velocities (60 m/s) and lower sprinkling rates (2–4 dm^3/m^3) than those of variant I and variant II (the flow resistances being almost identical).

Much better results were obtained when using variant IV. Gas velocities in the throat ranging from 50 to 70 m/s and flow resistances of up to 5.5 kPa made it possible to achieve sprinkling rates of 5 to 8 dm^3/m^3 and separation efficiencies of some 86%. The same variant was subject to experiments in which water had been replaced by the water–ES oil emulsion to act as the working liquid. When the emulsions of ES oil concentration of up to 0.02 vol. % are used, the separation efficiency increased by several percent (fig. 7). This brought about, however, a certain rise of gas flow resistance in the contactor. Further increase of oil concentration in the emulsion failed to increase the separation efficiency.

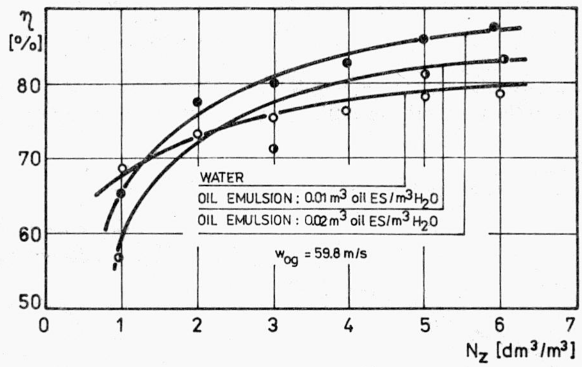

Fig. 7. Efficiency of oil-mist droplet separation η in the contactor versus type of working liquid for variant IV

3. RESULTS OF LABORATORY INVESTIGATIONS

Laboratory investigations made the following generalizations possible:

1. Injection contactors with an automatic circulation of the working liquid are fit for separating fine-dispersion submicron oil-mist droplets.

2. The separation efficiencies obtained under extremely unfavourable conditions (separation of condensation aerosol) are satisfactorily high to give grounds for hoping that the degree of separation for actual oil-mist droplets may be much higher.

3. The results obtained are comparable with those reported for electrical precipitators and filter separators (with a non-movable filtering layer).

4. Of the investigated contactor systems, the design involving axial supply of the working liquid through a slotted nozzle with a short throat and a diffuser enabled achieving the efficiencies of 86% and 88%, respectively, for water and oil/water emulsion, acting as the working liquid at flow resistances between 5.5 and 6.0 kPa.

4. POSSIBLE APPLICATIONS

Taking into account the data sets obtained during the study, attempts have been made to assess the usability of injection contactors when applied to the separation of oil-mist droplets entrained in the aerosol drawn off from machine tools. Consideration has been also given to the problem of whether the injection contactors may or may not be included in the technological system of air pollution control. Although the separation efficiency of the injection contactor is comparable with that of the electrostatic separator or of some filter separators, injection contactors have the inherent limitation of involving higher flow resistances than most of the filter separators do. The advantages of the injection contactor are as follows: simple design and operation, small dimensions as compared to the quantity of the air to be treated, operational reliability, and low capital cost.

The choice of an appropriate separator depends on a number of different factors (both economic and technical), e.g., the desired ambient air quality (in the immediate vicinity of the work-stand and in the plant), the size of the plant, the type of production, the cost and efficiency of oil-mist separation, economic potential of the plant, the type of the cooling agent used, the degree of air-tightness of the processes involved, recirculation of the air under treatment, etc.

The possible applications of injection contactors as separators of oil-mist droplets entrained in the aerosol drawn off from single machine-tool casings are limited. Injection contactors may be used here to the same extent and in the same way as "dry" filter separators or electric precipitators. Better possibilities are offered when the injection contactor is to be applied in a treatment system for the aerosol drawn from the technological seatings of several machine tools. Moreover, the choice of the treatment technology depends on whether the treated air is to be recirculated to the engine room or not. It so, preference should be given to filter separators or electric precipitators, because injection contactors require separation of the polluting gas phase present in the recirculated air. The gas phase owes its origin to the evaporation and thermal decomposition of the oil coolants applied in the machining process, and might be removed by absorption or adsorption.

Nevertheless, the removal of gas-phase pollutants by absorption calls for a careful choice of the absorbent in order to prevent secondary air pollution. On the other hand, adsorption on activated carbon may work quite well despite the high costs involved, but it has the inherent disadvantage that the oil-mist separation should be a "dry" process. Hence, the application of an injection contactor may bring about a rapid increase in the humidity of the treated air, contributing thus, to a serious drop in the capacity of the adsorption bed in relation to hydrocarbons.

Catalytic combustion (which is sometimes suggested as a process of the removal of gas-phase pollutants) does not seem to be recommendable for economic reasons (low temperature and low concentration of flammable substances).

Taking all these factors into account, it is advisable to abandon recirculation of air, and apply a one-stage treatment process, which includes separation of liquid-phase particles in the injection contactor (primarily, for the recovery of the cooling agent). After treatment, the air might be passed to the local boiler room to mix with the air which is normally used for the needs of combustion. The combustion of hydrocarbons via this route has the advantage of eliminating the nuisance of gaseous air pollutants influencing the immediate vicinity of the plant. The problem of how to compensate the heat loss, experienced by the machine-tool room in the heating season, may be solved by making use of the waste heat produced in the plant. The task itself should be easy to fulfil because mechanical work shops apply such technologies that are either part of the manufacturing process or are involved as aiding operations. All these operations (and particularly casting, forging, quenching or heat generation for the needs of a plant) produce large amounts of heat which is released together with flue gases.

Each of the oil-mist droplet separation methods, presented in this paper, involves high capital and operational costs. A maximum air-tightness of the machine tools is therefore a prerequisite to apply the injection contactor method on an industrial scale.

REFERENCES

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SEPARACJA MGŁY OLEJOWEJ W KONTAKTORZE INIEKCYJNYM CZĘŚĆ II. ZASTOSOWANIE KONTAKTORÓW INIEKCYJNYCH – TESTY LABORATORYJNE

Przedstawiono wyniki badań laboratoryjnych separacji mgły olejowej w modelowym kontaktorze. Zbadano wpływ parametrów konstrukcyjnych i ruchowych na skuteczność odemglania oraz opory przepływu. Przeanalizowano możliwości zastosowania kontaktorów iniekcyjnych do separacji mgły olejowej z powietrza odciąganego od obrabiarek.

СЕПАРАЦИЯ МАСЛЯНОГО ТУМАНА В ИНЪЕКЦИОННОМ КОНТАКТОРЕ ЧАСТЬ II. ПРИМЕНЕНИЕ ИНЪЕКЦИОННЫХ КОНТАКТОРОВ – ЛАБОРАТОРНЫЕ ТЕСТЫ

Представлены результаты лабораторных исследований сепарации масляного тумана в модельном контакторе. Исследовано влияние конструкционных и двигательных параметров на эффективность обестуманивания, а также сопротивления протекания. Проанализованы возможности применения инъекционных контакторов для сепарации масляного тумана из воздуха оттягиванного от станков.