Journal of Electrostatics 70 (2012) 117–125

Contents lists available at SciVerse ScienceDirect

Journal of Electrostatics

journal homepage: www.elsevier.com/locate/elstat

Improvement of filtration speed of charge injection type of electrostatic oil filter

H. Yanada [a,*], Y. Daiou [b], Y. Ogi [c]

[a] Department of Mechanical Engineering, Toyohashi University of Technology, 1-1, Hibarigaoka, Tempaku-cho, Toyohashi, Aichi 441-8580, Japan
[b] Tohkai Shipbuilding & Engineering CO., LTD. 2-2-12, Shirasuka, Yokkaichi, Mie 510-0018, Japan
[c] Department of Mechanical Engineering, Toyohashi University of Technology, 1-1, Hibarigaoka, Tempaku-cho, Toyohashi, Aichi 441-8580, Japan

ARTICLE INFO

Article history:
Received 18 June 2011
Received in revised form
7 November 2011
Accepted 25 November 2011
Available online 20 December 2011

Keywords:
Electrostatic filter
Charge injection
Lubricating oil
Oil saving
Ion drag

ABSTRACT

This paper deals with the effects of the configurations of electrodes and filter elements on the filtration speed of a charge injection type of electrostatic oil filter, which has been proposed by Yanada et al. It has been demonstrated that the filtration speed can be increased by injecting charges into oils. However, investigation into the effects of the configurations of the electrode and filter element has been limited. In this paper, several types of filter model with different configurations are proposed and their performance is experimentally investigated. A better filter configuration is proposed.

1. Introduction

Oil filtration is very important to maintain the condition of a machine. It is known that the majority of the failures of machines are caused by the contamination of lubricating oils and that the removal of contaminants including submicrometer-sized ones such as the oxidation products of additives from the oils is essential to reducing the failures of machines and to lengthening the life of oil [1]. Usual mechanical filters cannot remove submicrometer-sized contaminants, while electrostatic oil filters can remove them. However, the filtration speed of electrostatic oil filters is slow and it usually takes a long time for a contaminated oil to be purified.

Yanada et al. [2,3] have proposed a new type of electrostatic oil filter, named charge injection type of electrostatic oil filter. The filter uses a charge injection phenomenon [4] to augment quantity of the charges adsorbed on contaminant particles. It has been demonstrated that the filtration speed can be increased by charge injection [2]. In addition, it has been shown that an ion drag flow generated from the projection tips may detach part of the particles captured on the collector electrodes [3]. This indicates that the effect of the ion drag flow needs to be taken into consideration when designing a charge injection type of electrostatic oil filter.

Conductive contaminants such as metallic wear debris are not easily captured on the electrodes; therefore, filter element(s) has to be inserted between the emitter and collector electrodes to capture the conductive contaminants. The insertion of filter element also contributes to increasing the surface area to capture non-conductive contaminants. A charge injection type of electrostatic oil filter in which metallic filter elements are inserted has been proposed and the effects of the shape and position of the filter elements have been investigated using one type of filter configuration [5]. However, there may be many other possible configurations of the electrodes and filter elements.

In this paper, aiming at finding out a better configuration of the electrodes and filter elements, several filter models with different configurations are proposed and their filter performance is experimentally investigated.

2. Filtration principle

Solid particles in liquid are usually charged positive or negative due to the preferential adsorption of ions in liquid and the dissociation of dissociative groups on the particle surfaces [6]. Therefore, contaminants in oil are also charged. Charged contaminants in oil are attracted toward the electrodes or the filter element and are captured on them mainly by the action of the Coulomb force when a high DC voltage is applied to the electrodes. Contaminants cannot be removed from oil without applied voltage, except for a very

* Corresponding author. Tel.: +81 532 44 6668; fax: +81 532 44 6661.
E-mail address: yanada@me.tut.ac.jp (H. Yanada).

0304-3886/$ – see front matter © 2011 Elsevier B.V. All rights reserved.
doi:10.1016/j.elstat.2011.11.005

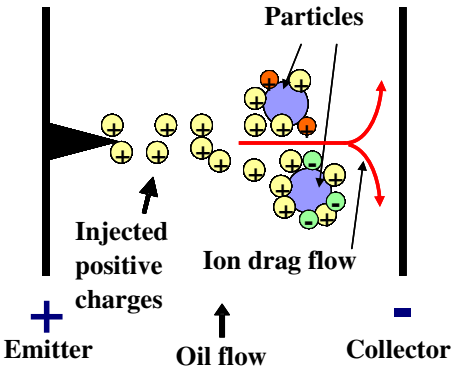

Fig. 1. Injection of positive charges.

small part of contaminants that are settled by gravity. The percentage of the particles' gravitational sedimentation during 1 h filtration experiment was 1.2 percent for the combination of Oil 1 and Kanto loam (see Section 4) and will be varied to some degree according to oil viscosity, the difference in specific gravity between particle and oil, particle size, etc.

The charge injection type of electrostatic oil filter uses one or more set(s) of an emitter electrode with many sharp projections and a smooth collector electrode. The application of a high DC voltage between the emitter and smooth collector electrodes enables electric charges with the same polarity as that of the emitter electrode to be injected from the tips of the sharp projections into oils as schematically shown in Fig. 1. The electric charges on contaminants can be augmented by the injected charges being adsorbed on the contaminants; the magnitude of the Coulomb force exerted on them becomes larger; therefore, the contaminants can be removed from oils at a faster speed.

The filtration principle of this filter resembles that of an electrostatic precipitator used for the purification of gases. While the electrostatic precipitator utilizes the corona discharge phenomenon to generate ions, the charge injection type of electrostatic oil filter utilizes the charge injection phenomenon [4] that takes place as a result of the movement of electrons at the interface between an electrode and some types of the molecules in liquid. The charge injection phenomenon begins at an electric field strength lower than that of the onset of corona discharge [4]. Fig. 2 shows an example of current versus voltage relation measured using Type 1 filter and Oil 1 (see Sections 3 and 4). The experiment for no charge injection was done by replacing the emitter electrode with a smooth plate electrode. The current under charge injection is larger than that under no charge injection resulting mainly from the injected charges and partly from the increased electric field strength between the emitter projections and collector electrode. For the case of charge injection, spark discharge takes place at about 18 kV or higher, which is much higher than the operating voltage, 10 kV. However, corona discharge may take place at the operating voltage. The occurrence of corona discharge in oil may deteriorate the oil. Therefore, no occurrence or a low probability of

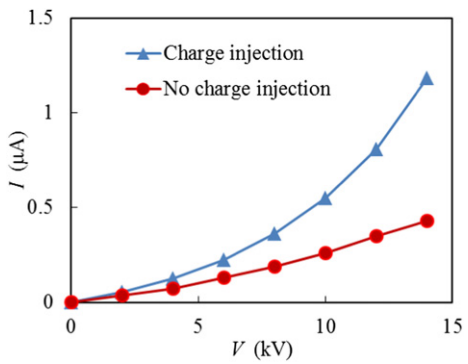

Fig. 2. Current vs. voltage (Type 1 filter, Oil 1).

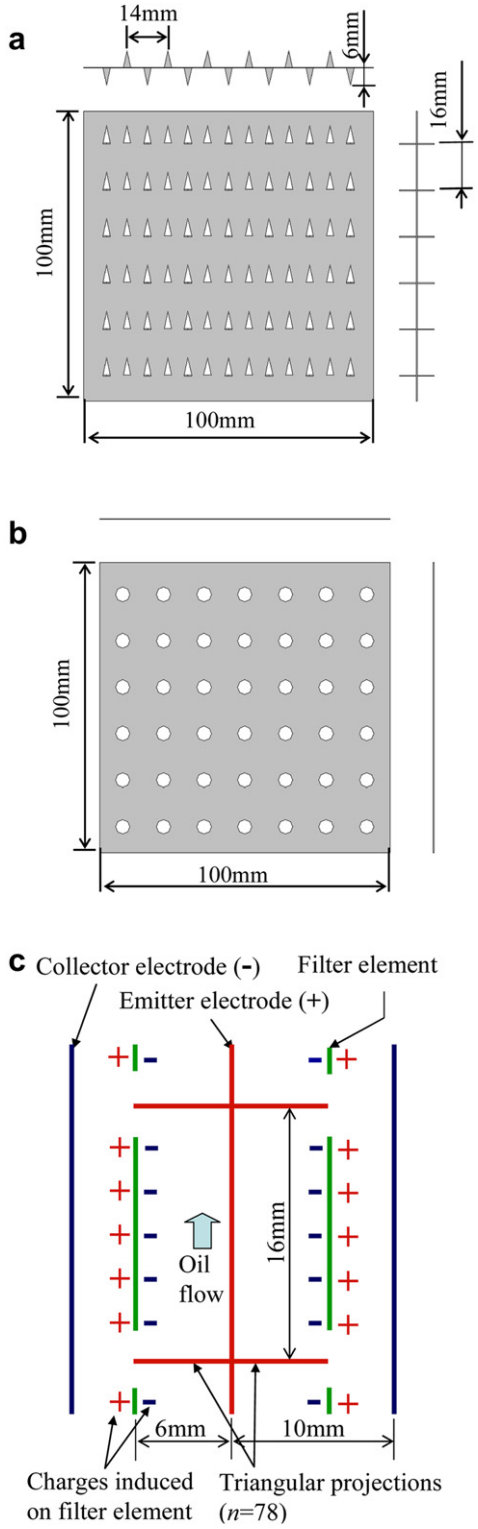

Fig. 3. Type 1 filter (a) emitter electrode (b) filter element (hole diameter = 5 mm) (c) schematic of filter configuration.