Development of Twin PEN-Jet System for Oil Film Removal

Hirofumi TAKIKAWA*, Haruki SAITO*, Hajime SHIKI*, Kenichi TSUJII*, Shinichiro OKE*, Yoshiyuki SUDA*, Shigenobu YAMANAKA** and Takashi OKAWA**

* Department of Electrical and Electronic Engineering, Toyohashi University of Technology

** Daiken Chemical Co., Ltd.

Abstract

A twin plasma-energized-jet (twin PEN-jet) system was developed to remove residual machine oil film from a workpiece surface after machining instead of using a wet cleaning method with organic solvent. The twin PEN-jet is an atmospheric-pressure mesoplasma to be operated in an open atmosphere with a working gas of air. The twin type jets were designed for higher speeds and reliable treatment. The air flow rates were optimized for each PEN-jet. A treatment speed 20-times higher was achieved with the twin PEN-jet, compared with a single PEN-jet, although the twin PEN-jet consumed 2.2 times more electric power than the single PEN-jet.

Keywords: Machine oil film removal, Atmospheric-pressure mesoplasma, Twin PEN-jet, Treatment speed

1. Introduction

Machined parts are sometimes washed with an organic solvent to remove the residual oil before proceeding to the next process, such as bonding or sealing with glue or paint. However, from an environmental point of view, e. g., the disposal of waste solvent and treatment of the volatile organic compounds generated during the process, an alternative method is much needed. One such potential candidate is a dry treatment with plasma. Some attempts have been made by using plasma under a vacuum[1-5] or in a chamber[6]. In order to achieve low-cost treatment, however, the process should be carried out in open air.

The authors have been investigating atmospheric pressure mesoplasma systems based on a pulsed arc discharge under a gas flow[7-11]. Mesoplasma has a temperature between that of conventional thermal plasma and cold plasma. There are two types: a gliding arc, which generates a pseudo-flat plasma jet, and a PEN-jet (Plasma ENergized jet), which generates a cylindrical plasma jet. The temperature of a PEN-jet is higher than that of a gliding arc. A certain level of higher temperature is considered necessary for oil removal. The feasibility of using a PEN-jet to remove machine oil has been investigated. Results show that the oil was removed when the plasma was traversed twice at the same position. However, a higher treatment speed and only one traverse treatment are still required[11] for practical use. In the present study, a twin PEN-jet system was developed to shorten treatment time.

2. Experimental

Figure 1 is a schematic diagram of the twin PEN-jet system. Two rod electrodes were located in two through-holes of a body electrode and fixed by polymer caps. Ceramic nozzles were placed at the exits of each through-hole. Electric power was supplied simultaneously to the rod electrodes from a pulse power supply through a high-voltage transformer and reactors (L, 60 mH) in each discharge circuit. For reasons of expediency, we named the jets front jet and rear jet. The former was used for the first irradiation of the plasma and the latter for the second irradiation. The distance between the plasma jets was 30 mm. When the system used a single PEN-jet, only the front jet was used with a 30 mH reactor in the circuit.

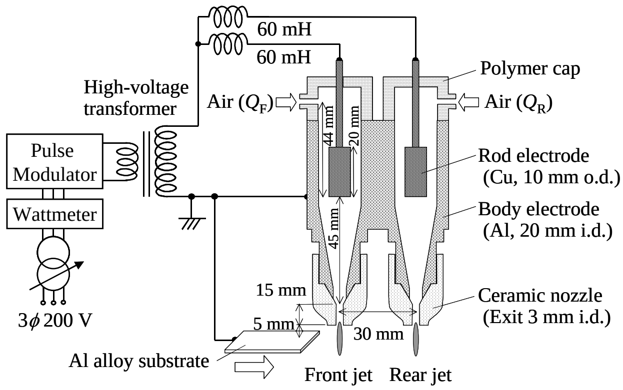

Fig. 1 Twin PEN-jet system.

Electric power was supplied by a pulse modulator (6 kW, 30 A) and high voltage transformer (12 kV, 2A), and was controlled with a slide regulator (5.2 kVA, 200 V). The power input or electrical consumption was measured with a wattmeter connected between the slide regulator and the pulse modulator. The plasma output was measured as the root-mean-square value of the product of the waveforms of the discharge voltage and the current during an appropriate length of time and with an appropriate resolution. The pulse modulator was operated under the following conditions: pulse frequency, 20 kHz; pulse width, 4 μs; duty, 16%. Air