P2-13 Development of Real-time Particle Counter Using a Laser Diode

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1. Introduction

Development of a real-time particle counter which can measure the size distribution and number density of small particles contained in liquid is required in various engineering fields. In mechanical system, it is important to measure the number of small particle in hydraulic or lubricating oil because severe surface damage occurs due to contaminant in oil. In addition, analysis of wear debris in oil are very useful to monitor lubricating conditions and predict the failure of machin components.

In this study, we have developed real-time particle counter using a laser diode and applied it to on-line monitoring of surface failure.

2. Measurement Principle and Structure of Particle Counter

Fig.1 shows the cross section of sensing area. The laser beam with uniform distribution of strength is passed through in rectangular area of A (a × b) . When a particle (diameter d) passes perpendicular to the laser beam in sensing area, a part of laser beam is extinguished by a particle, then a pulse is generated at the output of photo detecting device.

At the region of $\pi d/\lambda \gg 1$ (λ : wavelength of the beam) , the amount of the relative attenuation of penetrated photoelectron power Ir is proportional to the geometrical section of particle.

$Ir = \pi d^2/4A$ · · · · · · (1)

Particle diameter is calculated from the peak value of

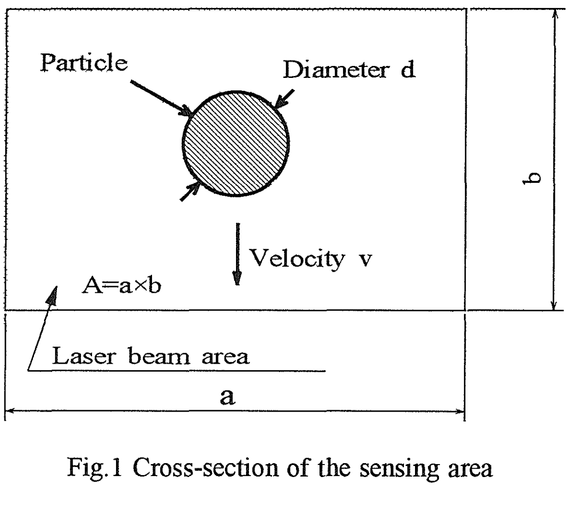

Fig.1 Cross-section of the sensing area

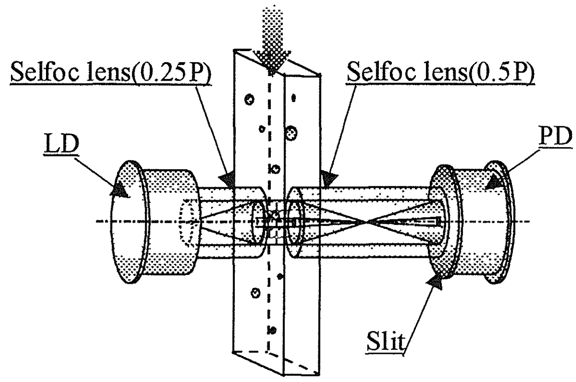

Fig.2 Shematic of particle sensor

Table.1 Specification of the particle sensor components.

Component	Specification
Laser diode (LD)	P_0 = 40 mW (Max), λ = 810 nm
Selfoc lens (1)	Diameter : 2.0 mm Length : 6.42 mm (0.25P)
Selfoc lens (2)	Diameter : 2.0 mm Length : 12.8 mm (0.5P)
Slit	Metal plate Rectangular [50 × 50 μm, 100 × 100 μm] Thickness : 0.1 mm
Photo diode (Si-PD)	Size : 2.4 × 2.8 mm^2

the output pulse of photo detector as equation (1) .

Fig. 2 shows a schematic of particle sensor based on the principle mentioned above. The specification of the sensor components is summarized in Table 1.

A selfoc lens of 0.25P is arranged to lead the laser beam from Laser Diode (LD) to the sensing area and a selfoc lens of 0.5P is arranged on the receiving side. A selfoc lens of 0.25P, which has the same characteristic as a usual convex lens, can make the beam parallel in the sensing area. On the other hand, a selfoc lens of 0.5P can build up a upside-down real picture of the particle passed in the sensing area at output face of the lens.

In general, a slit corresponding to the size of the particle ahead of the receiving lens is necessary to measure the laser beam that attenuates with the particle. However, the particle piles up the slit because of the thickness of the slit. Then, a

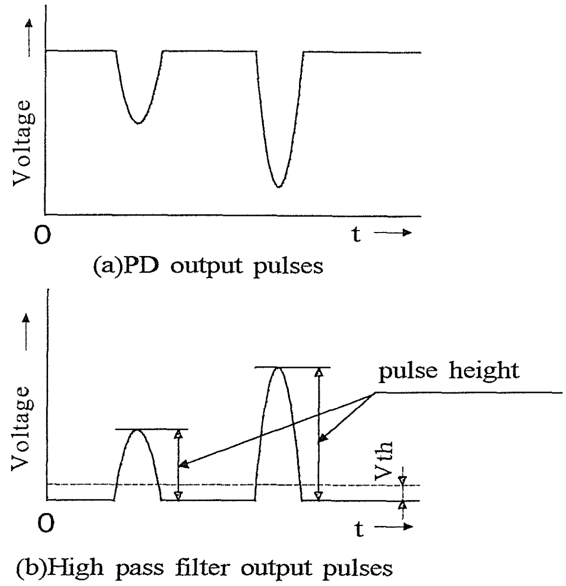

Fig.3 Signal pulse shapes

rectangular slit for measurement area limitation is arranged behind the receiving lens. The laser beam which passes through the slit is detected by a Photo Detector (PD). The slit was made on a metallic thin plate with a thickness of 0.1 mm by chemical etching method.

Fig.3 shows the schematic shapes of the signal pulses. When a particle crosses the laser beam, an output voltage of PD drops in proportion to the projected area of the particle (Fig. 3(a)). The pulse passes through a high pass filter and is reversed. (Fig. 3(b)). The peak of pulse is detected and stored. Followingly the peak hold value is converted by an A/D converter and counted by a signal processor. The value of a pulse height is converted into a diameter of equivalent circle of the projected area. Particle counter consists of a particle sensor head, an amplifier, an A/D converter and a personal computer. Sampling duration of measurement is possible to set up arbitrarily.

3. Results

The properties of our developed particle counter was verified by the measurement of spherical glassbeads (mean diameter: 40 μ m) in water by means of bottle-sampling technique. The concentrations of glassbeads was 0.1 ~ 0.001 volume percentage. Fig. 4 shows the particle size distributions with the 100 μ m slit. The size of the largest number of glassbeads appeared at about 40 μ m in particle counter measurements.

4. Application to Surface Failure Diagnosis

Fig.5 shows variations in the accumulated total number of wear debris in lubricaring oil as a function of sliding distance during the wear tests. Test material was Sn-based bearing metal. A real-time measurement was repeated at every 10 minutes. We can easily

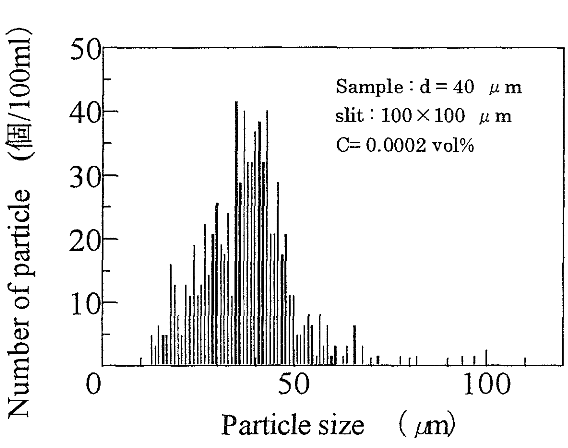

Fig.4 Particle size distributions

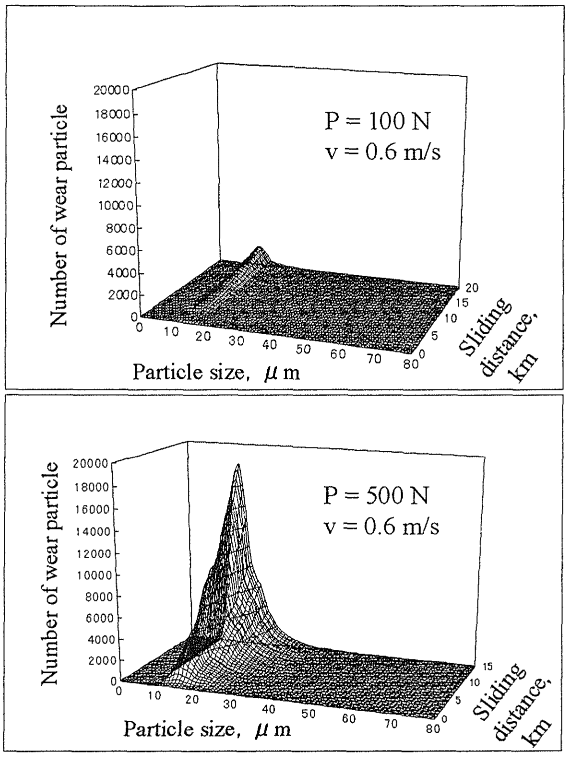

Fig.5 Accumulated total number of wear debris of various size vs. sliding distance

detect the difference of severity on the sliding surface depending contact load by the particle counting.

5. Conclusion

We have developed an on-line particle counter. It was found that the size distribution of small particles larger than approximately 5 μ m could be measured precisely with our counter.