High Tc SQUIDs Based Food Contaminants Detection System for Sale

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Abstract— **We have designed and constructed a PC controlled food contaminant detection system for practical use. The system we have developed is the High-Tc SQUID based system, which is covered with waterproof stainless steel plates and acceptable to HACCP (Hazard Analysis Critical Control Point) program. The outer dimension of the system is 1500L mm x 477W mm x 1445H and an acceptable object size is 200mmW x 80mmH. An automatic liquid nitrogen filling system was installed in the standard model. This system employed double layered permeable metals shield with thickness of 1mm as a magnetically shielded box. The distribution of the magnetic field in the box was simulated by FEM (Maxwell, Ansoft Corporation); the gap between each shield layer was optimized before fabrication. Then the shielding factor of 730, which is good enough to operate the system in a factory was achieved in z- component. As a result, we robustly detected a steel ball as small as 0.3 mm in diameter with distance of 80mm above the object.**

I. Introduction

WE are consuming processed foods such as a hamburger or a TV dinner in our daily life. There is a possibility that unfavorable contaminants are accidentally mixed with foods even if many efforts has made to exclude such a chance in the factory. Examples of these contaminants are small chips like fine wires of a strainer element of processing machines and broken syringe needles used for immunization or hormone injections. Because of the increase in international concern regarding food safety, we should develop a highly sensitive detector to ensure food and drug safety. There are some detection methods such as *eddy current, X-ray and SQUID system*. The Eddy current method is widely used in the world; however, the sensitivity is much affected by the conductivity of the contaminants and the food itself. Since wires of strainer elements or syringe needles are made of stainless steel, their conductivities are lower than carbon steel. Therefore it is hard to detect stainless steel contaminants by the eddy current method. X-ray method is strong candidate and is getting popular in food factories. It can detect not only metallic but ceramic contaminants. However, the maintenance cost is expensive and its lower detection limit is in the range of mm order. Several institutes and we have proposed the detection system using a SQUID magnetic sensor to circumvent the difficulties [1-4]. Here we describe a contaminant detection system for food contaminants with a robust magnetically shielded box.

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II. Detection Principles

A block diagram of the detection system is shown in Fig. 1. It consists of a permanent magnet, a conveyor, a magnetically shielded box and SQUIDs. All of the samples move from left to right and pass below the magnet tunnel before the detection. This magnetization is also effective for austenitic stainless steel contaminants. The magnetic field from a metallic contaminant in food is detected by the SQUID magnetometers when it passes below the magnetometer.

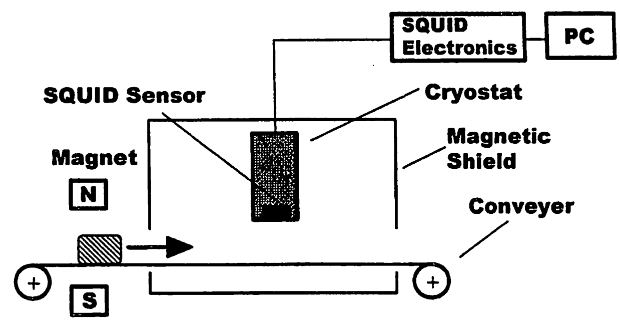

Fig. 1. Block diagram of food contaminant detection system. It consists of a permanent magnet, a conveyor, a magnetically shielded box and SQUIDs.

III. System

A. General Specification

The size of the whole system is 1500L mm x 477W mm x 1445H mm and is covered with stainless steel, which is approvable under the HACCP (Hazard Analysis Critical Poit). The magnet is made of Nd base alloy and its magnetic field is 0.1 T. The LN_2 cryostat used for maintaining the temperature of the SQUIDs at 77K consists of three separated glass dewars. The size of the each dewar is O.D.70 mm x I.D.50 mm x 300L mm. The total volume of the cryostat is 1.5 liters and the liquid nitrogen can be maintained for 12 hours without filling. An automatic LN_2 supply system is attached.

Three SQUIDs are used for this system. The SQUID and its driving electronics employed here were manufactured by Sumitomo Electric Hightechs. The size of the pickup loop is 10 mm x 10 mm square and of high-Tc directly coupled type. The sensitivity of the SQUID is nominally 300 fT/Hz1/2 at 10 Hz. The SQUID driving eletronics is of modulation type and its bandwidth is 10 kHz. The signal was passed through a low-pass filter (LPF) at a frequency of 5 Hz. The system was totally controlled by a PC and you can operate it by touching the display panel in front of the system. The appearance of the system can be seen on the web site [5].

B. Magnetic Shield Design and Performances

Since the magnetic shield covering the sensors is the crucial part of the system for practical use, it was designed in cautious manner. Thus, before the design of the system we performed 3D analysis of the magnetic field using a model as shown in Fig. 2. The simulation software *Maxwell* of Ansoft Corporation was used. A magnetic field of 50μT was applied from the Y-direction with angle of 10 degree and the field distribution inside was calculated by FEM. The thickness of the permalloy layer and the relative permeability were supposed as 1 mm and 20,000, respectively. The number of the shield layer was two. The size of the internal shield box was fixed as (1000L mm x 252W mm x 482H mm); the spacing between internal box and external box was changed from 10 mm to 400 mm [6]. The shielding factor was calculated as ratio of the imposed external magnetic induction (50μT) to the value of the magnetic induction on the internal region of the shield. Fig. 3 shows the shielding factor calculated as the region between the z- component of magnetic field outside and at the center of the shield (z=140 mm from the bottom of the internal shield box). The shielding factor presents a non-linear behavior and maxima at around the layer separation of 100 to 200 mm. The separation of 100 mm was used for the design of the shield box by the consideration of its cost of the material. In this model the shielding factor *SF* of 634 was obtained. Then the shielding factor when the length of the internal shield was shortened into 700 mm was analyzed in the same manner; *SF* of 523 was obtained. Finally we decided the shield design as internal shield: 700L mm x 252W mm x 482H mm and external shield: 902L mm x 454W mm x 684H mm and manufactured them with aluminum spacers. The actual shielding factor of the shield box was evaluated; *SF* of 732, which is 40 % larger than that of expected value was obtained. We think this is because of unexpected large relative permeability of the shield materials.

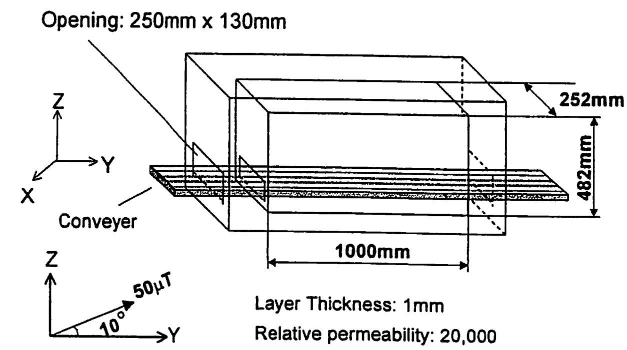

Fig. 2. Model for 3D analysis of the magnetic field. The number of the shield layer was two. The size of the internal shield box was fixed as (1000L mm x 252W mm x 482H mm); the spacing between internal box and external box was changed from 10 mm to 400 mm.

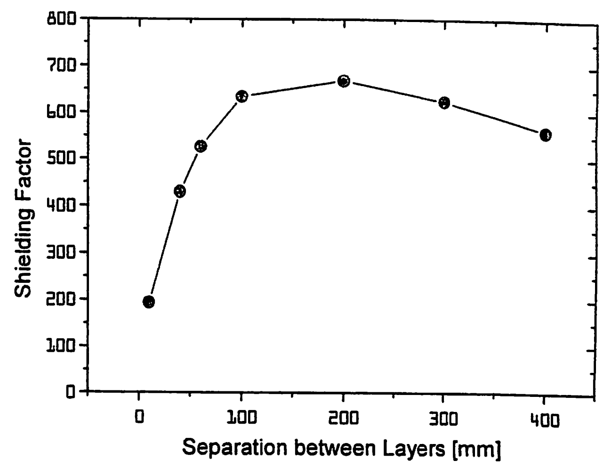

Fig. 3. Shielding factor a function of layer separation. The shielding factor presents a non-linear behavior and maxima at around the layer separation of 100 to 200 mm.

IV. Performances of the System

The performances of the system were tested. Stainless steel balls with different diameters were prepared as test samples. The samples were put on the conveyer and magnetized. Then they were passed below the SQUIDs with speed of 14 m/minute. Fig.4 shows the signal from austenitic stainless steel balls with diameter of 0.3 mm and 0.6 mm. The clear signals with S/N of more than 4 were obtained. The signal was not affected by either electromagnetic radiation of a mobile phone or motion of a bulky steel cart near the system.

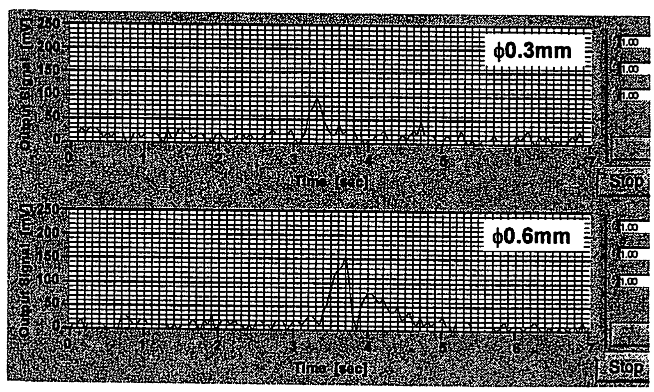

Fig. 4. Time trace of the SQUID signals for the sample with diameter of 0.3 mm and 0.6 mm . The signal was processed with output signals of three SQUIDs on real time.

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