Detection of foreign objects in food products

The company Food Radar Systems AB is a provider of systems for increased product safety within the Food Industry. The company’s product LOOK100® is a sensor optimized for detection and removal of foreign bodies in emulsions and food products being pumped through a pipe system. LOOK100® detects all kinds of foreign bodies such as glass, metals, polymers, stones, wood and bones, down to a typical particle size of 1 mm. However, the minimum detectable size of a foreign body depends on the homogeneity and mixture of the food product itself.

Up until today there have been three major system technologies for detecting foreign bodies in food products. These competing systems are Metal detectors, X-ray imaging systems and Visual inspection. The technologies have their own pros and cons. For instance; metal detectors only detect metals, X-ray systems can best detect calcium rich bones and metal, whereas vision systems only detect information from outermost surface of the object.

Food Radar Systems AB, has developed a fourth unique system, based on microwave technology, that can detect all types of foreign bodies - e.g. glass, wood, plastics, cardboard, bone, stone, shells, nuts/kernel, rubber and of course metal. The first product from Food Radar Systems is the LOOK100® sensor designed for finding foreign bodies in emulsions and “pumpable” food products.

LOOK100® sensor head. The food product is pumped through the 63 mm diameter stainless tubing. Four microwave antenna transmit and receive the microwave signal. The recorded signals are further processed in the signal processing unit (MTRX). If the signal processing detects a foreign body, a three port valve opened and the volume containing the foreign object is disposed. Two identical sensor heads coupled in series are used to improve the detection. The sensor head contains no moving parts and it is easy to clean.
Basic electromagnetics

Regardless of method it is a quite delicate task to detect sparsely occurring foreign bodies in a complex environment such as a food product. In physical terms the food product is a material that is inhomogeneous, turbulent and possibly also stratified. All detection technologies assume a certain contrast between the foreign bodies and the surrounding material, the bulk. The contrast, as experienced by the electromagnetic waves, is physically described by the difference in electromagnetic permittivity, or the dielectric “constant” between the two materials. The permittivity, which in its most general form is mathematical/physical very complex, and an important physical property determine transmission, reflection, attenuation and scattering of the electromagnetic radiation when it impinges on the foreign object. The fact that the dielectric permittivity is frequency and temperature dependant makes it even more complicated. Another important parameter is of course the physical shape of the foreign object. Thus, it can during some instances be easier to detect an object with sharp edges, than a spherical object. Our definition of contrast includes all the above mentioned differences between the bulk and the foreign body from a electromagnetic point of view.

Schematic measurement procedure

We have chosen to implement our technology for frequencies in the range 1-30 GHz, i.e. in the microwave region. The main reasons are that the physical properties of the foreign objects as well as the bulk material (the food) have pronounced features in the mentioned frequency range. The measurement cell consists of short (<50 cm) sensor pipe made of stainless steel with a inner lining, allowing the microwave radiation emitted by one of the antennas to pass through the bulk and propagate further to the receiving antenna. Both antennas work in the so called near field regime. To ensure there are no dark spots (i.e. the whole volume of the measurement cell should be penetrated by microwaves) we use eight different antennas. When a foreign object passes through the sensor a set of eight digital signatures is calculated, as illustrated in the three figures above. In the first figure the microwave radiation passes “straight and clean” through the measurement cell. When the bulk is added is the microwave field inside the chamber somewhat distorted and noisy due to the blend of products in the bulk material. And finally, as illustrated in the right most figure, when a foreign object passes through the measurement chamber the microwave field is considerably distorted.

The overall control of the measurement procedure and the analysis of the digital signatures are all carried out in a dedicated electronics unit (with the capacity comparable to a powerful PC) developed by Food Radar Systems AB. This unit, called the MTRX, calculate, analyze and compare the digital signatures at a very high speed. If the digital signatures indicates a foreign object the ejector unit is activated and a certain volume of the product is ejected and disposed. The MTRX and the measurement cells constitutes an autonomous unit capable of detecting and rejecting a foreign object.
The compact and very powerful MTRX microwave transmitter and receiver control unit, high speed analog to digital signal conversion, data handling and high speed parallel signal processing. The MTRX contains no processor and, thus, it has no operating system that can fail, it has virtually no startup time. Up to two sensor heads can be connected to each MTRX. The rejector valve is controlled directly by the MTRX.

Typical installation

The LOOK100® consists of three parts: the sensor head, the electronics and the display unit (a built in PC touch screen). Four microwave coaxial cables connect the LOOK100® sensor head and its hardware. The display unit is the interface between the sensor system and the operator. From the display module it is possible to set control parameters and fine tune the control parameters of the LOOK100®. Examples of control parameters are: pass and reject levels. The signal processing has also the capability of suppressing production specific disturbances such as transients induced by pump start and stop. All control parameters for a certain product are stored and can be recalled for later usage. The display unit also displays production statistics.

The LOOK100® contains no moving parts and can easily be cleaned (CIP, clean in place). It is designed to be permanently installed in the production system without causing extra flow resistance or turbulence. Furthermore, it can be mounted in any position. Important is however that the flow pipe is completely filled with food. The pipe diameter can be user specified. The pictures below are taken during installation of the LOOK100® system in a baby food production line.
Furthermore, the LOOK100® sensor system can also easily be interfaced with a sausage filling machine, as illustrated in the figure to the left.

Examples of two different types of foreign objects found by the LOOK100® sensor system. Left: Wooden stems from apples, and a tiny piece of plastic. The sensor system has also ejected lumps of organic hard material which is not a foreign body but an unwanted body. Metric units.

**LOOK100® product features**

- analyzes whether a product (emulsion or pumpable) passes through the sensor contains any foreign bodies or not.
- detects foreign bodies of all kinds: Glasses, Metals, Polymers/Plastics, Wood, Paper, Stone, Bone, Kernels, Nutshells.
- 1 mm diameter foreign bodies can be detected in laboratory environment
- easy to install
- easy to clean in place (CIP)
- compact measurement cell allows high throughput.
- contains no moving parts.
- low energy consumption, less than 150 W, 230 V, single phase
- the microwave power level 0.001 Watt, which is 1000 times lower than that of a conventional mobile telephone.
- tube diameter according to customer’s specification.
- pilot test facility available for production scale evaluation.