Smart Idlers

RFID in conveyor belt monitoring

Dr. ir. Yusong Pang, Section Transport Engineering and Logistics, 3ME TU Delft

Radio Frequency Identification (RFID) is a technology that offers unique identification of objects and processes. It can actively or passively communicate and, in combination with sensors, it can capture more detailed physical information. RFID technology has been integrated into our daily life.

Gaining access to a building, paying road tolls without stopping, managing traffic, preventing theft of vehicles and merchandize, tracking library books, are some examples of successful RFID implementations. Nowadays, RFID technology became more and more widely applied in transport and logistics. Since 2005 the section Transport Engineering and Logistics TUDelft has established the laboratory of RFID Research and Realization (TUD3R) to study the applicability of state-of-the-art RFID technology.

Section Transport Engineering and Logistics

Future transport and logistics systems need to be designed with focusing on automated control and management, the powering of the equipment used, the effects of automation and the ambient impact. To achieve the safety, mobility, flexibility and the increase in capacity essential for future systems, the section Transport Engineering and Logistics develops new methodologies and tools for design, control, simulation, innovation and optimization based on the new insights gained into the physics of continuous transport phenomena, as well as the development of agile logistics control for discrete transport systems using distributed intelligence.

Large-scale Belt Conveyor Systems and Monitoring

Belt conveyors are used worldwide in mining industry, bulk terminals, cement and power plants, food and beverage, chemical production, etc. to transport large volume dry bulk material rapidly, continuously and efficiently. Nowadays, the application of belt conveyors has become widespread not only for in-plant but also for overland transportation (Figure 1). Regarding to the belt conveyors used in large-scale ma-

Figure 1: Belt conveyor systems

Figure 2: Conveyor belt rolls

terial transport, the length of the belt may be up to tens of kilometres and the velocity can reach up to 9 m/s. Today's highest capable belt conveyor is able to carry out up to 40,000 tons lignite per hour.

A belt conveyor system needs to be monitored to ensure the reliability of both the overall system and its components. Traditionally, the inspection or monitoring is considerably labour intensive and therefore expensive. Although the most of belt conveyor components and parameters can be monitored online due to the development of sensing technologies, the idler rolls are the most difficult components to be monitored without or with less human involvement due to the large scale of the system. A belt conveyor system may contain thousands of idler rolls (Figure 2). For instance, the amount of rolls may vary from 2,000 in a 1 km conveyor to more than 20,000 in a 10 km conveyor. In present, idler rolls are inspected individually by human operators by means of either visual inspection or acoustic detection (Figure 3).

Figure 3: Idler rolls inspection

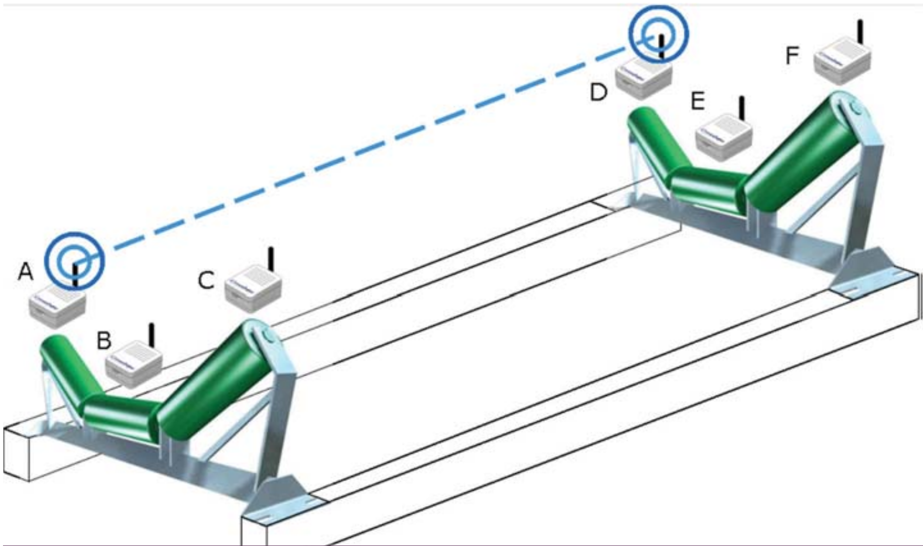

Figure 4: Node to node communication of active RFID sensor nodes

Smart Idlers of Belt Conveyors

Monitoring the highly distributed conveyor idler rolls encounters several technical challenges. Firstly, individual rolls need to be identified so that the actual rolls can be uniquely indicated when degradation or failure happens. Secondly, the large number of rolls does not allow the sensors that attached to individual rolls to be wired to a central control system. The data communication from sensors to the control centre should be performed remotely and wirelessly. Thirdly, the parameters, that are able to represent the health condition of idler rolls, need to be specified and monitored to indicate the degradation and failure of rolls.

The first two technical challenges can be overcome by RFID technology that is able to identify millions of unique items simultaneously. As well, the data communication based on radio frequency provides wireless communication solutions in large industrial area. Regarding to the third challenge, the solution of monitoring rolls and transferring the data of roll condition can be done by combining bearing monitoring sensors to RFID tags. The most direct indicator of roll failure is the operation temperature of the roll bearing. Therefore a sensor node can be made via combining an active RFID tag and a temperature sensor. Such sensor nodes provide the ability that individual rolls notify the central control system when bearing temperature exceeds a threshold value. After analysing the collected temperature data and the identities of the rolls, the rolls with potential failures will be replaced before they actually fail.

"The amount of rolls may vary from 2,000 in a 1 km conveyor to more than 20,000 in a 10 km conveyor."

To achieve wireless communication and remote data transfer from the sensor nodes to the central control system, the ability of direct node to node communication (Figure 4) of active RFID tags can be applied to form a ZigBee wireless communication network (Figure 5). In this network, the idler rolls that are equipped with the sensor nodes are considered to be smart idlers. In the smart idler, the sensor node is embedded with a transceiver into the shaft of idler roll (Figure 6). The roll is not only capable of receiving information but also capable of starting communication and transmitting information. The nodes create a network that allow them to communicate with neighbour nodes and eventually with the central control system. In the network, each roll can participate in the data transmission route. If the sensor node in one of the rolls fails then the network can reconfigure the neighbour nodes of the failed node to maintain the communication. It ensures a self-healing and highly reliable communication network.

In the monitoring of large-scale belt conveyor systems, the smart idlers provide the possibility of simultaneously, continuously and remotely online monitoring the large amount idler rolls.

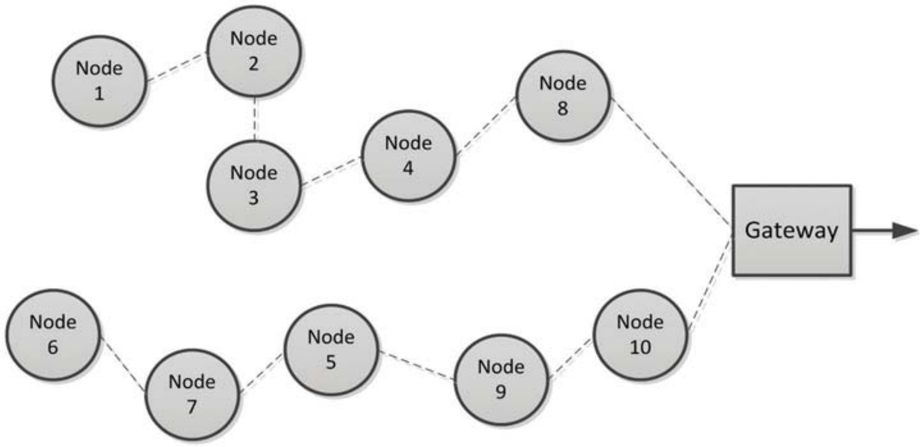

Figure 5. Multi-hop routing and ZigBee network configuration

Future research

The traditional battery powered active RFID is not really an optimal solution for smart idlers when for example more than 20,000 batteries need to be replaced or recharged. Therefore, the investigation and development of energy harvester to power the sensor nodes become critical. Considering that an idler roll is a mechanically rotating component, one solution to power the sensor nodes is to combine the technologies of mechanical energy harvest and electromagnetic energy harvest.

In 2011, a concept of self-power generation smart idler had been proposed. In the smart idler, an electromagnetic power generation system contains the winding fixed on the roll shaft via a winding frame, at least one pair of permanent magnets attached on the inner side of the roll against the winding, and the winding output circuit connected to the sensor node. The rotation of the idler roll rotates the permanent magnets to form a rotary magnetic field. Excited by the magnetic field, the winding produces electromotive force to power the sensor node. In 2012, a prototype of this concept has been built and tested in laboratory environment (Figure 7). Experimental results showed that the generated power is sufficient for the sensor node. Future research will focus on the detailed design of such energy harvester, which will bring a new generation of idler rolls in belt conveyor industry.

Figure 6. Idler roll with embedded sensor

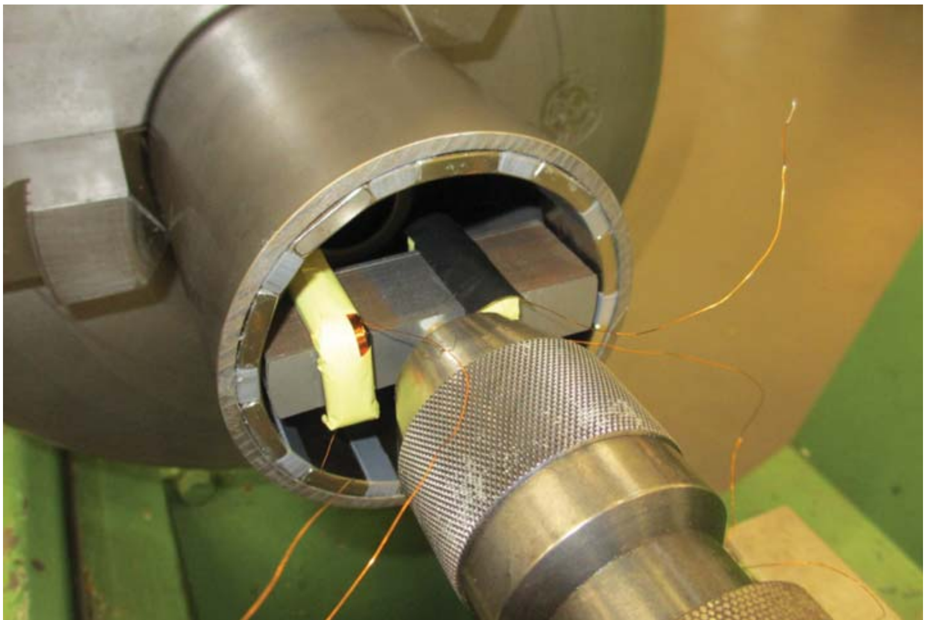

Figure 7. Prototype and experiment of self-power generation smart idler