

## Automating the complex examination of roofing tiles as part of the production process

→ The quality of concrete roofing tiles depends on a large number of criteria, and controlling them calls for individual measurement and inspection techniques. A roofing tile is expected to be waterproof, frost proof, difficult to break and to have a long lifetime. On top of this, it is important that roofing tiles of various shapes, colours and surface types are all delivered to the same high quality standard.

# The TwinCAT "Flying Saw" for a highly dynamic measurement system

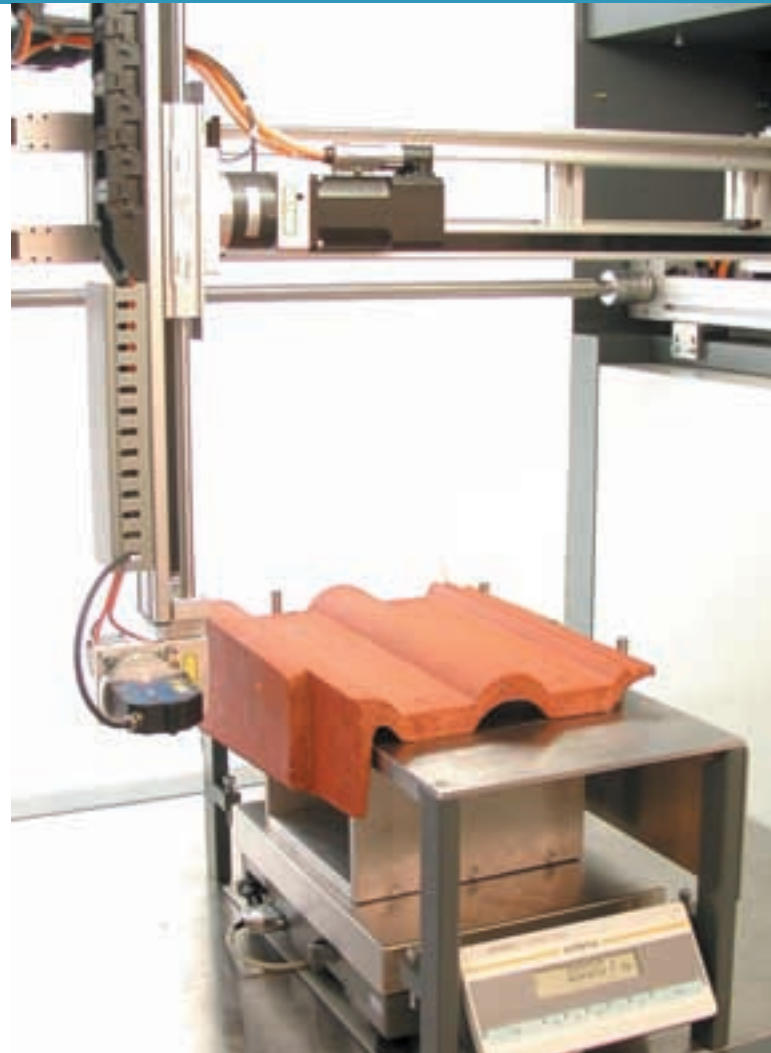
Modern methods for the production of concrete roofing tiles make use of automated production lines operating at rates of more than two tiles each second. Such manufacturing technology places high demands on the measurement, inspection and automation technology; a PC-based solution from Beckhoff was selected to provide the foundation for this.

The beginning for a co-operative research project involving the Institut für Automation und Kommunikation (ifak) and Braas Dachsysteme GmbH was the need to find a practical, technically feasible and, most importantly, economical solution to the qualitative assessment of concrete roofing tiles, without the need to remove them from the production process. The goal was to achieve significantly faster inspection cycles than had previously been possible with manual inspection, while ensuring constantly high product quality. Another goal was to use the pilot plant for inspection with new criteria or existing criteria that was previously obtained solely by the central laboratory. In order to ensure efficient exploitation both of the plant and of raw materials, it would be necessary for the examination to take place at the earliest possible stage in the production process (as the concrete is first cast). It was particularly relevant to inspect, visualize and record properties such as mass, surface quality (roughness) and a large number of undefined characteristic dimensions for roof tiles.

### The concept:

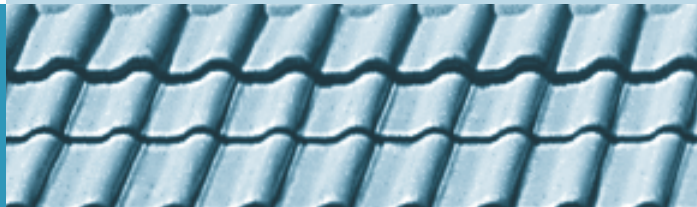
#### Grip – Test – Next

A 4-axis positioning system was developed to handle the items being tested. It has two vertical z-axes, each having pneumatically operated gripper units. The pilot equipment was built above a segment of conveyor belt in such a way that it is possible to remove and replace the items on the belt automatically. The structural conditions left very little room for installing the pilot equipment, and this meant that particularly tough demands were placed on the dynamics of the moving mechanical parts and on the associated control technology. The type of movement processes used for changing the test items are known as a "flying saw". This is characterised by the movement of a slave axis being syn-



chronized to a master axis while at least one other axis is in movement, for instance for the manipulation of objects (labelling, sorting...) in relation to the master axis.

In the pilot equipment, the items being examined are changed as described here. First, a start signal indicates that an item is to be changed, the x-axis, which is moving parallel to the production line (conveyor belt = master axis) is accelerated so that at a precisely specified location it is synchronized with the master axis. Secondly, the rear gripper (in the sense of the direction of movement) is used



← The DASTOKON test area, including the test item support, scales and 4-axis portal system, as well as the laser triangulation sensor on the rotating axis.

→ Plant for the examination of roofing tiles at Braas Dachsysteme GmbH, developed and manufactured by ifak.



## ifak – Institut für Automation und Kommunikation (ifak) e.V.

### Innovative technologies for automation solutions

The Institut für Automation und Kommunikation (ifak) e.V. in Germany performs research, development and testing in highly varied application areas for intelligent systems in the fields of automation, industrial communication and sensors, without creating artificial barriers between these sectors. It is in fact the synergy between these sectors that characterizes ifak. In this way, any modern development method may be used, providing a flexible reaction to the customer's wishes. And this is all offered with a good price/performance ratio. These are benefits that are not just exploited by many companies and public contractors in the Sachsen-Anhalt region and in the whole of Germany, but over a much wider area. Clients are found in many European countries and in the USA, primarily because of the leading scientific role ifak are playing in the methodology for the development of communication protocols.

ifak are developing "future-proof" communication protocols. This is an important requirement if present and future manufacturing/process technology fieldbus systems, stand alone systems, as well as systems in the mobile radio sector, are to understand each other. ifak are involved in international standardization committees for the world-wide unification of fieldbus systems, programmable logic controllers (PLCs) and distributed automation systems. Because their expertise is recognized around the world, ifak are the first test laboratory to have been accredited by PLCopen, the body that is internationally responsible for the unified implementation of PLC language standards. Their activities in the sensor and measurement technology sectors are aimed at the development of innovative, complex, sensor solutions for automation. Whether sensor systems are to be developed, or the signal processing optimized, the important point is always that innovative technologies should increase the quality of the product or of the process, while simultaneously reducing the costs.

→ [www.ifak.fhg.de](http://www.ifak.fhg.de)

to remove the item to be measured while it travels at the speed of the belt. Then, a distance compensation is carried out with a new synchronisation to the gap that has been created, so that gripper unit 2 can replace the previously measured item into the space. Finally, the new test item is then moved to the test area that is installed in parallel with the conveyor, where it is then subjected to complex examination.

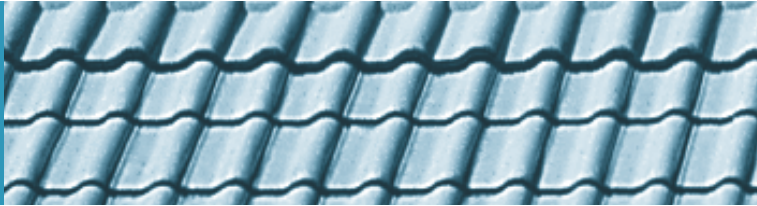
The measuring system used for this purpose includes scales, three laser triangulation sensors, a camera, a number of photocells and a total of two identification systems. The reader head of an RF identification system is installed immediately under the transport belt, shortly before the pilot equipment. This identifies pallets that have been fitted with a data medium. These pallets are cyclically measured, evenly distributed, weighed, and then returned to the production flow. Examination of the pallets means that it is possible at a later stage to acquire data on the differences between the unhardened tiles. The measuring system is located in the roofing tile machine, after the extrusion machine and before the first sprayer with coloring agent.

### PC-based solution for complex control systems in demanding applications

Because of the complexity of the structure, the large number of system components, test tasks, and the high demands made of the controller for the four-axis portal system, ifak decided in favour of the PC-based solution using the TwinCAT Software PLC/NC from Beckhoff. This allowed functionalities such as the flying removal and return of the roof tiles, operation and observation, data acquisition, data evaluation and data storage all to be implemented in one Industrial PC. The control system itself consists of:

- | a control cabinet PC C6140 with one Control Panel at the equipment and another in the control room
- | Bus Terminals for the I/O system networked via Lightbus
- | servo drives and controllers
- | TwinCAT software PLC/NC with integrated "flying saw" NC functionality

Inside view of the BSPK pilot plant, with test area, scales, gripper units and the production belt with roofing tiles.



### The TwinCAT "Flying Saw" function block

The PLC and NC controllers with the integrated "flying saw" functionality, included in TwinCAT, operate the movement processes in the roofing tile inspection system. They remove the new test item from the belt and return the previous test item back to the belt.

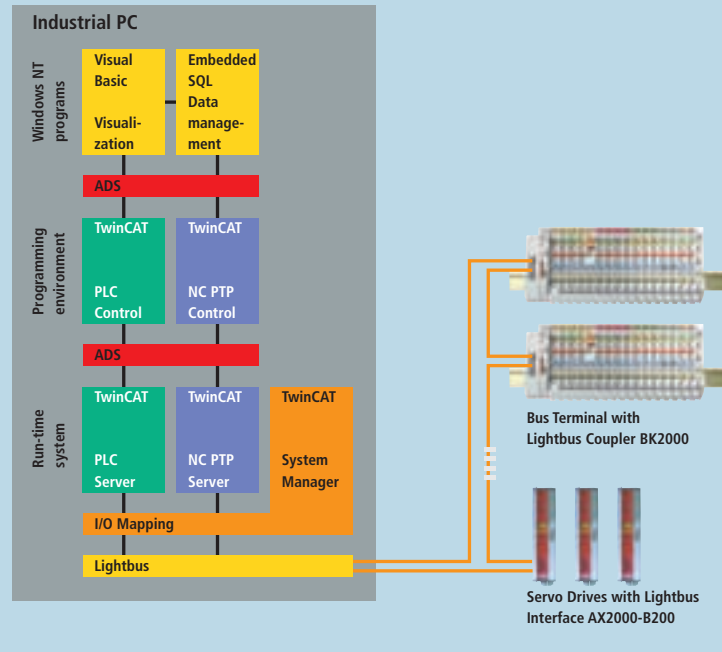
In the application described here, the production belt is the master axis, while the x-axis of the 4-axis portal installation is the slave axis that is coupled to the master. The "flying saw" procedure operates in three phases:

1. The slave axis is accelerated and until the speed of the master axis is achieved (initial synchronisation phase).
2. At a certain point (or distance co-ordinate), the slave is moving at exactly the same speed as the master. The slave immediately matches all subsequent changes in the master's speed. The two axes move in a precise synchronisation (the synchronous phase). During the synchronous movement, the pneumatically operated gripper jaws close, and the roofing tile is lifted from the conveyor belt.
3. At a second pre-defined point, the slave axis is "decoupled" from the master (the decoupling phase).

This procedure is followed twice in immediate sequence. This causes the procedures to merge in such a way that the decoupling phase of the first cycle and the synchronisation phase of the second cycle form the "distance compensation" phase. Between the decoupling of the slave and the second synchronisation phase the master axis covers a certain distance, and this distance is larger than the distance covered by the slave axis by a precisely defined amount. This distance, for which compensation has to be made, is in this particular case precisely the distance between the two z-axes. The resulting effect is that by the time of the second synchronisation travel, the gap created when a roofing tile is removed from the belt is located immediately under the z-axis that has the previous test item in its gripper. During the synchronisation travel, the z-axis is moved downwards, and the test item is placed on the conveyor belt. The slave is then decoupled and stopped. Examination of the next roofing tile can begin.

### Optical fibre fieldbus ensures fast and secure communication

Data exchange with the de-centralized I/O system and the drive functions is implemented via the Lightbus fibre optic network, which is specifically developed for fast machine controllers. The I/O system consists of bus terminals that directly handle the sensor, actuator signals and wire termination. The Lightbus network makes it possible to handle the PLC process data, and the drive process data such as provision of the set rotation speed and acquisition of the actual position, all over a single bus system. Communication over the ring structure operates ac-




ording to the master-slave principle. The complete system failure of a bus system with ring topology when a single bus device fails is often considered to be a disadvantage, but here it has been used deliberately as a safety measure. The use of fibre optic means that electromagnetic interference, typically found in the neighborhood of drive components, cannot affect the bus devices or the controller.

The Lightbus network's reserve capacity protects investment because of its high speed, the possibility of implementing priority control, and the facility to have up to 255 bus components.

### Operation, observation and data management

All the operating, control, visualization and archiving tasks are implemented on one Industrial PC. A Beckhoff Control Panel with 12" TFT displays and a resolution of 800x600 is used as the operating unit. The operating and display elements create an independent unit, separated from the control level. Because of the application-specific requirements, the operating interface was developed with Visual Basic. The data connection to TwinCAT is made here via Windows Interface TwinCAT ADS (Automation Device Specification).



The data that is relevant to the product quality is structured in the Embedded SQL Server relational database from Microsoft. The database system is implemented on an Industrial PC, which provides effective management of the measurement and test results. User-specific analysis of the database permits individual views of the test data at the factory level, or at a management level higher than the factory through remote data transfer. For the plant operator, trending of the measurement over time, represented in the associated tolerance band, provides a statistical analysis tool for guidance of the manufacturing process in such a way as to maintain quality. This makes it possible to detect developing trends in the production process that would lead to the permitted tolerance range being exceeded in the near future. Thus, prompt compensation can effectively minimize the scrap rate.

### **Effects for quality management**

The statistical manufacturing and process control implemented for roof tile manufacture now permits

- | parameters, such as surface roughness, that formerly could not be inspected, to be examined while the production process is running; this may either be seen as a useful extension to the cycle of examination of individual roofing tiles in the central laboratory, with long waiting times before the test results are presented – such examination may even become unnecessary
- | the rate of inspection is significantly increased
- | systematic errors can be detected very promptly, while the level of wear and the abrasion rate can be determined through cyclical examination of the pallets
- | test items to be selected and examined objectively, since this can no longer be influenced by the tester
- | all the test results are managed in a relational database
- | generation of test reports is automatic
- | interrogation of the data remotely, because the system can be networked. The requirements of remote servicing and remote diagnosis are thus also covered. More significantly, the plant operator's time is not consumed by, notoriously monotonous test requirements.

Use of the pilot installation and the lessons potentially learned from it are a significant element in a higher level of quality management, and help guarantee a continuously high quality product.