

Grace project

The EU FP7 Grace project aims at **integrating process and quality control within a production line**. This goal is fully in line with the trend to develop modular, intelligent and distributed manufacturing control systems.

The system is based on a collaborative Multi-Agent System (MAS) which operates at all stages of a production line and it is complemented by self-adaptive control schemes developed at the level of process resources and quality control stations as well as at line or factory level. The MAS aims to individually tune parameters of each product taking into account information collected during the whole production process, so to compensate production process variance.

The innovation is the **new vision of the production process which leads to a deep integration of process control with quality control and finally product value**.

Drum Geometry Control Station

Automatic quality control station with conic vision system for in-line inspection

The objective of control station is to measure the final gap existing between the rotating drum and the front tub, in particular its seal, whose thickness depends both on the marriage process and on the geometry of the components being assembled (that is basically the front and rear tubs and the drum). The gap thickness is important because if it is too large clothes may be trapped between the rotating part and the tub, damaging the appliance and the clothes, while if it is too little the drum may touch the rubber seal in the front tub, causing friction, noise, wear and an increase in energy consumption due to friction losses.

Concept of operation

The drum geometry control station developed carries out the **gap measurement through a vision system based on a conic mirror that takes a 360° view of the gap with a single acquisition**.

The conic vision probe used for the inspection is composed of a camera, a conic mirror mounted in axis with

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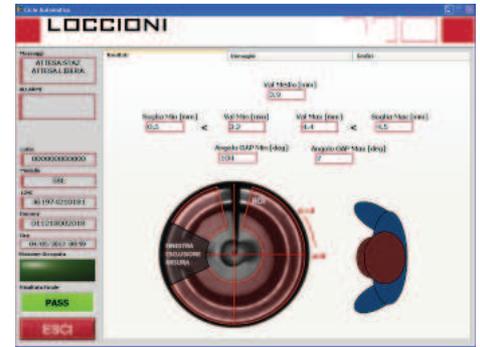
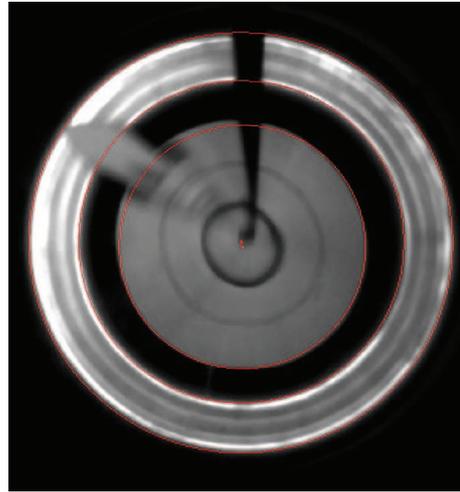
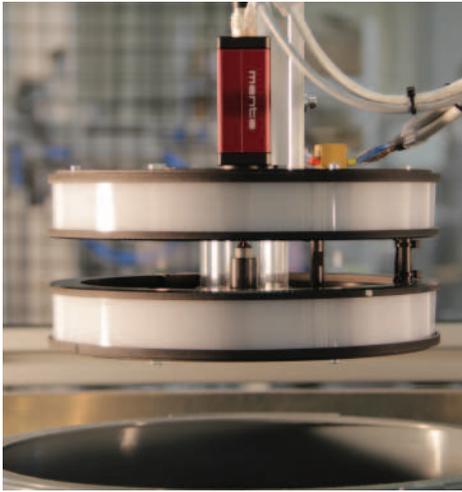
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The drum geometry control station consists in an automatic test bench positioned in the production line that performs a quality control on the assembled Washing Unit (WU) and it provides as outputs the measure of the gap between the front tub and the drum, and the Pass/Fail result according to predefined thresholds. **The station represents one of the Quality Control Agent prototypes for the Grace project final demonstrator.**

A WU is basically composed of a polymeric tub (rear and front parts), the bearings (inner and outer bearings), an internal metal drum with its pulley and a rubber seal.



- 1 Engineered version of the conic vision probe
- 2 Gap image acquired by the conic vision system
- 3 Screenshot of the test bench software showing inspection results
- 4 Test bench installation in a washing machine production line

the optical axis of the camera and a customized LED illuminator. The engineered version of the probe is represented in figure 1. The conic mirror has a tip angle equal to 90°. The imaging system forms on the camera sensor an image of a cylinder centred in the cone axis; in particular, the conic mirror performs an optical transformation that generates a circular image of a cylindrical region. In such a way, the gap between the drum and the tub is mapped into a ring-shaped dark region, while the rubber seal on the top of the gap is mapped into a clearer internal ring shaped area. Figure 2 reports a real image taken by the conic vision probe inside a WU.

The conic mirror establishes a geometrical correlation between the linear dimension over a cylindrical surface coaxial with the mirror itself and the image plane. Therefore the gap measure consists in analysing the grey level profile along a radius and measure the gap thickness with reference to the seal thickness. This operation is repeated along the whole circumference, so that **with a single acquired image, the gap thickness is measured for a fixed position of the drum.**

An additional point to consider is that during the image acquisition, the internal

part of the washing unit has to be illuminated so to maximize the contrast between the dark region of the gap and the clearer surrounding regions (the drum on the lower side and the rubber seal on the upper side) and, in the meanwhile, to minimize the camera exposure time so to satisfy the strict time constraints.

- The illumination system is composed of:
- > Two LED illuminators placed at fixed distance outside the conic mirror's field of view and equipped with light diffusers to avoid direct reflections by the internal metal drum;
 - > A holding element for the conic mirror also assuring the coaxiality between the mirror itself and the camera.

System layout

- The conic vision system is mounted in an automated test bench which is in charge of:
- > Placing the conic vision system into the drum at the target position;
 - > **Controlling and adapting camera axial position** so to optimize image quality (self-adaptation on-line);
 - > Managing image acquisition and processing;
 - > Controlling the angular position of the drum so **to perform the measure at different drum rotation angles;**
 - > Generating the gap measure as output information (Figure 3).

- The main components of the automatic test bench are:
- > A mechanical structure made of aluminum profile to integrate the measurement unit and the other components of the station in the existing conveyor line;
 - > A control cabinet placed aside the production line, integrating the PC, a touch screen monitor, the main data acquisition hardware and electrical components;
 - > The conic vision system;
 - > A pallet lifter system used to separate the WU being inspected from the

- conveyor line during the measure;
- > A system for the drum rotation, composed of a stepper motor and a pulley gripping system.

Results

A typical measurement cycle is composed of WU loading and unloading, adaptation of the vertical alignment of the probe, 360° rotation of the drum with 8 acquisitions (1 acquisition each 45° rotation), image processing and visualization of the inspection result and it **lasts about 16.5 seconds**. The gap is measured along the whole circumference with an angular resolution of 3° and all the values are shown in graphical form to the operator. **The gap mean value, its absolute maximum and minimum values, and the relative angular positions are also provided, along with the overall inspection results (Good/Fault) based on specifications provided by the factory.**

The station has been already installed in a washing machine production line, as shown in figure 4.

