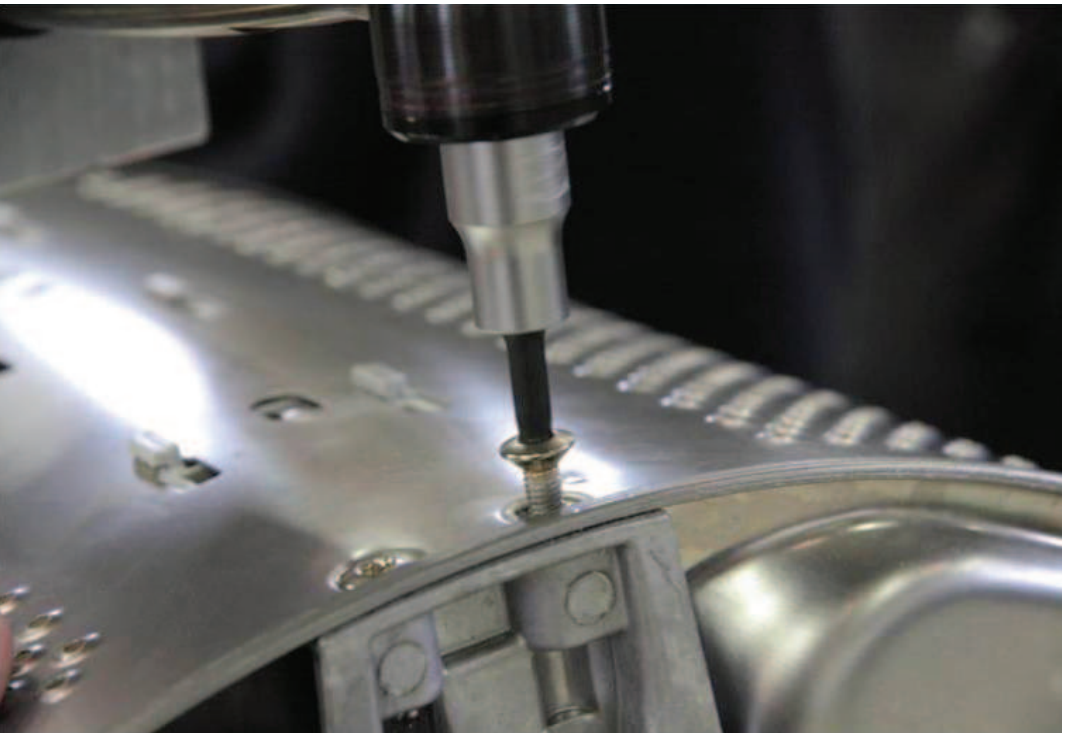
Grace

inteGration of pRocess and quAlity Control using multi-agEnt technology



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**.

Local self-adaptation

Adaptation in bearing insertion and screwing process

An important objective of the Grace project is to analyse, develop and implement self-adaptation and self-optimisation in manufacturing systems and assembly processes, both at a local and global level. At local level adaptation and optimisation of manufacturing operations and assembly machines are considered. Each machine is controlled by local controllers which in typical manufacturing are based on simple control functions handled by standard controllers. By introducing self-adaptability mechanisms machines are more robust to desired variation of process set-point and process variables and to unplanned fluctuations of process/product parameters. Adaptation and optimization of manufacturing operations and assembly machines are achieved by adjusting the operation parameters of their controllers according to the tests performed by the quality control in the production line.

Bearing insertion process

The process of inserting the bearings in the tub appears early in the production line of a washing machine.

The insertion process receives input from the bearing process and a tub process and delivers an output that is stored in the storage process. The storage process sends the product to the quality check where the product is either rejected or sent back to the storage dependent on a quality measure.

Insertion Depth and the *Force* are essential parameters in the bearing insertion process.

The insertion is carried out imposing a constant pressure to the pump and occurs at a constant insertion velocity.

Information or additional measurements related to tub and bearing properties, and environmental conditions, could be utilized to achieve self-adaptation

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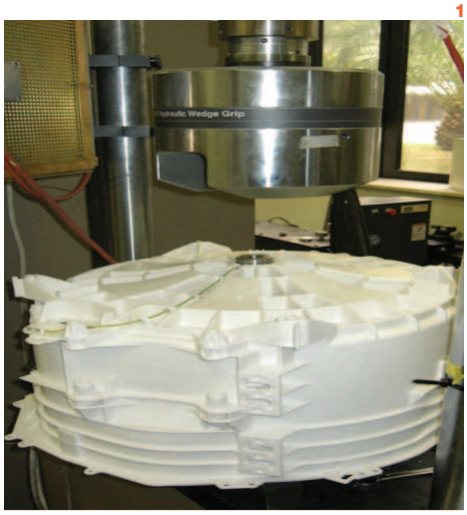

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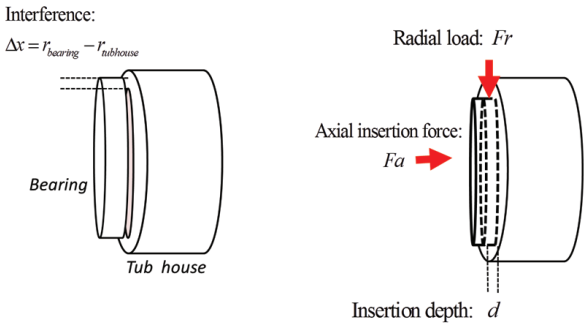

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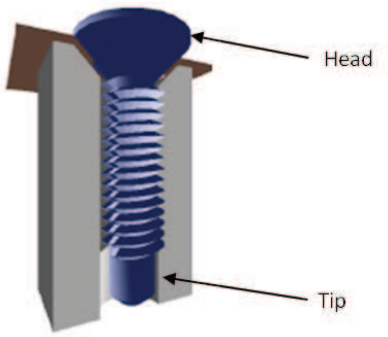

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in the process, either in a feed-forward static function or a feedback structure with state estimation and parameter adaptation. In order to define such relations, mathematical models that can be validated in experimental settings have been developed.

Mathematical models

A simple mathematical model of the tub hub has been developed based on force balance in an idealized network of virtual springs characterised by basic material properties and geometry.
The main purpose has been to develop an understanding of the insertion process, classify variability in material properties and insertion process effects.
The model has also been used as a structural basis for analysing possible quality indicators of the process.

Self-adaptation mechanisms

The main goal of the mathematical model of bearing insertion process is to provide estimates of internal physical states and to calculate the quality of the assembled product.

This information may be used to:

- Adjust the processes downstream of the bearing insertion cell;
- Adjust the functionality of the finished product related to some quality tolerances;
- Check if the tub hubs manufacturing process is precise and if the products are compliant with the design tolerances.

The quality assessment procedure at the bearing insertion cell may get information feedback from downstream cells providing additional quality estimates and elaborating the estimation process at the bearing insertion cell.

Screw process

In washing machine production line several screwing stations exist.
A typical screwing process consists of several phases as run-down, alignment, clamping and yield phase. The last three phases constitute the tightening process, where a pre-described torque is applied to the screw for joint creation. During these phases, tension is produced in the screw and must be kept through out the screw life time. Also, friction and clamping force are important factors affecting the quality of the process.

Self-adaptation mechanisms

A control strategy of tightening to the yield point is developed based on the maximum preload capacity of the screw. This strategy calculates the yield point of the screw under the combined action of tension and torsion. This is done by monitoring the rate of change of torque over fixed angle increments. The value obtained is the torque gradient. As the yield point is reached, the torque gradient declines rapidly and the tightening process is halted.
The main control objective in screwing processes is to guarantee a certain quality of the assembly while minimizing the power consumption and maximizing the assembly speed (i.e. minimizing the screw insertion time).
For the processes studied in the Grace project, the control strategy will be common for all the screwing stations in the production line, although stations are used for different assemblies (screws, screwing holes, assembly tools etc.).