PROline – a standardized modular System for production integrated ultrasonic testing

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In general, the non-destructive inspection with ultrasonic technology requires individual inspection solutions according to each component and needs. Influences of the surface geometry, the defect position within the component as well as the regions of interest rarely allow standardized solutions. That’s why inspection systems need to be adapted to the specific application. To reduce the effort for the construction of such ultrasonic inspection systems, a modular system design makes sense.

The compact system design and the modular PROline concept allows for the use of various standard modules to create application specific solutions. Thereby the customized system construction is minimized and the price/value ratio of the inspection systems is optimized. The process-safe inspection systems and modules can be adapted to different inspection tasks, increasing requirements and application fields.

Each PROline solution consists of the PROline USB ultrasonic inspection device as the core element, the inspection and evaluation software and the inspection mechanics. All 3 solution components are modular configurable. The individual inspection solution is composed out of a variety of standard modules, perfectly adapted to the customers’ requirements. At this, the hardware (e.g. number of ultrasonic channels and probes, encoder interfaces, automated or manual component feeding) is as flexible as the inspection software (e.g. various evaluation and data processing possibilities). Depending on the inspection task, the system works with conventional ultrasonic technique or Phased Array technology. The coupling is performed in immersion-, squirter- or with bubbler technique for water-sensitive components. The water conditioning can also be individually compiled out of standard modules. The wide range of interfaces (digital and analogue) enables the integration directly into the production process and the communication with various customer systems.

Nevertheless, if specific modifications of the standard modules (mechanics, electronics and software) are required by the customer, VOGT will be pleased to provide additional customized solutions.

1. Introduction

A broad variety of quality checks is integrated in the production process. One of these is the ultrasonic inspection of components.

The ultrasonic inspection is a volume inspection enabling to view the inside of the component at a favourable price. The components may be of different make and have different material properties. In this speech we exemplify the mechanised weld seam inspection of gearwheels in serial production for the automotive industry and explain it by means of the modular and staged VOGT inspection system concept.
Every customer has specific requirements for his particular product range as regard to the ultrasonic inspection system. Such as:

- component geometry,
- detection capacity,
- inspection time,
- flow-rate,
- degree of automation,
- inspection technique,
- spectrum of components and –variety and
- flexibility of the inspection system.

1.1 Component geometry – cylinder vs. disk

Of course many component shapes exist. In this speech we shall concentrate on rotational symmetric components with a diameter of approx. 200 mm joined together from two individual components by means of a weld seam.

![Ultrasonic beam profile and weld seam](Image)

Figure 1. Inspection method for weld seam testing of gearwheels. The various inspection devices are exemplarily described by means of this gearwheel component.

1.2 Detection capacity – standard vs. specific

The universal or customised and site-specific inspection instructions determine what is to be tested and how. The requested inspection sensitivity defines the sensor system to be used as well as the inspection system technique.

1.3 Inspection time and flow-rate – rapid and short holding times

Depending on whether the ultrasonic inspection is requested following a set-up process during manufacture or as a statistic individual inspection or as inspection for each of the components to be manufactured various time periods result.
1.4 Flow-rate – individual inspection vs. 24/7 operation

Particularly the flow-rate already clearly determines how an inspection system is to be designed. Will it be a laboratory inspection system, a half-automatic (offline) inspection system or a fully automatic (inline) inspection system. These are important aspects for how to carry out the component handling.

1.5 Degree of automation – Laboratory application vs. fully automatic

The degree of automation defines the inspection process up to the presentation of the result. In this context the information whether the component is ok (iO) or not ok (NiO) is of importance.

1.6 Inspection technique – Immersion technique vs. non-immersion inspection

The following various inspection techniques may be used for the inspection task: (1) contact-, (2) immersion-, (3) bubbler-technique or (4) local immersion technique. The latter are characterised by a non-contact inspection technique. Here a dry component shall be available for further production steps. A trend is obvious, namely to only humidify the components locally with the coupling medium for the bubbler- or local immersion technique instead of carrying out an inspection by immersion technique.

1.7 Spectrum of components – Single component vs. variability

Certainly a further setting parameter is the variation range of the components. Is there only one type? Are the components of different design and are they to be differently inspected? These pre-settings have an important influence on the inspection task and the technical design.

2. Modular Design of an Inspection System

Depending on the requirements of the customer's technical specifications inspection may be carried out (1) in a laboratory or (2) in an "automat" (automation), either (2.1) by means of manual component handling or (2.2) as in a „Dark-Factory“ without any personnel.

A VOGT ultrasonic inspection system consists of the following main components:
• Ultrasonic inspection system with inspection software for data recording and evaluation as well as presentation of the results,
• sensor inspection,
• inspection mechanic,
• coupling medium,
• control of the inspection process and the mechanic as well as
• periphery.
2.1 Ultrasonic inspection device with inspection software for data recording and evaluation as well as presentation of the results

The VOGT Ultrasonics PROline\textsuperscript{USB} is a conventional multichannel ultrasonic inspection device. It is used for all PROline standard-inspection devices. Its compact dimensions and low weight are ideal for probe near mounting. Consequently it is not a hand-held inspection device but a front-end one being operated by a PC or a notebook with PROline\textsuperscript{PLUS} software. Parametrisation is easy and the software is user friendly. Implementation may be quickly realised.

By means of the PROline\textsuperscript{PLUS} inspection and evaluation software the inspection mechanic is controlled in addition to the PROline\textsuperscript{USB} ultrasonic inspection device and complete inspection processes may be determined. The inspection data recording is by means of locator data or on time-basis. For the use in a mechanised inspection device status signal input and output are required in order to signal a starting position or a result. Actions may be initiated by means of the status lines, i.e. removal of component, designation of component, N.i.O. (not ok) status.

![The 8-channel-inspection device PROline\textsuperscript{USB}](image1)

![Typical example of presentation of results with PROline\textsuperscript{PLUS} for a weld beam inspection of a specifically manufactured component.](image2)

\textit{Figure 2. Left: The 8-channel-inspection device PROline\textsuperscript{USB}; right: Typical example of presentation of results with PROline\textsuperscript{PLUS} for a weld beam inspection of a specifically manufactured component. The C-image may be subject to further evaluation steps.}

The PC disposes of interfaces to peripheric devices such as a bar-code scanner in order to easily and quickly register component features. Basing on this data the PROline\textsuperscript{PLUS} Software automatically choses the inspection settings and prepares for inspection. Interfaces to controls are available by default by means of realtime-capable PROFINET. Especially when robots are used for the component handling this interface is used for the inspection result communication. Following this information the robot transfers the component for instance to the i.O. (ok) or N.i.O. (not ok) storage places. The features of the component are clearly recorded together with the testing result data in a reporting.

Data exchange with an existing central storage medium for instance can be set up by means of PC and the PROline\textsuperscript{PLUS} Software. Evaluation of the inspection data is either
manually or automatically. The inspection system operator can evaluate the captured data manually.
In order to systematically carry out automated, periodic evaluation tasks the programmable software user interface allows for choosing various statistic evaluation algorithms. Thus the share of displays can be set into relation to the overall surface.

When using the SDK licence the inspection system operator can carry out individual software adaptations. This may be reasonable if the inspection tasks change regularly. A quick inspection and simple operation are essential for an economic component inspection.

2.2 Sensor inspection

The customer decides which inspection technique is to be used. For the described components mostly immersion or bubbler techniques are requested. Both techniques are of advantage because the used probes are 0°-probes which may fulfil the various inspection tasks either directly or by mirror re-direction. By means of mechanic modification of the intromission direction and -position various intromission angles can be realised by means of the inspection mechanic. The VOGT Ultrasonics range of supply includes appropriate probes for the different inspection tasks.

Our example components require a high detection capacity. Beyond they are water sensitive and therefore should only be humidified locally. Thus, the bubbler technique is the ideal solution. After inspection a just humidified component can be simply dried either automatically or mechanically.
The subsequent drying of the component after inspection can be of a more simple design.

2.3 Inspection Mechanic

A precise and reproducible positioning of the component and the probe is required for an exact inspection. By means of the inspection mechanic one or several probes are mechanically moved exactly towards the inspection surface. As the components for this example are designed rotationally symmetric they are installed on a turning device. Thus the ultrasonic inspection of the lateral surface or the front surface can be carried out. By relocating the probe position during inspection travel a line and a surface can be captured and shown as line scan or surface scan.

2.4 Coupling medium

Usually the coupling medium is water. Degassed water is required for inspection tasks by immersion or bubbler technique. It must be guaranteed that no test engineering artefacts by means of air bubbles influence the inspection result. A module for water conditioning is available and essential for the constant quality of the coupling medium and for the inspection result.
2.5 Mechanic control of the inspection process

Depending on the principles of the inspection system the PC controls the inspection process schedule. This includes the mechanic inspection process in addition to the inspection methodology data recording and evaluation. Thus the movement of the probe from home-position to inspection position at the component is controlled namely for each inserted component type.

2.6 Periphery

Various functions can be activated by means of the PROlinePLUS Software. For instance the component part data can be captured by bar-code scan and automatically be assigned to the measurement data set. A component can be colour-marked or designated if it is not ok. Depending on the system design the safety is regularly checked and also the dialogue with possible customer storage mediums and status information.

3. Inspection system depending on application and requirement

PROline is used in the following types of inspection systems:
• Laboratory inspection system designed as table-top unit for temporary use,
• Half automatic (Offline-) inspection system for shift operation, or
• Fully automatic (Inline-) inspection system for 24/7 operation.

The inspection system concept is designed so that the same ultrasonic hardware and software are used for the laboratory system as well as the automated inspection system. The setup and upgrading to have larger inspection systems is at any time possible. Only minor training investment is required.

3.1 Laboratory inspection system

Figure 3. Laboratory-inspection system PROline-mobil, consisting of a notebook with PROlinePLUS Software and mechanic with integrated PROlineUSB
Figure 4. Left: Presentation of an inspection result of a gearwheel. Inspection is in radial direction. In addition to the detection of the introduced inspection defects the evaluation shows a percentage total result. Right: Example of a PROline PLUS inspection result-report following a realised component inspection.

3.2 Automated inspection systems (partly or fully automatic)
The inspection system consists of an inspection station usually comprising three standardised levels.

Figure 5. Half-automatic inspection system for bubbler- and immersion technique with PROline equipment technology

Upper level:
The inspection devices are designed in accordance with the international machinery directive (CE).
The operation of the inspection system may be carried out

- manually by the inspection system operator. Then he is responsible for the handling of the component (inserting and removing the component). In such case a light barrier or a 2-hand-operating activation is integrated in order to avoid crushing hazard of the inspection mechanic, or
- computer controlled via a mechanised component insertion, for instance insertion and removal of the component by robot. Then the inspection device is installed in a secured robot cabin.

Both cases can be setup for the same station. For both cases exists a machine interface so that the inspection system operator may pursue the actual inspection progress. An all-in-one operating unit for operator-machine interaction is ergonomically installed at the system.

Medium level:
The work bench resp. the working surface consists of an inspection basin, which may be designed as immersion- or collecting tank, the mechanic axes for moving the sensors as well as the component rotation disposing of a component seat.
By default adapters are used in order to insert various components in a reproducible manner into the inspection device for inspection purpose.
Optionally either immersion technique, local immersion technique, ponding technique or bubbler technique can be used. In the event that the techniques are to be used alternatingly or side by side the working surface may be enlarged and expanded by modules.

Lower level:
This level is reserved for the water conditioning and designed so that maintenance may be carried out easily.
Furthermore, there are the electric installations and connections if a switch cabinet is not necessary.
For a fully automatic inline production the inspection device can be incorporated into a production line and the inspection results may be integrated in reproducible manner into the documentation system of the component.

Figure 6. Fully automatic inspection device for bubbler technique with PROline equipment technology in operation (Realised with EMAG Automation)
4. Summary

The inspection task and the basic conditions for an ultrasonic inspection of components are significant factors for the design of an inspection system. Apart from the detection capacity the inspection period is decisive for the layout of an ultrasonic inspection system. Due to the corrosion behaviour of the water sensitive components as well as for avoiding following complex process integrated drying stations, the bubbler or local immersion technique is often used. Thus a fast cycle time can be achieved.

These customer requirements are taken into consideration by the modular concept of the inspection system. The customer can chose the suitable inspection system for each component and requirement.