3D VISION SYSTEM FOR HAIRPIN LASER WELDS QUALITY CONTROL

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1. ATOP AT GLANCE: YOUR STRATEGIC PARTNER FOR WOUND STATOR AND ROTOR PRODUCTION

ATOP is the company part of the IMA Group leading in manufacture of machines and automatic lines for the production of wound stators and rotors of electric motors.

Our tasks include development of tailored technology to meet quality and production requirements in all winding and assembly processes.

- **18000 m²** PRODUCTION PREMISES
- **2000 m²** OFFICES
- **600+** COMPLETE AUTOMATIC LINES DELIVERED
- **2.700+** WINDING MACHINES FOR STATORS AND ROTORS DELIVERED
- **490+** PATENTS GRANTED (TOP CLASS PROPRIETARY KNOW-HOW)
- **250+** EMPLOYEES
2. PURPOSE OF THE TECHNOLOGY AND BRIEF DESCRIPTION

- Utilization of a 3D vision system based on the "fringe pattern projection" technique for the quality control of laser welds in the hairpin stator welded wires

- "Fringe pattern projection": the 3D camera projects a stripe pattern to a target [work] by a pattern projection optical system. A 3D shape is acquired by capturing and arithmetically processing the light reflected from the work.

- The quality inspection is performed on each welding joint of the stator.

- Cycle time indication for each welding joint inspection is approx. 0.6 sec.
3.1 WELD TOPOGRAPHY FOR WELD DIMENSIONS

ATOP DETERMINATION

- “Total welded area” and “bare area” in 3D topography of the weld:
  - Total welded area definition:
    - Measurement made by 3D vision system that determines the area of the welding joint in the 3D topography of the weld
  - Bare area:
    - Measurement made by 3D vision system that determines the bare area in 3D topography of the weld

- Based on the minimum and maximum bare area extensions it is possible to define different welding joint quality “levels”.

- The good welding joints are identified based on its welding joint “level”, according to the Customer quality criteria.

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<th>Maximum bare area %</th>
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<td>7</td>
<td>3,0</td>
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</table>

Fig. 1: 3D picture build up by means of CCD picture according to ATOP process.

Fig 2: example of the welding joint quality levels

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3.1 WELD TOPOGRAPHY FOR WELD DIMENSIONS

Fig. 1: internal test to verify the welded area calculated by means of CCD pictures according to ATOP process [left picture] in comparison to the visual inspection [ATOP Lab – right picture].

Fig. 2: picture of bad welding joint detected by the 3D vision system.

Fig. 3: picture from an in-line inspection with the detection of the maximum welding joint cross section area.
3.2 DEFLECTION

- Deflection refers to the distance between the geometrical center \([x', y']\) of the weld at its base and the orthogonal projection on that base of the highest uppermost \([x, y]\) point of the hemispherical weld; where the base is considered to be at a fixed known predetermined depth from the highest uppermost point of the weld.

- The quality criteria is based on the calculation of the distance between red and green centers, according to customer requirement.

  - **Green crosses** ➔ Geometrical center of the welding joint at its base
  - **Red crosses** ➔ Uppermost point of the welding joint projected on the geometrical center plane

Example of the deflection inspection output and relevant distance measurement between the two geometrical centers.
3.3 BUBBLE DEFECTS

- Possible defects to be detected by the 3D vision system are:
  - Presence of porosity on the welding joint surface (concave surface)
  - Presence of bubbles on the welding joint surface (convex surfaces)

- The quality inspection is made by the 3D vision system through top view screening to look for the possible defects on the welding joint surface.

- The operator can set the minimum areas dimension to be searched by the 3D vision system inspection and considered as scrap.

Example of the bubble defects inspection: particularly in the picture is well seen the presence of a weld porosity.
3.4 MAIN DIAMETERS

- The purpose of this quality inspection is to calculate the diameters in the radial and tangential directions [main directions] of each welding joint.

- The radial and tangential directions are the stator main axis, and the measurement is taken according to the following inspection steps:
  - Detection of the radial and tangential directions for each welding joint.
  - According to the above identified directions the welding joints diameters are being calculated.
  - Good or bad welding joints are identified based on Customer quality specifications.
3.5 WELDING JOINT HEIGHT MEASUREMENT

ATOP WELDING JOINT HEIGHT MEASUREMENT DETERMINATION

- Due to the general limitation of the welding joints configuration and their positioning in the stator, it is not possible to use efficiently the 3D vision system to measure directly the welding joint height through a side inspection of the welding joint.

- To overcome the above limitation, ATOP has developed and validated a process for an indirect measurement inspection.

- The taken measurements are providing a smaller height value, confirming a conservative result in comparison to the optical inspection.

- Quality criteria to confirm good welds are based on Customer specs.

Example of two welding joints heights comparison between ATOP Lab measurement and 3D Vision system measurement.
4. ONGOING ACTIVITIES AND R&D ROADMAP

- To replace expensive destructive quality tests, ATOP is targeting to calculate the welding joint pulling force resistance (according the pulling test specification requested by ATOP Customers), without performing the pull test.

- Measured by means of the 3D vision system and ATOP quality inspections process, the methodology under development by ATOP R&D Engineers is to create a correlation between the “main welding joint dimensions” [see Fig. 1], the cross-section areas of the two broken welding joints [see Fig. 2] and the applied pulling force during the test.
THANK YOU
FOR YOUR ATTENTION!

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