Nonconventional Technologies Review
Romania, June, 2019 

# TRASABILITY OF AN AUTOMOBILE BATTERY SENSOR ASSEMBLY

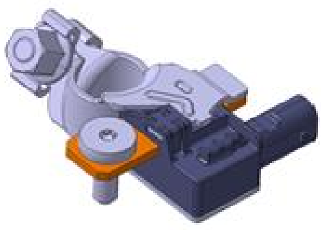
Elena Stela Muncut [1],Bogdan Tanasoiu[2] and Aurelia Tanasoiu[3]

[1] A University "Aurel Vlaicu" of Arad, B-dul Revoluţiei Nr. 77, 310130, România. P. O. BOX 2/158 AR, muncutstela@yahoo.com
[2] A University "Aurel Vlaicu" of Arad, B-dul Revoluţiei Nr. 77, România. P. O. BOX 2/158 AR, bogdan.tanasoiu@gmail.com
3 A University "Aurel Vlaicu" of Arad, B-dul Revoluţiei Nr. 77, România. P. O. BOX 2/158 AR, aurelia.tanasoiu@gmail.com

ABSTRACT: For automotive batteries to have a workable operating mode that also reduce power consumption, they need sensors to measure voltage, current and temperature. The paper presents the concept of a production line with all the essential details starting with the automated assembly line and ending with the final functional testing of the sensors. The electronic part is developed on printed circuit board assemblies (PCBA) and smd (surface mounted devices) components to ensure long term flawless function. Advanced technology of brazing and welding is used to join the different parts of the sensors which are described in details in the paper.
KEY WORDS: PCBA, batteries, sensor, laser, brazing

## 1. INTRODUCTION

Automobile batteries need sensors in order to measure voltage, current, temperature and they can also be used for the start-stop function of the vehicle, in order to reduce fuel consumption. These sensors can have the following forms, figure 1:



a) sensor with bolt,

b) sensor with crimped contact element

c) sensor with welded cable

**Figure 1.** Sensor variants

The IBS sensor is attached directly to the negative pole of the battery through the terminal called a „pole clamp". Perpendicular to the pole clamp is the mechanical part of the battery sensor with consists of the shunt and the grounding bolt, figure 2.

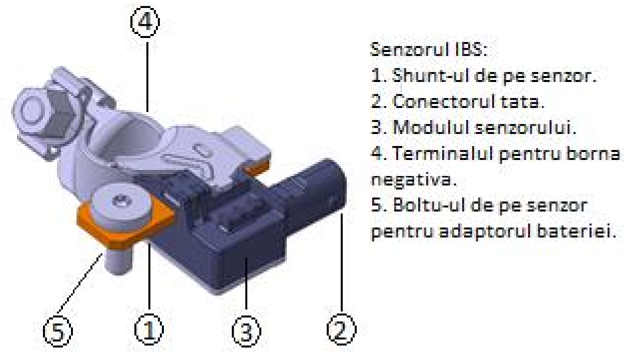



**Figure 2.** IBS Sensor components

The shunt is attached to the electrical circuit of the sensor thus acting as a resistor which measures the indirect current.

## 2. PRODUCTION LINE CONCEPT

The assembly line for the intelligent battery sensor is automated and comprises six modules controlled through an interface which offers access to the database through a HMI (Human-Machine Interface) installed for each module. The process is based on a step-by-step concept.

The assembly line contains the following modules: M11: ICT&Flashing, M10: Depaneling; laser marking; PCBA pressing, M20: SilicaGel StickyTest material insertion, M30: Laser welding, M40: Brazing, M50: EOL (End of Line Tester), M60: Bolt press; labelling and AOI (Automatic Optical Inspection), figure 3.

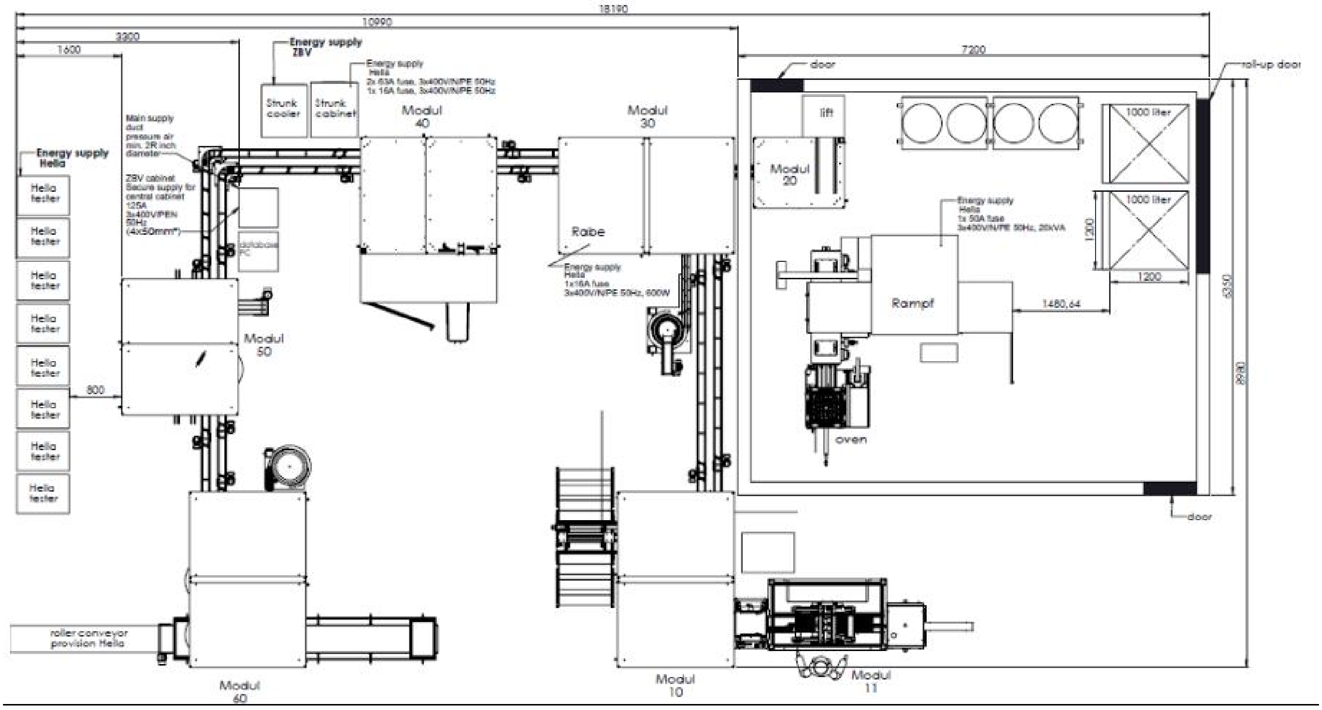



**Figure 3.** Assembly line layout

## 2.1 Module 11 –PCBA Feeding for ICT and Flashing

A PCBA panel (Printed circuit board assembly) is brought into the work area automatically through the automated loading system for the ICT (In-circuit test) and Flashing stations.

The automatic scanning of the DMC (Datamatrix code) from the panel surface follows, in order to check if the correct variant has been loaded. In case the system detects a problem, the station automatically stops and the loaded panel is removed from the process. The first row of the panel containing PCBAs is moved to the flashing adaptor. The connection of the flashing adaptors to the first row of the PCBA panel follows, starting the flashing process of the PCBAs. All defects detected during testing will be 100% recognized by the ICT/Flashing station and the process will not be finalized.

All process parameters and measurements are stored and introduced into the traceability system. The test adaptors return to their home position and the panel advances by one row.

Connecting the first row of tested PCBAs to the ICT station follows, while the second row of PCBAs undergoes flashing. Test adaptors return to home position. The process steps are repeated until the whole panel is tested.

The panel is automatically transported to the next line module with the use of a conveyor.

## 2.2 Module 10 – Depaneling; Laser Marking; PCBA Press

The tested panels will be transported towards the depaneling process using conveyors, or if the process is already loaded with panels, they will be stored in a buffer that can hold up to 50 panels.

Before the process starts, the panel will be scanned using the DMC, to check that the process sequence is correct and the PCBA is correctly loaded.

The panel is fixed using centring pins, after which the depaneling process begins. The system will check the positioning of the panel and if necessarily make the necessary corrections. A robotic arm will grip each PCBA individually while it is depaneled.

The PCBA is removed from the depaneling area and placed on an intermediary platform for the next process. This storage ensures that the PCBA is not damaged during transfer, figure 4.

**Figure 4.** PCBA after depaneling

PCBAs can be populated with SMD components on the top and bottom parts, figure 5.

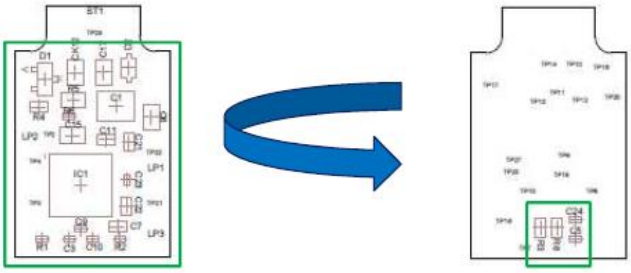


**Figure 5.** PCBA with SMD components on bottom and top.

The status of each PCBA can be checked using the traceability system. The process is repeated until all PCBAs are depaneled. Once the panel is empty, the excess material is removed automatically from the process. PCBAs with NOK status, from ICT/Flashing are stored on a special retesting platform. Scrap material are automatically removed from the process and stored in a special container.

## 2.3 Laser Marking

The cases are fed automatically from the tubes in which they are stored. Each case is marked with an identification number and unique DMC, which are provided by the traceability system (10÷14 characters). Once the case is marked, the presence and quality of the marking is checked. The marking area of the case can be seen in figure 6.

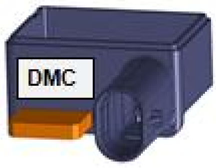



**Figure 6.** DMC marking area

Parts which are OK are placed automatically on a transfer platform. Depaneled PCBAs and the marked housing are preassembled. The identification number of the housing and PCBA are merged, resulting in a unique number for both components.

## 2.4 Module 20 – Potting and Heat Treatment

Housings are transferred from the transfer platform on a platform dedicated to this process. These reach a platform with multiple products positioned for transfer using a conveyor to the potting process. The platform is transferred to an antechamber in which vacuum is produced. After the vacuum is obtained, this is transferred to the main chamber. The platform is positioned beneath the silicone dispersion head. Each housing is scanned in order to check previous processes.

The dispersion machine starts the process of filling the housing with silicone. The information relevant to the process are loaded into the traceability system after the process is finalized, for each product.

After the process is finalized, the platform is transferred to a chamber in which the pressure is adjusted to atmospheric pressure over 60 seconds.

## 2.5 Module 30 – Lid Feeding and Assembly Using Laser Welding

A fixture containing a silicone loaded housing is automatically fed using the conveyor. The parts are lifted from the fixture by a robotic arm and placed on a fixture feeding the laser welding process. Parts containing excess silicone are automatically eliminated from the process. The DMC from the part is scanned to check that is has undergone the previous work steps and if their status is PASS, otherwise the parts are eliminated from the process and stored in the box containing NG components.

The sensor placed on the lid feeding station checks if they are correctly oriented. When the part that its o be welded and the lid are in fixed position, the welding process begins. After the process, the parts are transported either in the line storage area or on a fixture that feeds the next process, figure 7. If the parts are not correctly welded, they are eliminated from the process.

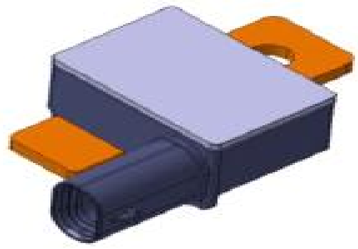


**Figure 7.** Housing with welded lid

## 2.6 Module 40 – Pole Clamp Feeding, Solder Band and Brazing

The station is fed by a fixture that contains the part from the preceding process. The DMC is checked for the part correct traceability. The part is moved to a fixed position and solder tape is fed for the copper element and it is cut at the desired dimension.

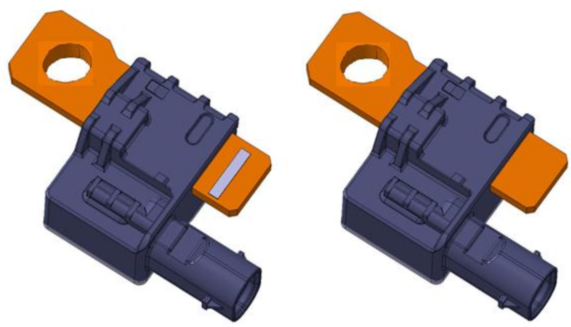


**Figure 8.** Copper element with solder tape attached

The position of the solder tape needs to be according to the specification and is checked using video cameras. The results are transmitted to the traceability system, figure 8.

## 2.7 Brazing Process Parameters

The length of the solder band after cutting must be within the tolerance +/- 0.08 mm. The length needs to be adjustable between 5 – 10 mm, figure 9.

The positioning of the soldering tape needs to be adjustable in the X- and Y- axes. The camera system must be capable to detect the position of the solder band on the copper element.

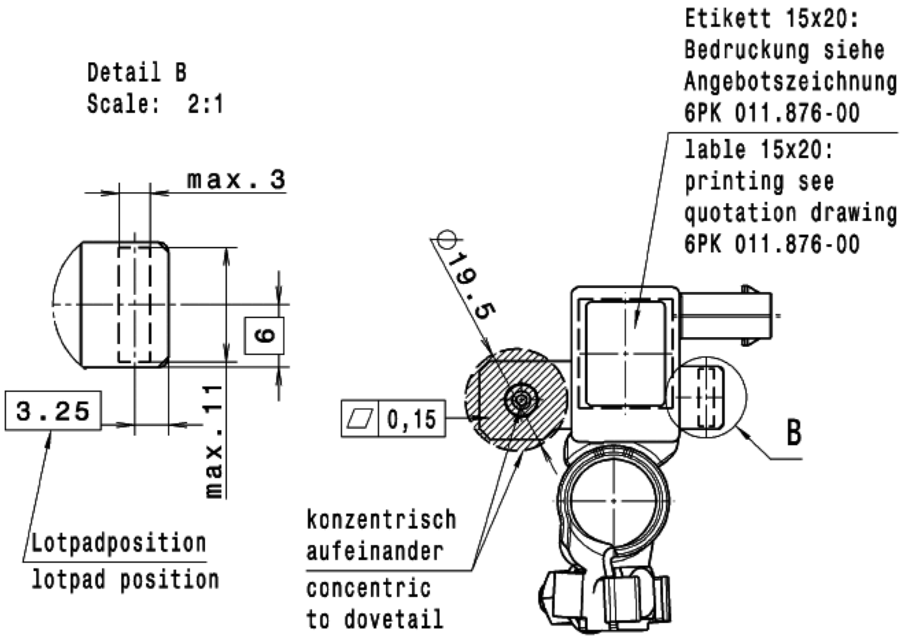



**Figure 9.** Positioning of the solder band.

Materials used: the part containing the housing with silicone inside, the welded lid and the solder band, fed from a roll. BrazeTec S15. Material specifications, solder tape: nominal composition [wt.-%] Cu; Ag 15; P 5, maximum allowed impurities [wt.-%] Al 0,01; Bi 0,030; Cd 0,01; Pb 0,025; Zn 0,05; Zn + Cd 0,05, approximate melting temperature 645 - 800°C (DIN EN 1044), working temperature 700°C (DIN EN 1044), density 8,4 g/cm³, electrical conductivity 7,0m/ Ωmm$^2$.

## 2.8 Feeding Contact and Brazing Elements

An automated system is used. The contact element on the housing is mechanically fixed. The contact element is pushed through the window on the housing all the way through, such that the edges in which the contact element and the copper element are brazed are aligned, figure 10.

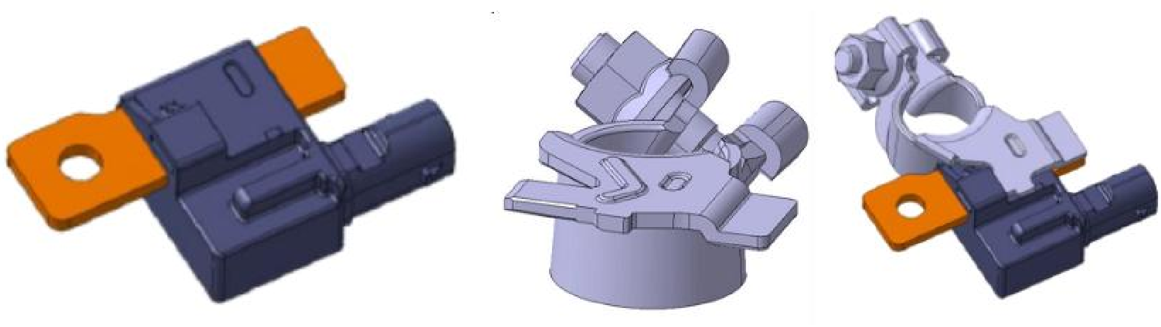


**Figure 10.** Components used in the brazing process and the resulting part.

In case the contact element is not in the final position, the brazing process is not completed and the part is eliminated from the process. If the part is in the correct position, the process continues. In case the part has not been correctly brazed it is eliminated from the process. After the process is complete the part is released on the conveyor which has a cooling system.

## 2.9 Process Parameters

The module needs to be capable to utilize various models of contact elements.

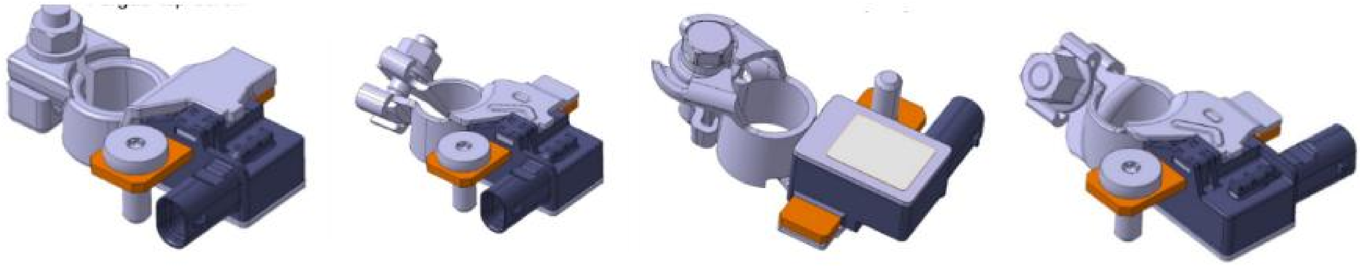


**Figure 11.** Contact elements used in the process.

The fixture on the which the part lies during the welding needs to protect against solder contamination. The process needs a cycle time less than 5 seconds. The batch number of the contact elements needs to be registered in the traceability system. Scanning a new batch is only possible once the feeding conveyor is empty.

## 2.10 Inserting the Contact Element

The force and speed of the insertion machine needs to be adjustable. The detection system needs to be able to detect the presence of the screw and the variant of the used contact element. The moment that the edges of the contact element and the copper element of the housing are aligned these must respect a tolerance of ±0.05mm, figure 12.

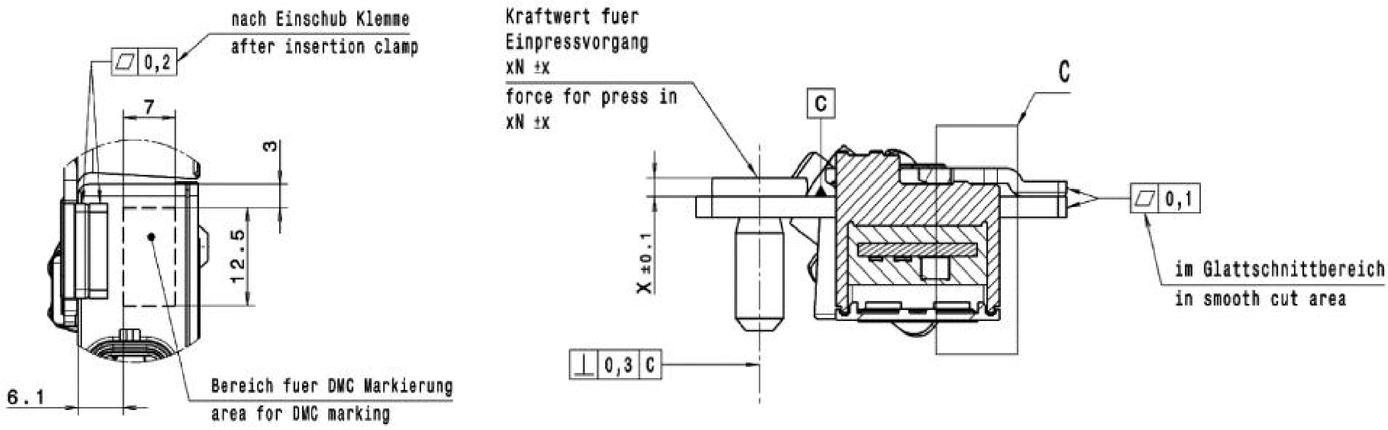



**Figure 12.** Alignment between the contact element and the housing copper element.

At the time of insertion of the contact element, the solder band must not be moved or damaged.

A lack of solder tape must be detectable the moment when the electrodes come down during welding. Monitoring and registering process parameters (maximum current, displacement, power, resistance, voltage, welding time) is done. The holding time of the electrode after the welding process must be 3 seconds. The welding point must hol dup to a torque of 9Nm +/-5% (breakage test). The electrode with polarity - is applied to the contact element. The electrode with polarity + is applied on the copper element of the housing, which helps dissipate the resulting heat. The electrodes must be permanently parallel.

## 2.11 Module 50 – Functional tester

The fixture containing the part from the previous process is fed into the testing process. The part is scanned and checked if it has undergone all the previous process steps and if it is within determined parameters.

**Figure 13.** 3D Model of IBS sensor before testing

If the part is not OK, it is eliminated before being tested. A robotic arm transfers the part from the transfer fixture to the testing fixture. The part is tested and calibrated, figure 13.

## 2.12 Process Parameters

The robotic arm which transfers the sensors from the transfer fixture to the test fixture must obey a cycle time of 5 seconds. The gripping system of the arm must be capable to detect the presence of the part.

The current during testing can reach 880 amperes. The fixture containing the part from the previous process is fed into the bolt pressing process.

A scanning camera scans the DMC and checks if the part has undergone the previous steps in the traceability system. If the checked part is OK, then it is moved using a rotating table to the bolt pressing station, figure 14, otherwise it is eliminated from the process. The bolt is fed using an automated system.

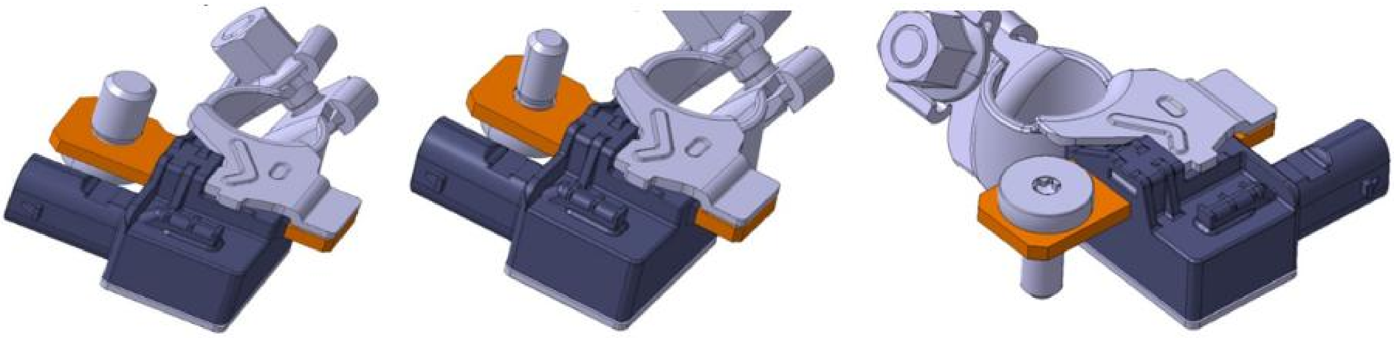


**Figure 14.** Bolt orientations on the IBS sensor.

The bolt is picked up by a robotic arm from the feeding station and inserted into the hole on the housing contact element. An automated press presses the bolt into the housing and checks if the force exerted is within the specified parameters, figure 15. If the bolt is not correctly pressed, the part is eliminated from the process before it is packed.

**Figure 15.** Parts used in the process and resulting part.

Each batch of bolts must have a traceability label with the source batch. The label is scanned manually to register the batch into the traceability system. Scanning a new batch is allowed only when the feeding system is empty.

Bolt pressing:A servo press is used and is capable of pressing up to a force of 50 KN. The pressing process parameters are permanently monitored using the assembly line database. After the pressing process, the part must not be damaged. The fixture on which it lies must withstand the forces exerted on the part. The pressing distance is between 1.5 – 2.5 mm, figure 16.

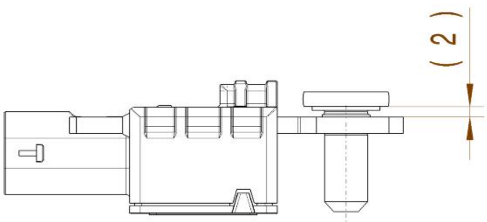



**Figure 16.** Bolt pressing distance

Labelling process:The fixture containing the part from the previous process is fed into the labelling process. The part is moved using a rotating table to a fixed position on the labelling station. The labelis applied using an automatic printer. If the part is labelled correctly, the part is released from the labelling station. Otherwise, it is eliminated from the process.

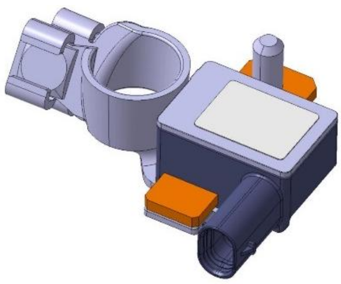


**Figure 17.** Labelled IBS sensor

AOI process (Automated Optical Inspection): The fixture containing the sensor is transferred into the process from the previous station. The DMC is scanned to check all the previous steps. A robotic arm picks up the sensor andpositions it in front of the AOI camera. The camera checks if the label contains the correct information, if it was positioned correctly, the integrity of the bolt, label and lid. The system does not allow a sensor to be scanned twice. If the resulting status is OK, the sensor is transferredto the next step, otherwise it is eliminated from the process.

Packing process:The station is fed with a box on which a traceability label is applied, on which the part identification number is printed, the batch, the date of production, and a barcode containing all the information from the label. The label is scanned and the batch number is assigned in the traceability system to each part in that specific box. Using the robotic arm from the previous station, the box is filled with 40 sensors. The moment the box is full, it is released from the process for pelleting.

## 3. CONCLUSIONS AND REQUIREMENTS

As a result of the study, the assembly area for the sensors has 7 specific work zones. The following rules need to be followed: during the process, PCBA must be detected and positioned accurately by the fixtures from the station using centring pins. During testing, the pins are not allowed to touch any other components of the PCBA other than those tested.

The unique identification numbers of the panels are registered in the traceability system after the DMC from the panel was scanned. The unique number will be written in the ASCIC on the PCBA during its programming.

The strain measured on the panel during testing must not be higher than 500 µm/m. The testing head must not damage the PCBA. Retesting must be available using the HMI function.

All robotic arms, fixtures and feeding systems must be changeable in less than 5 minutes. The number of depanelings completed by the drill bit must be monitored and a predefined number of uses must generate an automated warning. Deviations in the depaneling system must be within +/- 0.1mm. Deviations of the positioning system must be within +/- 0.05mm.

The surface of the PCBA must be clean after the process was finalized. The distance between PCBAs must be 1.6mm. The depaneling router bit diameter must be between 1.1mm and 2.5mm. The precision of the robotic arms must be: +/- 0.05mm (on each X, Y, Z). The depaneling station must have an exhaust system built in.The process must stop automatically if this exhaust does not work. The station must check the integrity of the router bit before starting the depaneling process.

The atmosphere within the station must be ionized to avoid electrostatic discharges.

## 4. REFERENCES


1. Coniglio, N.Mathieu, A.Aubreton, O. andStolz, C. *Weld pool surface temperature measurement from polarization state of thermal emission.* Quantitative InfraRed Thermography Journal, Taylor and Francis, 2016, 13 (1), pp.83-93
2. *** *Material and applications*, parts 2, volume 4, pp 135-155
3. Muncuţ,E. *Influence of temperature on the thermoemissivity coefficient in the aluminium /copper brazing*, Sudura XXI, nr.3, 2011**,** ISSN 1453-0384, pag. 27-30. http://www.csa.com/factsheets/supplements/weld
4. Mathieu, A, *Etude de l'assemblage heterogene acier/aluminium obtenu par faisceau laser*, docteur de l'universite de Bourgogne 29 novembre 2005
5. Katayama, S.; Mizutani, M., *Laser welding of aluminum and steel*. Proceeding of ICALEO'03 (Jacksonville, USA), 2003, CD-ROM.
6. Muncut E., Perianu, A. Glavan D., Sima Gheorghe, *Structural Analysis for Joining Dissimilar Thin Sheets with CMT* (Cold Metal Transfer) Process, Structural Integrity of Welded Structures XI 03-05.06.2015, Advanced Materials Research volume 1111, pp. 49-55. ISSN 1022-6680,
7. Sima, Gh., Lile, R, Glavan, D. and Muncut, E., *Management, Traceability and Control ol Industrial Processes*, Proceedings of the 6th International Workshop on Soft Computing Applications SOFA 2014, Volume 1, Series: Advances in Intelligent Systems and Computing, Vol. 357, Editors: Valentina E. Balas, Lakhmi C. Jain, Branko Kovačević, Springer Verlag, 2015, ISBN 978-3-319-18415-9 (ARC Cat. C, SCOPUS, ISI Proceedings), http://www.springer.com/engineering/computational+intelligence+and+complexity/book/978-3-319-18415-9