Micro-CT application within Automotive R&D: Optimising Metal Weld joints in automotive sensors

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Aims

Sensata Technologies is a world leader in pressure sensing technology. One of the key industries in which Sensata operates is the Automotive industry, supplying sensors to all of the household name OEMs. As sensors become more and more integral in the operation of vehicles it is the duty of suppliers like Sensata to ensure these products are designed to last the lifetime of the car and beyond.

Micro-Computed Tomography has been introduced in Sensata as an analysis method to aid research and development and to provide a method of non-destructive failure analysis. The technology is currently being used in the following applications: assessing injection moulded plastics, identifying failed electrical components; assessing adhesives and many others.

This paper discusses the use of Micro-CT to optimize a metal laser-welded joint (figure 1) between a connector and lead-frame of a sensor located in the engine of an internal combustion vehicle. The optimisation of this joint is an iterative process. Traditionally it would have been necessary to assess a number of sensors at each iteration of the weld settings by conventional metallography and microscopy techniques, requiring extensive man-hours of technicians and design engineers. The introduction of micro-CT analysis allowed the development time to be cut significantly by giving design engineers feedback on weld joints within 24 hours rather than several days or weeks. The non-destructive nature of micro-CT also means the parts are usable for testing after the weld joint has been analysed.

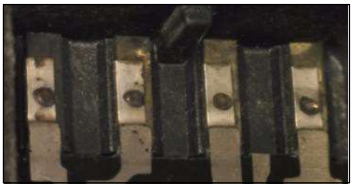


Figure 1. Weld joints between connectors and lead frame

Method

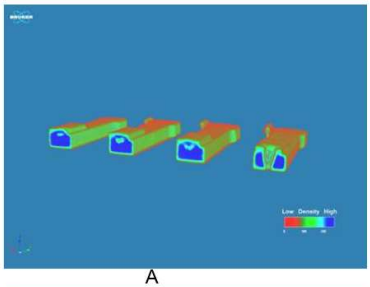
Laser spot welding of metal components is a topic which is covered in literature (Yilbas and Kar, 1997), (Tao et al., 2008). The literature gives a great understanding of the welding process but for the specific purpose of laser spot welding the sensor components it was necessary to perform an iterative trial-and-error development process. Initial laser weld settings for the optimization were established based upon visual inspection of several of the preliminary iterations. Criteria was set out for what would constitute an acceptable laser weld. The criteria was as follows:

- Good melt must be achieved on lead frame and connector, resulting in both

components being joined.

- Over-melting resulting in a hole through the spot weld location is not acceptable
- Voids should be kept to a minimum to ensure long-term weld integrity.
- A high level of sample to sample consistency must be observed

Results



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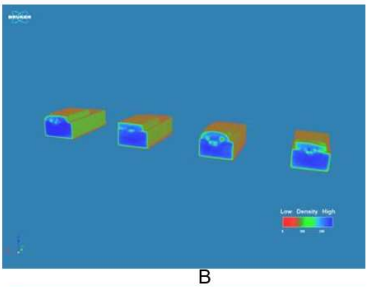

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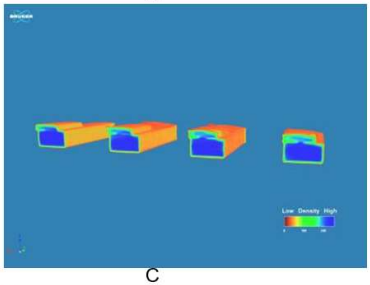

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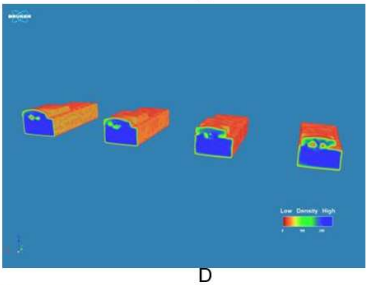

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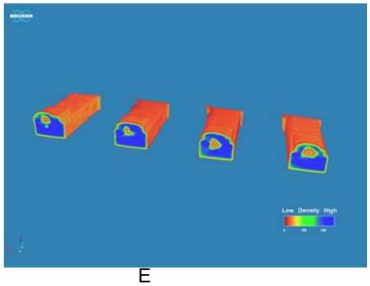

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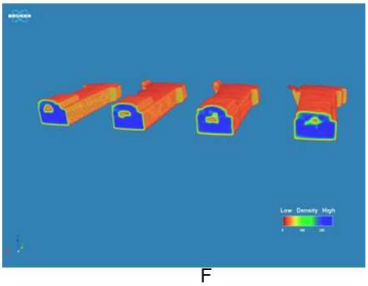

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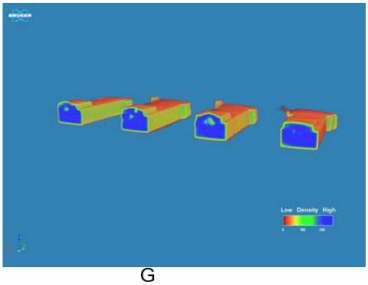

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Figure 2 (previous pg): Sample from each iteration of laser spot weld optimization. A) Initial laser weld settings caused too high melt on one joint causing melt through material. B) Inconsistency of weld joints, one shows good weld with some voiding, others haven't melted enough. C) Poor melt resulting in poor joint. D) Better melt but inconsistent over four joints resulting in some poor joints. E) Good melt in all four joints, consistent but void is large and potentially problematic. F) Good consistency of melt over four joints, void is still larger than preferred. G) Good consistency of welds, good melt, voids are still present but at a more acceptable level.

Three samples were welded, scanned and analysed at each iteration of weld optimisation. The images shown in figure 2 are screenshots from one sample of each iteration of laser weld optimisation. The first iteration of welded parts showed poor weld consistency within single parts and across the three samples. The sample to sample consistency improved vastly over the optimization process and the welds within each sample also showed a significant improvement in consistency as well as weld quality.

Conclusion

The implementation of micro-CT analysis to assess laser spot weld quality meant the time to complete a weld optimisation was more than halved and the man-hours required to complete the process improvement was reduced by over 75%.

Automation of the micro- CT scanning process allowed for utilisation of down time such as evenings and weekends without the need for an operator. The use of an auto-changer carousel on the Bruker Skyscan1275 meant that for each iteration of the process optimisation, all 3 samples could be set up for scanning at once and left to complete. The use of batch reconstruction also meant that all parts could be reconstructed consecutively without the operator needing to be present.

The design engineers involved in the project were able to use the results of this optimisation to act as a base for subsequent validation. As a result of the success of this project, micro-CT scanning is being adopted by more designers as a key analysis method used during design verification and product validation.

References:

Tao, W., Li, L., Chen, Y. and Wu, L. (2008). Joint strength and failure mechanism of laser spot weld of mild steel sheets under lap shear loading. Science and Technology of Welding and Joining, 13(8), pp.754-759.

Yilbas, B. and Kar, A. (1997). Laser spot welding and efficiency consideration. Journal of Materials Engineering and Performance, 6(6), pp.766-770.