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NDE Sensors for Traceability by Material Fingerprints

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Summary:
The clear identification and traceability of components during and after processing is an essential prerequisite for the development of self-organizing, adaptive value chains. Conventional object markings such as labels, barcodes, etc. usually cannot remain permanently and undamaged on the object. Therefore, a markerfree technique is developed and first results are shown.

Keywords: Identification, markerfree, fingerprint, coldforming, traceability

Background, Motivation an Objective

In public, the topic of traceability is mainly considered from the point of view of legal regulations, standards and guidelines. In the increasingly globally networked world of production, however, this "traceability" also serves to safeguard production and reliably detect product counterfeits. Only the complete traceability of products, semi-finished products and raw materials enables the comprehensive monitoring and control of globalized flows of goods. Artificially applied object markings are only suitable for this task to a limited extent, since they cannot remain permanently and undamaged on the object. Even optically detected "natural" features of the surface can only be used to the extent that the surface of the component is heavily modified by a processing step (e.g. forming or painting). To overcome these limitations, a traceability system for metallic materials, with a focus on coldforming applications, is developed, which uses information from the interior of the component, i.e. intrinsic structural features of the material, similar to a fingerprint of the component, to identify the latter as a unique individual.

Description of the New Method or System

First experiments were carried out on tensile-samples made from HC280LAD steel. This sample geometry was used, because it provides a flat measuring surface and it allows to apply a defined uniaxial tension in order to generate different levels of plastic deformation. This allows to investigate, if the sample still can be identified after plastic deformation, as it will occur in sheet forming process. In a next step, the fingerprint method was tested on press parts from real industrial production. Here, a heavily formed press part was used. The first test were performed with a conventional single coil eddy-current system. The eddy-current sensor was moved over the measuring area of the tensile-samples in 2D meandering scan. Subsequently, a low-cost alternative in the form of Texas Instruments inductance to digital converter (LDC) was used. In order to extract information from the measurement data acquired in this way that allows the components to be identified, preprocessing is required. This means that disturbance variables such as temperature-related signal changes and lift-off effects must be compensated. The effect of lift-off on the fingerprint in terms of SNR is shown in Figure 1.

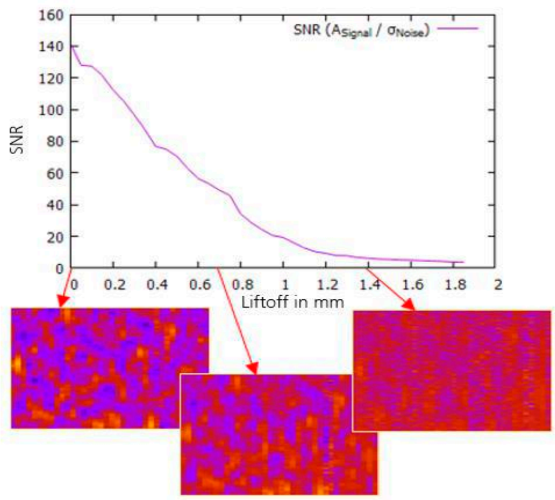

Fig. 1. Effect of the Liftoff on the SNR of the calculated fingerprint.

Since temperature changes are expressed approximately linearly in the measured impedance of the eddy current measurements, they are compensated by using simple linear regression.

Subsequently, lift-off effects are compensated. For this purpose, lift-off curves are first determined on a large number of measurement positions on the material to be investigated, from which a (material-sensor specific) mean lift-off curve is then calculated. The information used for identification (hereinafter referred to as the fingerprint) results from the deviation of the individual measured impedance values from the mean lift-off curve. Various machine learning tools can be used to compare two fingerprints to determine if they come from the same measurement position of the same component. While for small datasets good results could be obtained from a combination of optical flow and correlation, for large datasets better results are obtained using Siamese convolutional neural networks.

Results

In the case of simple tensile specimens, the fingerprint is merely stretched to the same extent as the tensile specimen. In this case, an accuracy of 100% was achieved for the identification. The measurement and identification of real components is somewhat more difficult. Figure 2 shows the fingerprint of a measurement position on a sheet metal, which was subsequently formed into a part for the rear lamp. Figure 3 shows the fingerprint after deformation, where in the upper right corner one can see artifacts or noise, because the material is bent away there. The measurement position of the deformed component is shown in Figure 4.

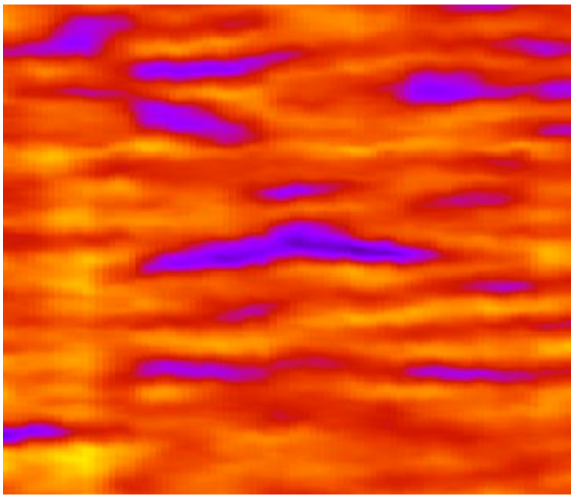

Fig. 2. Fingerprint image on the plane unformed sheet

It can be clearly seen that for identification purposes, frugal features are repeatedly measurable even after deformation. Due to the small number of samples and the resulting small data set in combination with the rather large change of the fingerprint, it was not yet possible to successfully train a classifier. With greater volume of training data, this can be addressed.

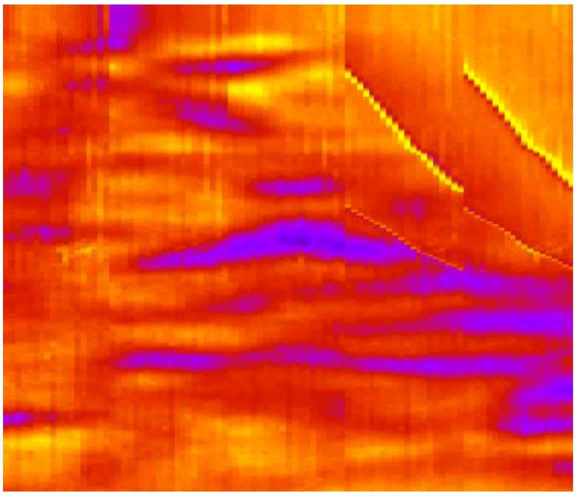

Fig. 3. Fingerprint image on the formed component

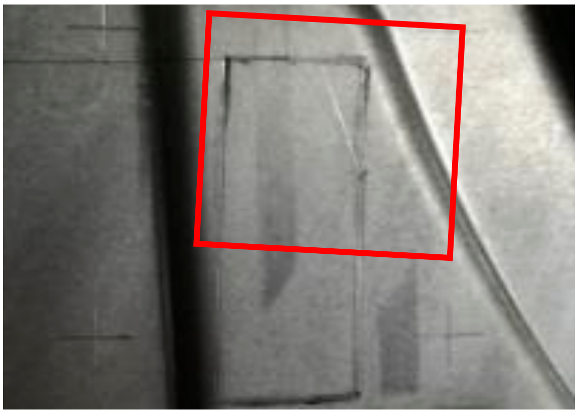

Fig. 4. Formed component with the marked measuring position

Conclusions

The basic feasibility of the developed method was thus demonstrated. However, further work is needed to develop this into an industry-ready solution. The following work includes investigations of the relationship between the microstructure and the measured fingerprints, optimization of the compensation of disturbances, minimization of the measurement time and the necessary development of an array solution.

It is obvious, that especially the combination of both electromagnetic NDE applications – material characterization and part identification - carries enormous potential for process improvements in the value added chain of sheet metal processing, e.g. in automotive industry. The possibility to trace a metal sheet with all its material properties "from the cradle to the grave" would offer complete new possibilities for self-organizing, cross-company production networks.