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LOCAL LASER MARKING – NEW TECHNOLOGY IN THE IDENTIFICATION OF STEEL PARTS

The importance of identification of machines in the field of maintenance becomes more and more significant. In the field of mechanical maintenance or especially in large-scale production serious difficulties cause to identify various metal parts which have similar form and/or size during technological process. The paper based and printed barcode seemed a safe resolution to this purpose. Unfortunately during the repairing or renewal process the paper based barcodes of steel parts very often were destroyed or damaged, the currently applied paper based and painted codes can cause data losses. This is the fact which indicated the research of steel marking system. In this type of marking the material contains the signs. Other advantage of this system is the readability beneath from painted layer.

Keywords: *Advanced materials, laser beam induced transformation, low carbon steel, barcode, eddy current loss, Fluxset sensor.*

1. Introduction

In this paper some new results of laser marking will be presented obtained during CO_2 laser irradiation. This type of marking is considered to apply as barcode for identification in industry and production logistics. The physical basis of the marker evolution is a local phase transformation in the vicinity of the surface in a low and high carbon steel occurring as a consequence of rapid heating and cooling process. A special Fluxset sensor [1] was applied for the read out which is based on eddy current measurements. The spatial resolution of the marker density will be determined from the point of view of applied sensor. The codes can be successfully detected using this sensor, even beneath the 1 mm painted layer. The markings are thermally stable enough to use them as barcodes in the field of maintenance.

The productions of laser marking on the surfaces of rails have been described in [2]. This type of marking is considered to apply for the detection of thermal induced stresses, as well as to produce bar codes as signals on low carbon steel surfaces for production logistics. The thermal stability of markings has of a primary importance for any application (particularly in the case of magnetic reading out technique like (i.e. using Barkhausen effect, eddy current testing). The fitting of the scribing parameters (power density, scanning rate, distance between the individual marks) are also important requirement for the point of view the reading out.

The physical basis of the reading out is the local phase transformations and the local modifications in the stress field around the individual markers. It is caused by the rapid heating and cooling processes during the laser-metal interaction.

The appropriate reading out is usually based on magnetic or classical eddy-current measurements. In our measurements a special sensor was used to reading out. It was found, that markers produced in 100-300 W power ranges with the 6 mm distance between them are successfully detectable using this sensor. The markings are thermally stable enough to use them as barcodes in production logistic and car industry to mark the car body sheets (Fig. 1). Magnetization processes are also involved in the development of eddy current losses therefore the local modification of the domain structure is also important in the process. Therefore, the direct observation of magnetic properties (domain structure in the surface layer) can also be important from point of view reading out. Some results associated with the outlined topics will be presented in this paper.

2. Experimental details

2.1 Materials

Samples are prepared from cold rolled low carbon steel sheets (C content 0.1 Wt%; Si 0.34 Wt%; Ti 0.06 Wt%; Mn 0.85 Wt%;). The sheets were covered with 0,01 mm thick phosphate layer. As the carbon content is low, the investigated sheets can be regarded

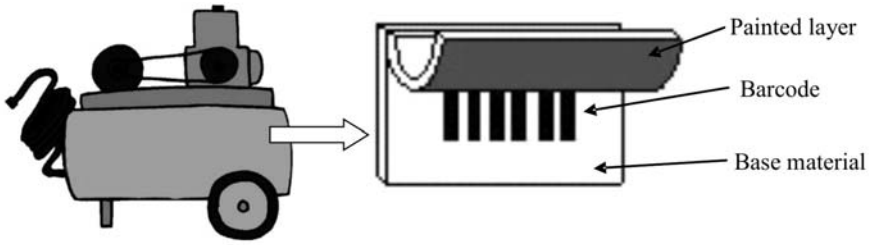

Fig.1.Identification of machines

as soft magnetic. The Fig. 2 shows schematically the local laser treating process and modal structure of laser beam. The applied diameter of laser spot was 1 mm and the movement speed was 1200 mm/min.

2.2 Principle and device for the reading out

The ECT probe

The principle of the applied readout device is described in [3]. The sensor consists of a magnetic field detector (i.e. Fluxset sensor, see in Fig. 3a) and pancake shaped exciting coil, which generates alternating magnetic field perpendicular to the specimen surface. This exciting field induces eddy current in the inspected conductive plate. The magnetic detector measures one of the horizontal (i.e. surface parallel) component of the field only, and it is located exactly in the axes of the exciting coil between the coil bottom and the specimen surface(see in Fig. 3a and b). The Fluxset magnetic sensor based on ECT (eddy current testing) is working at 20 kHz excitation frequency trough 1 mm thick plastic insulation (i.e. probe lift-off, the "*a*" parameter in Fig. 3b).

The described ECT method has two particular advantages for the laser scribing application. It is based on alternating magnetic field excitation despite of any constant (DC) methods such as the leaking flux technique. That means, it does not relay on the previous magnetic state of the inspected specimen or it does not require the magnetisation or demagnetisation in its whole volume prior to the measurement. On other hand, the probe is based on high sensitivity Fluxset sensor, which has high spatial resolution as well. The separation of the excitation and the sensing in the probe makes possible to increase the probe resolution, therefore the density of markers as well, without any risk of degradation in the sensitivity of probe. It can be observed well that even the effect of the lowest energy produced markers are clearly detectable. As a consequence, this arrangement is sensitive exclusively for magnetic field perturbations caused by the asymmetric distribution of the eddy currents in the presence of any localised changes of the magnetic material property inherited from the effect of the laser scribing

To detect the local changes of the conductivity as well as of the magnetic property in steels is traditional task for ECT methods. The ECT also offers contact free operation, which makes us possible to detect the existence of the transformed volume of alloy caused by the scribing even below the protective coating (like the painting). The transformed area, which is produced by using varying power density laser beams in which the magnetic behaviour differs from the untouched surrounding areas due to this treatment, can be made visible by help of the ECT technique.

2.3 The physical background of marker formation obtained by laser scribing

The laser scribing represents rapid local heating and subsequent rapid cooling in the vicinity of the surface of irradiated sheet. The Fig. 4 shows the markers on the surface of a low carbon steel. In Fig. 5 the photomicrograph on the cross-section of transformed zone can be seen. The resolution of micrograph is too low, consequently the structural changes are not visible in Fig. 5. As a consequence of the entrapped C atoms (metastabil solid solution formation) together with the heat shock induced stresses arising from the misfit between the heat affected and unaffected zones causes a local resistance increase in the sheet. This is the basis of the reading out.

The control of energy density is necessary in order to avoid the local surface melting (overheating effect). On the order hand the energy input should be high enough to rise the local temperature for the enhancement of solution of carbon in the austenite phase.

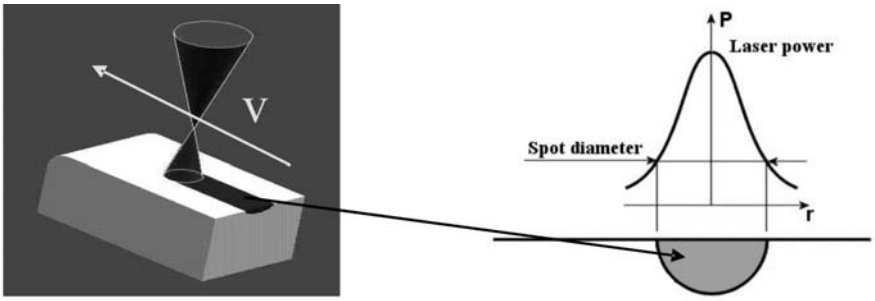

Fig. 2. Process of laser scribing and modal structure

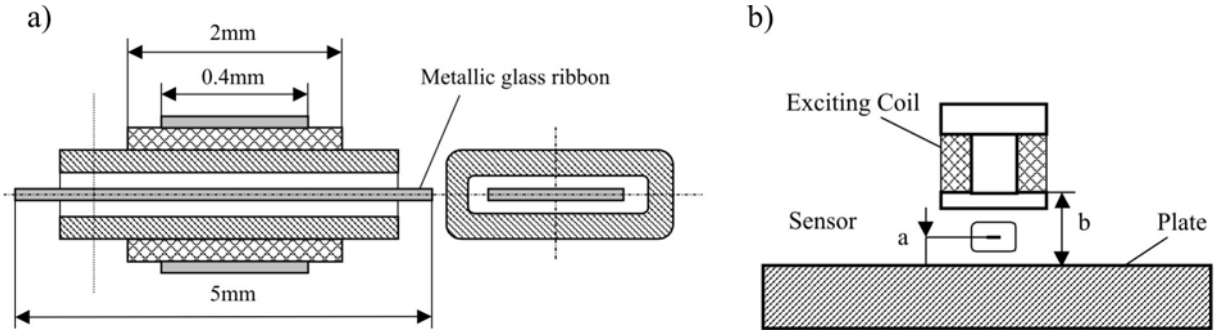

Fig. 3. a) Fluxset sensor geometry b) Probe set-up

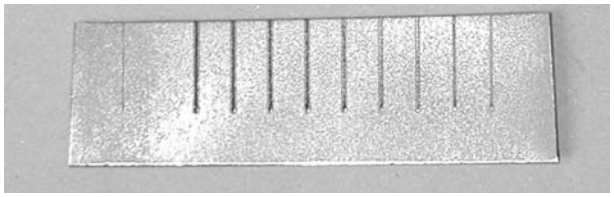

Fig. 4. Laser scribed low carbon steel sheets applying various laser power (100-300 W) and constant distance between marks

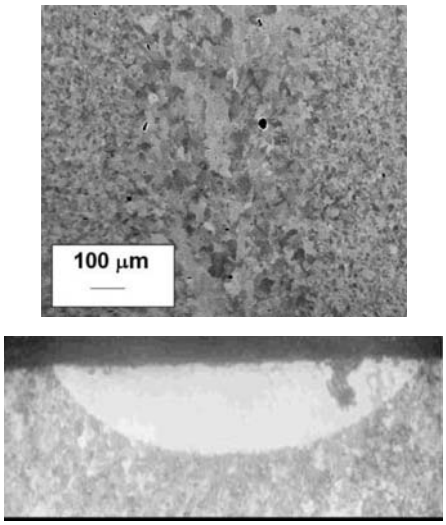

Fig. 5. Photomicrograph of laser marked sheets. Left: low carbon steel (0.1 C%); right: high carbon steel (0.6 C%)

2.4 Marker stability and the resolution of reading out

Fig. 6 does supply a qualification of the laser scribed markers. The position of periodic markings versus of the distance are plotted here. Distance between marks was 6 mm, the applied laser density is changed between 100 W to 300 W (raised by 25 W). The physical position of marks are at around of the inflectional points of signal curves. In this figure the influence of long time heat treatment on the shape of signal curves is also illustrated. It is obvious that the amplitude of the signal curve increases due to the subsequent heat treatment. Meanwhile no change in the position of maxima can be detected. These facts do confirm the sufficient thermal stability of markers from the point of view read out.

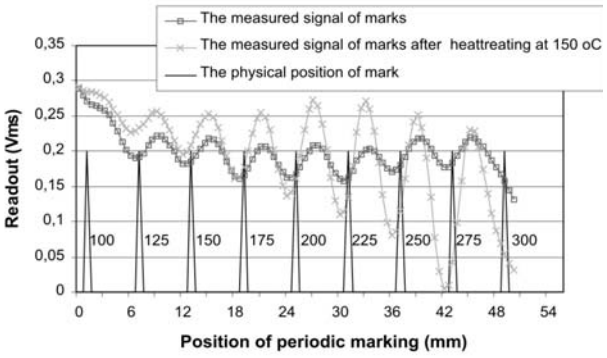

Fig. 6. Readout on laser scribed steel sheets using various laser density

The information density can be increased by lowering the distance between the individual markers. Therefore, the distance between the markers is also important factore from point of wiev of reading out. In principle, the density of markers can be technically also increased by applying the same laser power density as it is illustrated in Fig. 7. In this experiment the distance between the markers was gradually decreased using constant power density (see Fig.7). Fig. 6 shows the concrate arrengements of signs. The beginning overlap between the heat affected zones associated with the individual markers represents the limit of spatial resolution which can be attained with a given set of scribing-readout system.

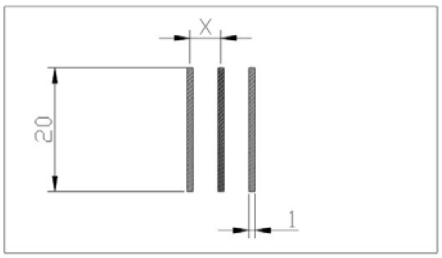

Fig. 7. The marking arrangement produced by constant (150 W) laser power density and spot diameter (1 mm) and various distance between marks

For example, the power density was 150 W, and the distance between markers was narrowed. The power density in a surface unit:

$$A = (d^2 * \pi)/4 = (l^2 * \pi)/4 = 0.7854 \text{ mm}^2 \quad (1)$$

$$Pd = P/A = 150\text{W} / 0.7854 \text{ mm}^2 = 190.98 \text{ W/mm}^2$$

Pd: power density in a surface unit [W/mm^2], *P* : applied laser power [W], *d* : diameter of laser spot [mm], *A*: area of laser spot [mm^2].

The results of readout obtained by the same Fluxset sensor is completely differ in the case of applied markers distance as the Fig. 8 shows. In this Fig. can be seen the results of reading out, when the distance between marks was diferent. The sensor can detect the individual marks when the distance between marks is relatively high. The arised heat affected zone around the marks influence the reading out.

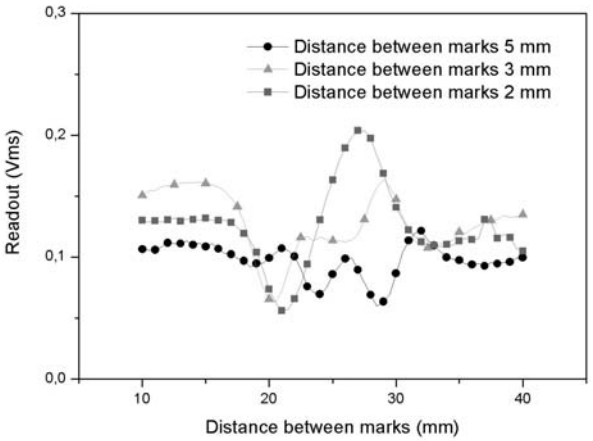

Fig. 8. The result of readout on laser scribed steel sheets. The applied laser density was 190 W/mm^2 (150 W)

3. Conclusions

Stable markers can be produced by the laser scribing within the power density range of 100-300 W (resulting good signal/ noise relation during the reading out). The distance between marks has of a crucial role from point of view of reading out. The exact reading out depends on the actual extension of the heat-affected zone around marks. Though the resulting markings are not always directly visible by light microscope, their thermal stability is sufficient up to 150 °C. Therefore one can conclude, that the FLUXSET type eddy current probe is suitable for detecting the laser-scribed markers on the surface of (0,1% C) Fe-C low carbon steel sheets even in the case of the signals produced by the lowest energy described. To reduce the length of barcodes should be important applying smaller laser diameter hereby decreasing the extension of heat affected zone.

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