Line Laser Scanning Thermography System for Paint Thickness Estimation

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ABSTRACT

In this study, a novel paint-thickness visualizing (PTV) system is proposed using a line laser thermography and image processing algorithms for the paint thickness estimation. The prior paint-thickness techniques have a high accuracy for estimating paint-thickness on steel structures, but the technical hurdles exist for using real structures such as contact type and single point inspection. The proposed PTV system offers advantage of non-contact and non-invasive paint-thickness inspection over the existing techniques. Once the proposed PTV system generates thermal waves on the steel structure surface using line laser beam scanning, the corresponding thermal responses are measured using an infrared (IR) camera. According to the paint thickness, the thermal wave reflecting phenomena alters at the layer between paint and steel structure and the newly proposed image processing algorithm quantifies the amount of the altered thermal wave reflection with visualizing the paint-thickness distribution. The performance of the proposed PTV system was verified through lab scale tests with painted steel structure. Six types of paints which are used for a real steel-box girder bridges were used for the verification and 40 μm of the paint thickness difference was successfully visualized.

1. ELECTRONIC SUBMISSION

The industries requires the efficient management system for the large scale infrastructure (Casas JR, 2015). In case of the paint thickness estimation, the prior paint-thickness techniques have a high accuracy for estimating paint-thickness on steel structures, but the technical hurdles exist for using real structures such as contact type and single point inspection (Casas JR, 2015). To overcome the remaining technical hurdles, a paint-thickness visualizing (PTV) system is proposed using a laser based thermography system and enables the fast and accurate paint thickness estimation.

2. PAINT-THICKNESS VISUALIZING SYSTEM

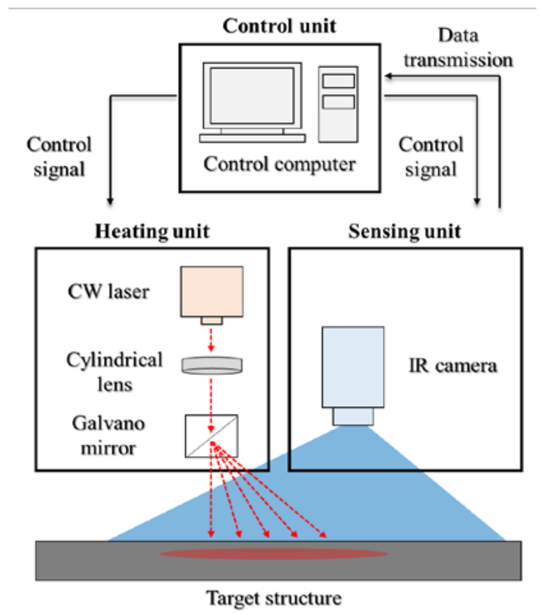

Figure 1. Schematic diagram of the paint thickness visualizing system

2.1. Hardware configuration

Figure 1 shows a schematic of the paint-thickness visualizing (PTV) system used for the paint thickness estimation, which is developed based on the preliminary study (An YK, 2015). The PTV system is composed of a heating unit, a sensing unit and a control unit. The heating unit is consisted of a continuous wave (CW) laser, cylindrical lens and galvano mirror for thermal wave generation on the target structure. Then, line laser beam is emitted from the heating unit and generates the thermal waves on the target structure. The sensing unit is consisted of the IR camera and records thermal waves on the target structure while generating the thermal wave from the heating unit. The heating and sensing units are controlled by the control computer in the control unit. Here, the IR images are acquired by the PTV system, and the paint thickness distributions on the target structure are automatically estimated and visualized by the image and signal processing algorithm.

2.2. Paint thickness estimation algorithm

The paint thickness estimation algorithm is developed to visualize the paint thickness distribution of the target structure and quantitatively estimate the paint thickness point-by-point. The proposed algorithm is based on the phenomena that the thermal wave reflecting phenomena alters according to the paint thickness (John HL, 2011). The paint thickness estimation algorithm follows the two major steps: (1) Image reconstruction using the thermal energy quantification: the paint thickness distribution on the target structure is visualized on a thermal response quantified (T) image and (2) paint thickness estimation using the reference data: a normalized thermal response quantified values (NT) are calculated for the whole pixel data on T and the paint thickness is automatically quantified using the baseline data.

3. EXPERIMENTAL VALIDATIONS

3.1. Target structure

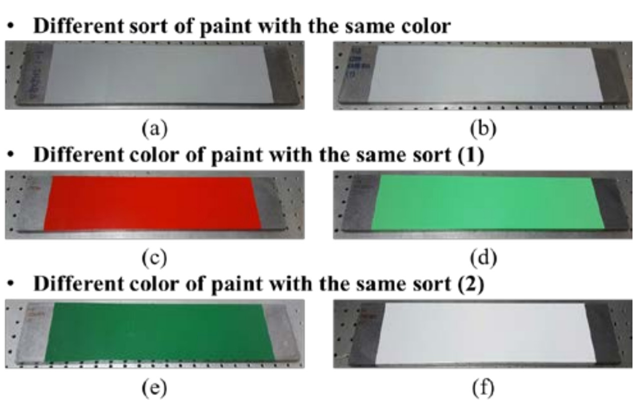

Figure 2. Test structures with uneven the paint thickness: (a) Epoxy paint with gray color (Paint 1), (b) Ceramic paint with gray color (Paint 2), (c) Urethane paint with red color (Paint 3), (d) Urethane paint with light-green color (Paint 4), (e) Ceramic paint with dark-green color (Paint 5), and (f) Ceramic paint with white color (Paint 6)

The experiments are conducted with six sort of structures which has $100 * 500\ mm^2$ of area and 12 mm of thickness as shown in Figure 2. Two structures has a different sort of paint with the same color and the rest of structures has the different color of paint with the same sort. Each structure has an uneven paint thickness with 40 μm of the paint thickness difference.

3.2. Experimental results

The IR images acquired by the PTV system are automatically processed. From the paint thickness estimation algorithm, the T images are automatically constructed from each target structures as shown in Figure 3. The paint thickness distribution on the target structure is successfully visualized on the T images. Also, the T images show that the calculated NT is nothing to do with the sort and color of the paint. Finally, the paint thickness can be quantified using the reference data as shown in Figure 4. Note that the paint thickness difference over than 40 μm can be quantified using the proposed PTV system and the data processing time is required less than 0.5 sec for each target structure..

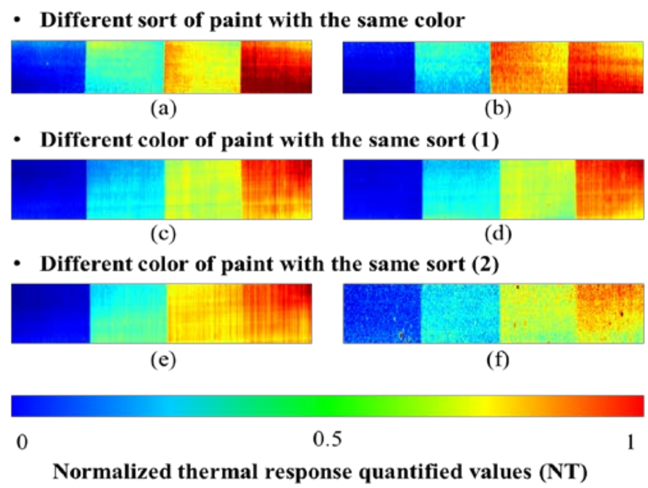

Figure 3. Test results with uneven the paint thickness using the target structure: (a) Epoxy paint with gray color (Paint 1), (b) Ceramic paint with gray color (Paint 2), (c) Urethane paint with red color (Paint 3), (d) Urethane paint with light-green color (Paint 4), (e) Ceramic paint with dark-green color (Paint 5), and (f) Ceramic paint with white color (Paint 6)

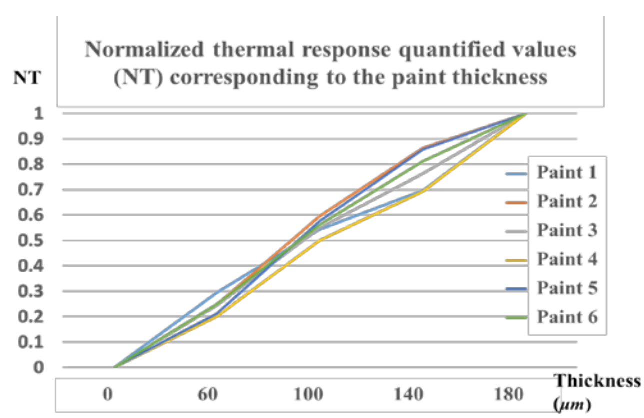

Figure 4. Paint thickness quantification using a normalized thermal response quantified values (NT)

4. CONCLUSION

The paint-thickness visualizing (PTV) system is proposed for the paint thickness visualization and estimation on the steel structure. The proposed PTV system is successfully verified through the experiment using the six sort of painted steel structure containing an uneven paint thickness with 40 μm of the paint thickness difference. The proposed PTV system enables (1) Fast and in-situ paint thickness visualizing and quantification with fully noncontact and automated manner, and (2) Long-distance and precise delamination inspection for massive target structure. These properties enables the automatic structural management with application of the proposed PTV system with the automated and unmanned robotics system, such as drone. However, the further studies for improving the inspection speed and removing the noise components induced by the uneven surface conditions are necessary for the real-field applications.

ACKNOWLEDGEMENT

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