

Automotive Production Control, Using Thermal Vision Systems – A Passive Thermal Imagery for Process Control

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Abstract

This work presents new generation of online inspection systems, developed and deployed in automotive assembly plants, to provide 100%, online evaluation of automotive processes and sub-assemblies. The presented systems are thermal-vision based, with capability to provide two dimensional, spatial and temporal temperature acquisitions, and are equipped with novel processing routines for data collection, conditioning and processing. Specific systems are presented in the stamping presses, paint curing practices, with inspection schemes designed to provide an efficient manufacturing sequence, through (1) pro-active diagnosis routines to monitor the process performance, while inspecting the product, (2) focusing on the error detection rather than defect detection routines, and (3) utilizing closed loop, feedback communications. This work will also present the processing computations that combine known image processing tools with inverse conduction computations, to correlate the process, product health parameters, to acquired scans temperature readings. Presented work will include two implementations of proposed thermographic systems; the automated detection of splits for body in white BIW sub-assemblies in automotive stamping presses, in addition to stamping die temperature control. Second example is a thermal vision system implemented, to evaluate the protective coating coverage and its curing uniformity for automotive, steel fuel tanks.

Key-words:

Thermal machine vision, Non-contact split detection, automotive assembly lines, quality control.

1- Introduction

Recent trends in shifting the automotive manufacturing and customer bases to global levels, led to increased emphasis on low cost, high quality attributes of the automobiles. Such attributes demand a high level of process and product control in the inter-process and the in the inter-chain levels. The inter-process control is hard to achieve due to following factors: (1) some of the automotive fabrication activities are not well understood and are still modeled as black-box. Additionally, (2) new generation of materials (High strength and dual phase steels) and technologies (Hydroforming, powder-coating) are being utilized without adequate expertise or inspection modalities or infrastructure. Above discussion highlights the importance of developing and implementing new process/product monitoring technologies to ensure not only defect detection but also error-detection, defect-prevention schemes.

Optical inspection modalities in its different modes (reflection, transmission, emission, and projection) provide the ability to monitor and record a process/product in non-contact, 100% inspection scheme, without interrupting the process flow. So, current manuscript describes the development and implementation of an emission-based modality for the detection of pinholes in protective coatings, also for the evaluation of the automotive stampings.

This manuscript structure will introduce the thermography as a passive vision modality in coming paragraph, followed by the two case studies. The conclusion will then summarize the text findings.

2- Infrared Thermography IRT as a vision tool

The Infrared Thermography (IRT in coming text) is currently used for two main usages; (i) the non-destructive testing of bulks, when accompanied with flash or pulse stimulation sources [Shepard, Plastic], and (B) the passive thermal imaging of objects or humans in surveillance and safety applications. In [Pedestrian tracking paper] we demonstrated the application of an IRT focal plane array for pedestrian tracking under night or low-light driving conditions. Additionally, the passive IRT technology is finding new applications in the industrial production lines, such as its implementation in seed detection on painted car shells in [1] and in analyzing automotive welding spatters in [2].

The thermal machine vision systems utilize the variety of the thermal focal plane arrays FPA (Alpha silicon, Vanadium Oxide VO_x coated, Indium Antimonite InSb, and Mercury Cadmium Telluride MCT) to acquire the thermal emission signature of objects. This signature is further preprocessed to reduce noise and background contribution, and finally processed and correlated to a specific bulk or surface attribute. Certain applications might utilize the difference in emissivity, thermal inertia, or the combined effect of both [1], between the sought features/objects and its surroundings. This methodology offers a new emission-based detection approach that complements the visible charged coupled devices CCD reflection operation, with the added advantage of being able to pinpoint both geometric and non-geometric (same geometry but different constituents) deviations. However, the utilization of the IRT-FPA is still challenged by the high cost and the limited spatial format of the basic IRT-array cores in comparison to the readily available visible CCD and CMOS arrays.

3- Stamping split detection

The stamping processes are vital in the automotive production chain, because it forms most

of the vehicle interior and exterior (body in white) structures; it is estimated that each vehicle consists of 300 – 400 in-house stamped components. However, the control of the stamping and forming processes is not yet optimized; due to large number of unexplained variations. Bluemel et al [3, 4] concluded that the sheet metal forming (stamping) has inherent deviations in the forming process itself, his study focused on the stamping stability with respect to steel-coil material variations. Additionally, Shi et al in [5] indicated that stamping processes are controlled through 40 process variables that does not even include the blank/material variations. So from the above discussion, it is evident that there is a need to develop a real-time, monitoring system for stamped components, to ensure the quality levels and to provide instant data feedback. Possibly this modality is to record the stamping defect-formation mechanisms through capturing the physics of forming.

The current/traditional quality practices at the automotive stamping facilities utilize circle grid analyses in addition to cup-drawing tests, to judge the quality of stampings and stamping process settings. The results from such tests are then correlated to the Forming Limit Curves FLC and finally to the formability indices. Such practices are applied offline and do not provide an online way of ensuring split free stamping or at least a feedback signal to stop a press once the first split is generated.

Next sub-section will briefly describe a split detection system using a thermal imaging module. The details of the processing and calculations are described in coming publication.

3-1 Split detection using thermal imagery

To begin usefully, the split detection system employed a 320 x 240 InSb (Indium Antimonite) cooled thermal detector, data cables, triggers and a processing unit. The thermal detector operates in the 3 – 5 micron spectra, with NETD (noise equivalent temperature difference) in the order of milli Kelvin. The detector is capable of 120 Hz of acquisition at full frame and up to 20 kHz, when sub windowed. While the processing unit employs a new data collection protocol based on pattern recognition to identify the formed parts, which then triggers the acquisition scheme. Further processing runs an in-