

Quality Inspection of Spot Welds using Digital Shearography

Nan Xu and Xin Xie
Oakland Univ.

George Harmon
Chrysler LLC

Randy Gu and Lianxiang Yang
Oakland Univ.

ABSTRACT

Spot Welding is an important welding technique which is widely used in automotive and aerospace industry. One of the keys of checking the quality of the welds is measuring the size of the nugget. In this paper, the Shearographic technique is utilized to test weld joint samples under the thermal loading condition. The goal is to identify the different group of the nuggets (i.e. small, middle, and large sizes, which indicate the quality of spot welds). In the experiments, the sample under test is fixed by a magnet method from behind at the four edges. Thermal loading was applied in the back side and the sample is inspected using the digital Shearographic system in the front side. Results show the great possibility of classifying the nugget size into three groups and the measurement is well repeatable.

CITATION: Xu, N., Xie, X., Harmon, G., Gu, R. et al., "Quality Inspection of Spot Welds using Digital Shearography," *SAE Int. J. Mater. Manf.* 5(1):2012, doi:10.4271/2012-01-0182.

INTRODUCTION

Spot welding is an important welding technique that is widely used in manufacture process. It is usually used when the to-be welded articles are sheet metal. One of the most common applications of spot welding is in the automobile manufacturing industry, where it is used almost universally to weld the sheet metal to form a car. Another application is spot welding thin nickel straps to the battery terminals. It can keep the battery from getting too hot, as might happen if conventional soldering were done.

Normally, the spot welding procedure includes three steps; the first of which involves two electrodes being brought to the top and bottom surfaces of the metal and then applying a small amount of pressure. After the current is applied briefly, the electrodes remain in place until the material is cooling. Weld times range from 0.01 sec to 0.63 sec depending on the thickness of the metal, the electrode force and the diameter of the electrodes themselves^[1].

In the past few years, researchers have been trying to figure out how to improve this procedure of acquiring the information of welding quality. However, despite intensive work over the past many years, there has been little advancement in sensors systems for monitoring of the quality

of spot welds ^[1]. The main quality control tests are the destructive chisel test and peel test, which are carried out on welds obtained from the production line of the product ^[2]. The failure rates are then detected examined and evaluated to get more information and then a feedback is sent to the welding machine so that the production process will be self controlled. However, this test will increase the labor cost and the product wastage.

THE BASIC OF SHEAROGRAPHY

Digital Shearography is a laser measuring technology, based on digital data processing, phase-shifting techniques and interferometry. According to the common sense of interferometry, two beams with an identical wavelength are usually required for a purpose of interference, such as an object beam and a reference beam used in the setups of holography and electronic speckle pattern interferometry (ESPI). A distinguishing feature of Shearography is the use of a self-reference interference system. Instead of using a reference beam, Shearography utilizes a shearing device to bring the light waves from two points on the object surface into one point on the image plane, which results in an

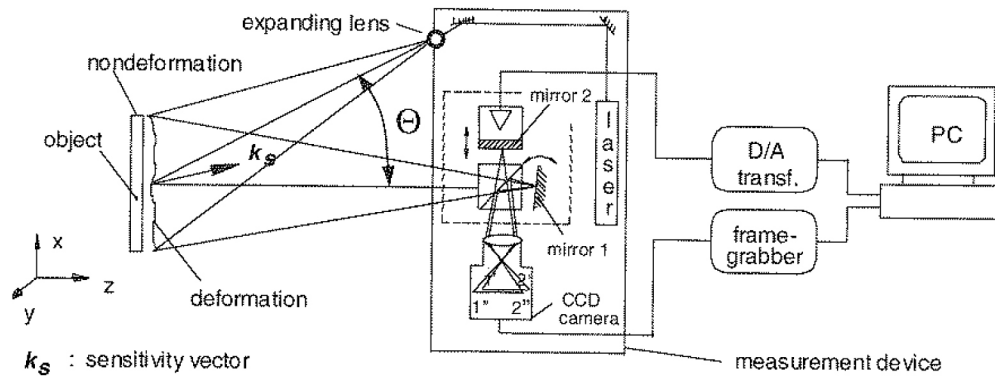


Fig.1. Typical shearography diagram using Michelson interferometer

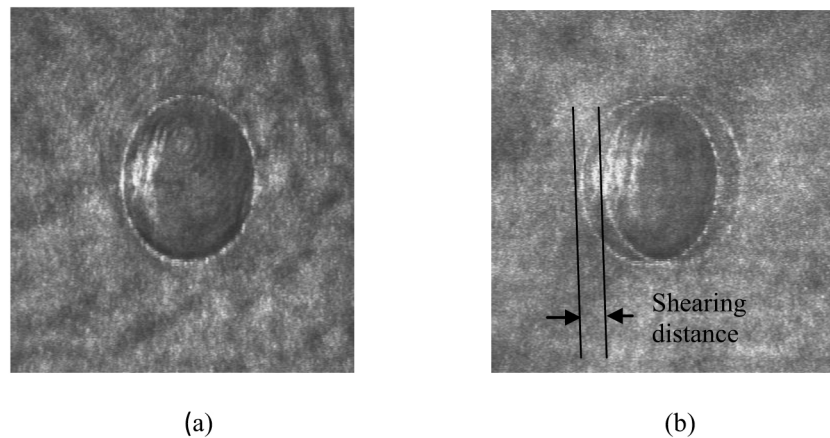


Fig 2. (a) normal image for a spot welding; (b) image captured by a shearing camera

interference phenomenon (i.e. so-called shearing speckle interferogram, without using an additional reference beam).

Fig.1 shows a typical digital Shearography system. The shearing device used here is a Michelson interferometer. The mirror 1 is parallel to the beam splitter while mirror 2 has a small angle to it. In this case, the image captured by the CCD camera is not a single image but two images that are a small distance apart, which is called the shearing distance. Fig 2 (b) shows the image captured by a shearing camera.

Shearography is an NDT technology that can provide the first derivative of the deformation along its shearing direction [4]. To apply this technique in real use, the samples have to be loaded in a certain way, and under this loading, the to-be detected defect or feature will deform differently along the shearing direction than the other area, so that the first derivative will reveal desired information.

The loading method varies according to the sample material, structure or dimension, and sometimes limited by the feasibility. The most common loading methods includes, but not limited to heating, vibration, bending, vacuum and static mechanical loading (e.g. compression and stretch). Selecting the loading method is always the first issue when introducing the Shearography technique.

MATLAB SIMULATION

The primary study of MATLAB simulation has been conducted before the experiments. The goal of this part is to predict the fringe pattern for different sizes of nuggets under the same loading condition.

Some reasonable assumptions have to be made ahead of time. First, because the samples were magnetically fixed on their four edges, when the sample was heated, the material will expand and the central part will be moving forward. Thus, from the Shearography's point of view, there is a cone-like deformation in the direction perpendicular to the object surface (i.e. the center area deforms more than the outer area). Second, the nugget is smaller than the indentation area. And finally, the deformation on the nugget area will be evenly distributed, so that the first derivative of the deformation of the nugget area should be a constant number.

The MATLAB simulation results show the difference between the smaller nugget and the larger nugget, (a.1) and (b.1) are the cross sections of the deformation across the indentation center. The peak tops distinguish the diversity of different nugget sizes. (a.2) and (b.2) are the cross section of the images from the shearing camera. Because of the shearing, there are two images on the same frame. So the