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Specular-Reduced Imaging for Inspection of Machined Surfaces

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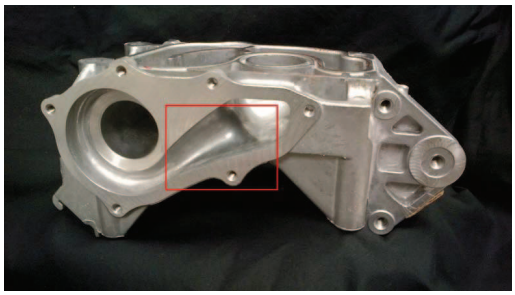
***Abstract*—Specular surfaces pose difficulties for machine vision. In some applications, this may be further complicated by the presence of marks from a machining process. We propose a system that directly illuminates machined specular surfaces with a programmable array of high-power light-emitting diodes. A novel approach is described in which the angle of the incident light is varied over a series of images from which a specular-reduced median image is computed. A quality factor is used to quantitatively characterize the degree to which these specular-reduced median images approximate a diffusely lit image, and this quality factor is shown to depend linearly on the number of specular images used to produce the single specular-reduced median image. Defects such as porosity and scratches are shown to be identifiable in the specular-reduced median images of machined surfaces.**

***Keywords*-specular surface inspection; adaptive lighting; high contrast imaging;**

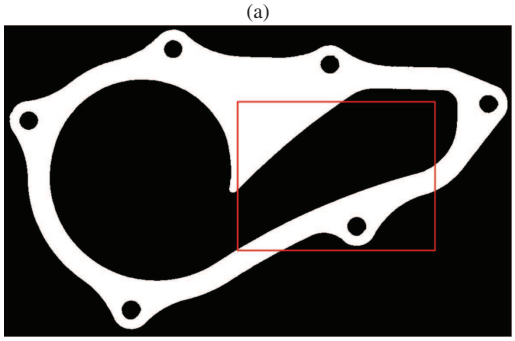
I. Introduction

Inspection of objects for defects requires an appropriate balance between the cost of inspection and the cost of delivering a defective object. Human inspection is expensive, and suffers from variations in reliability [1], but it is a typical task for identifying defects on machined metal surfaces. Enhanced images can be used to make manual inspection more reliable. Automation of this task is challenging because machined metal surfaces are highly reflective and exhibit marks caused by the machining process that can be mistaken for defects. Marks resulting from the machining process that are correlated to the radius and cutting direction of the machining tool will be referred to in this paper as *machining marks*.

The surfaces examined in this paper are the machined surfaces of a die cast aluminum automotive water pump shown in Fig. 1a. These surfaces, referred to here as *sealing surfaces*, contact other parts and must form pressurized seals. An image mask showing the area associated with the one of the sealing surfaces of this part is shown in Fig. 1b. Defects near the inner edge of the sealing surface, called the *sealing edge*, increase the risk of part failure, and must be identified prior to installation. Tool wear and differences in the microstructure of the die cast aluminum parts cause the machining marks to vary substantially from one part to the next. A computer vision solution is made more difficult by variations in the reflected light intensity caused by machining marks. The spatial extent of these variations overlaps the range of defect size that must be identified. In order to detect defects on a specular surface that exhibits machining marks, a human operator needs to vary the viewing angle of the surface to be inspected. Defects are identified because their reflection properties do not change in the same way as the rest of the surface. Rather than inspecting a specular object by changing the angle of the object relative to a fixed light source, an easier technique to implement using computer vision fixes the object and camera, and controls the direction of illumination.



(a)



(b)

Figure 1. (a) The die cast aluminum automotive water pump. (b) The image mask shows the sealing surface of the water pump in white. Defects close to the inner edge of the sealing surface must be identified prior to installation. The rectangles indicate the boundary of the 70 mm by 53 mm region that will be considered in this paper.

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