Chapter 3

Objectives and scope of present work

In a manufacturing industry, inspection forms an important component of product cycle which qualify the parts for usage by assessing them with respect to their design and functional requirements. In competitive market, as the demand for quality products are increasing the industries cannot completely rely upon conventional manual inspection techniques to improve their quality and productivity. Since manual inspection demands operator’s high attention, skill and precision, it is not suitable for in-process measurements as they interfere with the basic material processing. Many of the manufacturing processes impart a characteristic finish to the surface of component being processed, which reveals useful information related to the process and process variables. The ability of a typical machine vision system besides being non-contact, low cost and flexible to carry out the on-line measurement, the real time assessment of such component surfaces are explored to enhance the assessment task of wide range of manufacturing processes.

From the literature, it was found that machine vision technology has been adopted in many manufacturing processes either for on-line or off-line applications. The main fields include dimensional inspection of processed parts, measurements of surface characteristics of processed surfaces, evaluation of tool wear in various material removal processes, measurement of temperature in high speed machining and dimensions of hot formed and spray formed parts, monitoring of weld quality and seam tracking of different arc welding processes and assessment of FSW quality by analyzing the fractured weld surface.

Among the manufacturing processes as found in the literature, the metal joining technology seems to be important as it finds wide scope in fabricating the parts manufactured by different manufacturing processes.
It can be readily controlled and monitored during joining the parts of different shapes, sizes and materials precisely. In metal joining technology, welding is found to be applied largely in joining ferrous and non-ferrous materials in the various industries like machine tool, textile machinery, food processing machinery, civil structures, aircraft, automotive, shipbuilding, railroad, etc. The aircraft and automotive industries receive much attention from industry and academia for the development of manufacturing technology required for manufacturing precise components of aircraft and automobile. Some of the critical components are usually made of light materials like aluminum alloys, which have high strength to weight ratio.

Generally aluminum alloys show low weldability by traditional fusion welding process. An alternate, improved way for satisfactorily joining the aluminum alloys is provided by the development of FSW at The Welding Institute (TWI), U.K in 1991. FSW is environment friendly process proven for welding high-strength aluminum alloys with high mechanical joint efficiency. It is a solid-state localized thermomechanical joining process, predominantly used for butt and lap joints with no consumables and melting related imperfections. However, FSW is relatively new technology, though the scientific knowledge base is being established there are many issues remain open for the researchers. One of the inherent phenomenon is the occurrence of regular banded texture on the weld surface compared to other welding process, which is formed by interaction of rotating and moving tool pin and shoulder interface with workpiece during welding. The banded texture can be viewed as characteristic features relevant for the inspection and evaluation of FSW process by a low cost, non-contact, non destructive machine vision technology.

There is a very little published information available from the literature survey about the application of machine vision technology for FSW process. Therefore, keeping in the mind the need for automation of FSW
process, in the present investigation, systematic studies have been made to assess the weld quality by analyzing the digital images of weld bead texture using machine vision technology. Further, the above developed concept of weld quality assessment is integrated with contact type acoustic emission technique, a proven technique for monitoring FSW to suggest a reliable, sophisticated concept of multi-sensor technology for on-line monitoring of FSW process to produce defect free welds.

The specific objectives of present investigation are:

1. The shoulder of FSW tool is a key element which interacts with base material surface to generate required frictional heat and hydrostatic pressure necessary for material flow and consolidation to form the joint. It has been reported that the banded texture pattern of friction stir welded joints reveals highly deformed material interface after welding. By analyzing the banded texture pattern of weld bead, the interaction of tool shoulder in forming the weld can be understood. Hence, it has been proposed to conduct feasibility studies to understand the behavior of image parameter extracted from the weld bead images using machine vision technique.

2. When the input process parameters such as tool traverse speed and tool rotation speed of FSW vary, the interaction of tool shoulder also varies forming different quality of weld. Hence, it has been proposed to study the variations in image parameters by analyzing the images of weld bead surface of FSW specimens welded with different tool speeds. This has been proposed for digital image correlation by quantifying the image texture along different weld regions in comparison with X-Ray radiography results.

3. The image texture is quantified by extracting the statistical parameters, which depends upon the properties such as fineness, smoothness, coarseness, granulation, etc., of the image. As the Region of
Interest (ROI) varies, the size of the image also varies, varying the image properties and statistical parameters. Hence, it has been proposed to repeat above trial of digital image correlation for different sizes of ROI in order to arrive at optimum size of ROI required to establish the criteria for weld quality assessment.

4. The axial load which is applied during FSW to plunge the tool pin and shoulder into the materials interface plays an important role in the formation of solid state weld. As the tool starts traversing, variations in the applied axial load arises from material flow characteristics and the variation of material properties in the plasticized region underneath the shoulder, which is reflected in the banded texture of weld bead formed by tool shoulder interaction with base material. Hence, it has been proposed to record the axial force during FSW process and study its variation, while analyzing the images of weld bead surface to understand the interaction of tool shoulder in the formation of defect free welds.

5. The formation of banded texture on weld surface is resulted from material deformation and flow stress occurring under the action of axial load beneath the shoulder during welding for the chosen process parameters including tool speed. It has been reported that the strain rate and flow stress depends on the temperature history developed during FSW and is effected by the tool speeds. Since, practically it is very difficult to evaluate the flow stress and strain rate in order to understand occurrence of banded texture for the assessment of weld quality by machine vision technology, it has been proposed to develop thermomechanical model of FSW using Finite Element Analysis (FEA) and validate the model by comparing the temperature history measured practically during FSW using thermocouples with predicted temperature history from the model. Further, the parametric studies are proposed to study the effect of tool speeds on flow stress and strain rate by simulating the validated thermomechanical model for different tool speeds. The
predicted results are correlated with axial load, which can be measured practically.

6. It has been proposed to study the variations in statistical image parameters of weld bead surface of FSW specimens welded with different materials, different tool shoulder configurations and different weld parameters by comparing with non-destructive evaluation of welded joints to develop a model for assessing weld quality by establishing the relationship between statistical image parameters and weld quality.

7. It has been reported that AE technique is successfully used in on-line monitoring of FSW processes for welding similar and dissimilar materials. Hence, it has been proposed to test the machine vision model developed by studying the variations in AE data acquired during welding of FSW specimens with different tool shoulder configurations and weld parameters in conjunction with statistical image parameters of weld bead surface. It has been proposed to assess the performance of good weld which is indentified by machine vision model by conducting the destructive tensile test along the regions showing variations in AE data and correlating the weld strength obtained with statistical image parameters through AE data to achieve integration of machine vision technique with AE technique.

8. It has been proposed to validate combined model developed by non-contact machine vision technique and contact type AE technique by repeating trials of experiments with FSW specimens welded with different tool shoulder configurations and parameters to suggest an effective, reliable and multi-sensor model by establishing the relationship between weld quality and statistical image parameters supported with AE parameters with the intention for on/off-line monitoring of FSW.
Scope of present work is to carry out Digital Image Correlation (DIC) to assess the weld quality by analyzing the images of weld bead surfaces, which are captured off-line. Weld bead surfaces are studied for the defects which are reflected on weld bead surface like surface voids, surface galling, lack of fill, etc., during FSW of similar aluminum alloys namely AA7020-T6, AA6061-T6 and AA6082-T4 plates of 5mm thick using different shoulder geometry and weld parameters. The type of weld considered is of butt type.