EBSD Image Based FEM Simulation of Ultrasonic Wave Propagation in Dissimilar Metal Welds

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Abstract

Analysis of the ultrasonic testing (UT) in dissimilar metal welds (DMWs) is complicated due to acoustic anisotropy and local heterogeneity so that the ultrasonic wave is propagated along crystallographic directions as well as it is scattered by randomized weld boundaries. With the idea, development of a straightforward numerical modelling technique to predict ultrasonic wave propagation in weld boundaries and local heterogeneities has been necessary for reliable UT technique’s usages in non-destructive testing (NDT). In this study, application of electron backscatter diffraction (EBSD) was considered to obtain detail information about locally major crystallographic directions and grain boundaries. In order to analyse EBSD results, grain orientation density functions were used by MATLAB program since it provides distribution of major crystallographic orientation. And using digital image processing was considered to obtain grain boundaries of major misorientation in computer graphics. Due to limitation of measurement on the whole regions of DMWs in this study, similarity between results of digital image processing at same sectional sample’s EBSD image and chemical etching metallography image was reviewed and approximate similarities were consequently deducted. With similarities, FEM modelling contained the whole regions of DMW was implemented by using digital image processing. Simulation of the image based FEM model with ultrasonic phased array technique was implemented by using explicit dynamics FEM technique in commercial LS-DYNA FEM package. Results of ultrasonic wave propagation’s simulation in dissimilar metal welds were reviewed and verification of the simulation was conducted by comparison with analytical methods (phase velocity surface, slowness velocity) and laser Doppler vibrometer (LDVT) measurement for scanning of physical non-contact vibration on the surface.

Keywords: Non-destructive Ultrasonic Testing (NDT), Image based weld material modelling, Anisotropic and Heterogeneous Materials, EBSD (Electron Back Scatter Diffraction), FEM (Finite Element Method), Image processing

References

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Abstract

In this study, Electron Backscatter Diffraction (EBSD) was considered to obtain information about local crystallographic directions, misorientation, grain size, grain boundary character and texture distribution in order to development simulation technique due to local microscopic heterogeneity. In first step, texture analysis of EBSD were utilized by using open source code MTEX with MATLAB programming in order to compute and visualize orientation density functions since the function can be used to provide distribution of major crystallographic orientation. In general for this study, technique of digital image processing from EBSD and Metallography images was applied. Based on two images with the digital image processing major crystallographic grain segmentations could be matched approximately due to equal threshold coefficients that can be used in image processing. In perspective, image processing of whole of the metallurgy image in welded zone was carried out for segmentations based matched threshold coefficients. In next step, Finite Element Method (FEM) modeling based on the major crystallographic segmentations was carried out by using a commercial image processing. Moreover, each major crystallographic directions was defined in FEM model. For the FEM simulation of the ultrasonic wave propagation, the phase array technique is able to control beam steering was used in order to approach at damage as well as the wave propagation was able to be implemented by using explicit dynamic method in a commercial LS-DYNA FEM package. For verification results of Laser Vibrometer measurement was used.

Keywords: Nondestructive Ultrasonic Testing (NDT), Image based modelling, Anisotropic and Heterogeneous Materials, EBSD (Electron Backscatter Diffraction), Metallography, FEM (Finite Element Method)

Objective

- Development of image based FEM code and application for complex geometry
- Predict ultrasonic wave propagation due to acoustic anisotropic in local heterogeneous
- Studies of optimization of time delay for using phase array technique

Methodology

- Preparation of a specimen
- Automated FEM modeling included major grain segmentations by using image processing
- Aspiration Metallography, Measurement EBSD and EBSD data analysis
- Explicit method by a commercial LS-DYNA FEM package
- Wave propagation with using phase array technique

Results

1. FEM simulation

   A. Difference simulation between homogenous isotropic
      - (a) t = 3.96 μs
      - (b) t = 12.13 μs
      - (c) t = 22.87 μs
      - (d) t = 25.58 μs

   B. Difference simulation between anisotropic isotropic
      - (a) t = 7.48 μs
      - (b) t = 26.17 μs
      - (c) t = 37.94 μs
      - (d) t = 47.72 μs

   C. Fluid simulation between homogenous isotropic and heterogeneous
      - (a) t = 18.28 μs
      - (b) t = 22.87 μs
      - (c) t = 25.58 μs
      - (d) t = 47.72 μs

2. Measurement of Laser Vibrometer

3. Review of measurement

Conclusion

The presented methods of application EBSD image and data with microstructural crystallographic grains information aim to compute realistic simulation of ultrasonic wave propagation into welded materials. In this study, using image processing was able to provide similar segmentations from EBSD and metallography images approximately. Based on image segmentation from the image processing, FEM model could be generated automatically due to major crystallographic orientations. The wave propagation was able to simulate by using Explicit method. The result showed that ultrasonic wave into homogenous isotropic can be propagated without scatter with a good agreement. In contrast, the ultrasonic wave into transversely and anisotropy showed obviously difference and was extremely scattered from comparing with previous wave pattern in homogenous isotropic.

Future work

- Studies of theoretical relationship EBSD and metallography images
- Analysis wave pattern in anisotropy precisely and studies optimization of time delay for phase array technique

References


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