Geometric Multigrid Solver and Experimental Validation in Laser Surface Remelting

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Abstract

INTRODUCTION
The purpose of this work is to verify the effect of Multigrid method on the CPU time for the resolution of the heat transfer model, based on the Finite Element Method (FEM), in order to simulate the laser surface remelting (LSR) of the Al-1.5 wt.% Fe alloy. To accelerate the convergence of Single grid methods, Multigrid method (MG) was employed in order to reduce the CPU time. In this study we analyzed the influence of different geometric Multigrid parameters on the CPU time in the numerical simulation problem. Furthermore, to validate the result of numerical simulation with the experimental result was necessary to perform an analysis of the microstructural characterization of laser-treated layer by the techniques of optical microscopy and Scanning Electron Microscopy (SEM).

USE OF COMSOL MULTIPHYSICS®
The simulations were carried out with COMSOL Multiphysics software. The geometry adopted for simulations is shown in Figure 1.
The initial and boundary conditions were applied, according to Figure 2 and the material's thermophysical properties were considered dependent on the temperature and a moving heat source was established in the x-axis.
In this work two Single grid methods were considered: Multifrontal massively parallel sparse direct solver [1] (SG-MUMPS); and Successive over relaxation [2] (SG-SOR). These methods were incorporated to improve the numerical simulation of the laser-treatment of Al-1.5 wt.% Fe alloy by FEM.
To accelerate the convergence of Single grid methods (SG-MUMPS and SG-SOR) the Multigrid method (MG) was used.

RESULTS
Different analyses of 3D heat transfer by the Finite Element Method (FEM) were conducted in this work, optimized by Multigrid methods. The validation of numerical results was done by the comparison with the experimental results.
Figure 3 shows the comparison between the experimental result (SEM micrography) and the numerical simulation. The thermal distributions are indicated by isotherms in the molten pool and as well as in the heat affected zone. The alignment of the figures is different due to the thermal stresses involved in the treated region, the present study has not considered this phenomenon.

CONCLUSIONS

The CPU time was reduced through the use of Multigrid method (MG) to solve the problem, emphasizing the simulation with the optimum Multigrid (OMG-SOR) is about 122 times faster than the simulation with the MUMPS method (SG-MUMPS).

The experimental result of the microstructural characterization was validated with the result of numerical simulation optimized by the technique of Multigrid method, being that the validation was consistent.

Reference

[1] Guermouche A, Yves J, L'Excellent, Utard G (2003) Impact of reordering on the memory of a multifrontal solver. Parallel Computing 29: 1191–1218. doi:10.1016/S0167-8191(03)00099-1

[2] Burden R L, Faires J D (2010) Numerical Analysis. Brooks-Cole, 9th ed., Cengage Learning, Australia.

Figures used in the abstract

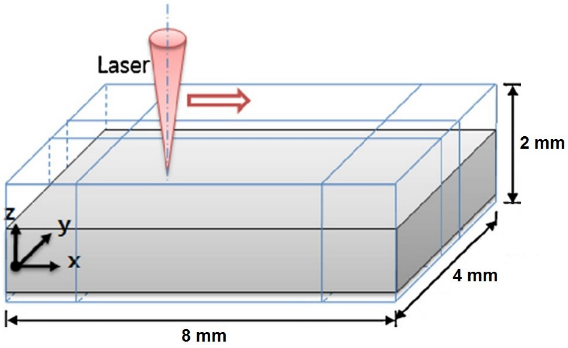

Figure 1: Schematic view of the laser welding simulation.

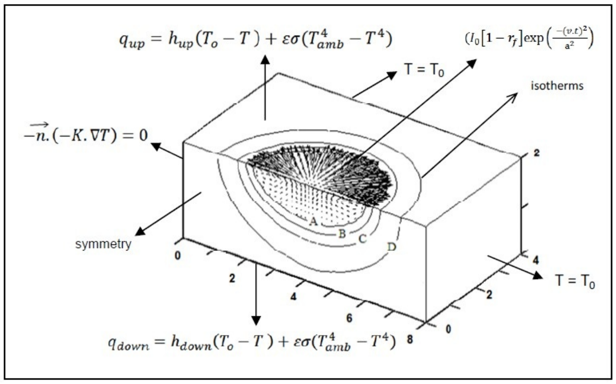

Figure 2: A 3D computational view of the temperature distribution, including isotherms, for the laser-melted zone. The initial and boundary conditions are also indicated.

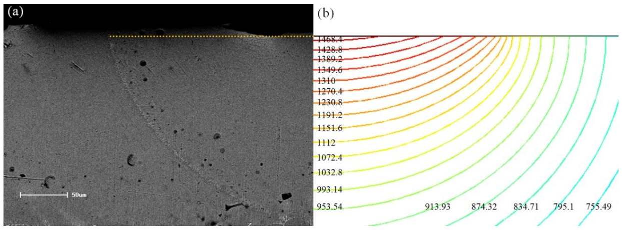

Figure 3: Comparison between the experimental sample and the numerical simulation, both in the cross section view, where: (a) is a SEM micrograph and (b) is the simulation result.