MESHFREE METHOD IN OPTIMAL DESIGN OF FUNCTIONALLY GRADED MATERIALS

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Materials for use in highly critical applications such as medical implants or thermal protective shields for avionics, have stringent and competing requirements with respect to their weight, strength under mechanical and thermal loadings, stress profiles, etc. Functionally Graded Materials (FGMs) are viewed as possible solutions to challenging material optimization problems where the material discontinuities have to be eliminated to prevent debonding of composites.

For example, medical implants, such as total knee replacement implants, require a surface providing little friction and wear without constant lubrication. Ceramics are ideal for such tasks, but their strength has to be improved and a metal-ceramic FGM seems to meet both requirements. Minimizing the mass of the FGM while strength constraints are not violated under mechanical and/or thermal loadings is a challenging computational problem. A one-dimensional variation of the ceramic volume fraction across the FGM cannot suit a case where loading conditions are asymmetrical.

We propose a meshfree solution to material optimization of FGMs where design variables are control points on a surface interpolation of the two-dimensional material variation function. We use the element-free Galerkin method [1] with a transformation method for imposing the essential boundary conditions [2]. We emphasize two main advantages of the meshfree method compared to finite element method (FEM) solutions of optimization problems:

- Material variation is captured at the level of the integration points that are independent from the approximation nodes in meshfree methods. As a result, a reduction in the size of the problem is possible without compromising the ability to accurately describe complex variation of the material composition across the FGM.
- The current approach offers the possibility of coupling material optimization with shape optimization of FGMs. Recently [3], a meshfree method has been employed in the problem of shape optimization of diffusive thermal systems and the results obtained show dramatic improvements over FEM solutions. In problems where the final design is significantly different from the initial design, meshfree methods are superior to classical approaches.

References

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