Case Study: Ablation of CFRP Laminated Composite – Ablation Rate

- The ablation rate is assumed to follow Park's finite-rate ablation formulation [3-5], the mass blowing rates, $\dot{m}_i$, due to various surface-gas reactions (i.e., oxidation, nitridation, and sublimation) are:

$$\dot{m}_1 = \rho_e C_O \bar{v}_O \beta_O \frac{M_C}{M_O}; \ \left(C_{(S)} + O \rightarrow CO\right), \quad \dot{m}_2 = 2\rho_e C_{O_2} \bar{v}_{O_2} \beta_{O_2} \frac{M_C}{M_{O_2}}; \ \left(2C_{(S)} + O_2 \rightarrow 2CO\right),$$

$$\dot{m}_3 = \rho_e C_N \bar{v}_N \beta_N \frac{M_C}{M_N}; \ \left(C_{(S)} + N \rightarrow CN\right), \quad \dot{m}_4 = \rho_e \left(C_{C_3,E} - C_{C_3}\right) \bar{v}_{C_3} \beta_{C_3}; \ \left(3C_{(S)} \rightarrow C_3\right),$$

$$\dot{m}_c = \dot{m}_1 + \dot{m}_2 + \dot{m}_3 + \dot{m}_4, \qquad \dot{m}_g = 0.21\dot{m}_c, \qquad \dot{s} = \left(\dot{m}_c + \dot{m}_g\right) / \rho_s,$$

- Such a formulation may be **inappropriate** to model ablation under radiative heating environment. The case study **does not** necessarily reflect the real physics, but should be regarded as a demonstration of the modeling capability of this proposed MMM procedure.

[3] C. Park, Stagnation-point ablation of carbonaceous flat disks. I theory, AIAA Journal, 21 (11) (1983) 1588-1594.
[4] C. Park, Calculation of stagnation-point heating rates associated with stardust vehicle, Journal of Spacecraft and Rockets, 41 (1) (2007) 24-32.
[5] C. Park, H.K. Ahn, Stagnation-point heat transfer rates for pioneer-venus probes, Journal of Thermophysics and Heat Transfer, 13 (1) (1999) 33-41.

Moving Finite Elements

Chien Ming Wang,Johnny C.M. Ho,Sritawat Kitipornchai

Moving Finite Elements:

Moving Finite Element Method Maria do Carmo Coimbra,Alirio Egidio Rodrigues,Jaime Duarte Rodrigues,Rui Jorge Mendes Robalo,Rui Manuel Pires Almeida,2016-11-30 This book focuses on process simulation in chemical engineering with a numerical algorithm based on the moving finite element method MFEM It offers new tools and approaches for modeling and simulating time dependent problems with moving fronts and with moving boundaries described by time dependent convection reaction diffusion partial differential equations in one or two dimensional space domains It provides a comprehensive account of the development of the moving finite element method describing and analyzing the theoretical and practical aspects of the MFEM for models in 1D 1D 1d and 2D space domains Mathematical models are universal and the book reviews successful applications of MFEM to solve engineering problems It covers a broad range of application algorithm to engineering problems namely on separation and reaction processes presenting and discussing relevant numerical applications of the moving finite element method derived from real world process simulations *Moving Finite Elements in 2-D.* Robert J. Gelinas,SCIENCE APPLICATIONS INC PLEASANTON CALIF.,1981 The moving finite element MFE method is a new PDE solution method which has shown significant promise in 1 D for the numerical solution of some of the most difficult problems under study with extremely large but finite gradients The overall objective of the present research is to explore further the promise of the continuous node moving properties of the MFE method in 2 D For this both the logical structure of the MFE method and its reduction to practice in 2 D are under investigation in this project This initial research in 2 D focuses upon such simple conservation equations as heat travelling wave and Burger s equations Work in this initial reporting period has resulted in significant computational economies for both unvectorized versions of the MFE method as it currently exists and for vectorized versions which may emerge in later efforts A working test code which is needed for essential scientific exploration and further enhancement of the MFE method in higher dimensions has been brought to nearly an operational stage of execution during this period Author *Moving Finite Elements: Regularisation Techniques* M. J. Baines,1986 *Moving Finite Elements* Michael John Baines,Professor in Applied Mathematics M J Baines,1994 This book is mainly concerned with finite element methods for time dependent partial differential equations when the grids are allowed to move in time but also describes grid generation techniques which include grid adjustment The mechanism for grid movement derives from a generalization ofthe residual minimization technique which is familiar from the Galerkin finite element method The book brings together most of the work done over the last decade or so which has been stimulated by Miller s original idea and discusses the interrelationships between the techniques of the method andthe established ideas of the method of characteristics Hamilton s equations the Legendre transformation and grid equidistribution The book highlights the issues involved and should provide the reader with a clear view of the current state of the subject and prompt further research *Applications of the Moving Finite Element Method for Systems in 2-D.* Science

Applications International Corporation,M. J. Djomehri,S. K. Doss,R. J. Gelinas,K. Miller,1985 **ACMSM25** Chien Ming Wang,Johnny C.M. Ho,Sritawat Kitipornchai,2019-09-03 This book presents articles from The Australasian Conference on the Mechanics of Structures and Materials ACMSM25 held in Brisbane December 2018 celebrating the 50th anniversary of the conference First held in Sydney in 1967 it is one of the longest running conferences of its kind taking place every 2 3 years in Australia or New Zealand Bringing together international experts and leaders to disseminate recent research findings in the fields of structural mechanics civil engineering and materials it offers a forum for participants from around the world to review discuss and present the latest developments in the broad discipline of mechanics and materials in civil engineering

Moving Finite Elements in 2-D -- Fluid Dynamics Applications ,1984 This report summarizes progress on the feasibility of using the moving finite element MFE method in two dimensional for the study of shock boundary layer interactions It is found that highly local physical dissipation processes in regions of large gradients can be sensitive determinates of macroscopic flow properties The MFE method continues to show promise for resolving such physical effects while suppressing anomolous or numerical diffusion effects over highly disparate physical scales Recommendations are given for improving the MFE method for further reduction to practice for airblast applications Keywords Viscous Dissipation Implicit Solutions Partial Differential Equation Navier Stokes Equations Local Moving Finite Elements M. J. Baines,1985

Mesh Free Methods G.R. Liu,2002-07-29 As we attempt to solve engineering problems of ever increasing complexity so must we develop and learn new methods for doing so The Finite Difference Method used for centuries eventually gave way to Finite Element Methods FEM which better met the demands for flexibility effectiveness and accuracy in problems involving complex geometry Now **A Moving Finite Element Method for Time Dependent Partial Differential Equations with Error Estimation and Refinement** S. Adjerid,J. E. Flaherty,RENSSELAER POLYTECHNIC INST TROY NY DEPT OF MATHEMATICAL SCIENCES.,1984 The authors discuss a moving finite element method for solving vector systems of time dependent partial differential equations in one space dimension The mesh is moved so as to equidistribute the spatial component of the discretization error in H1 They present a method of estimating this error by using p hierarchic finite elements The error estimate is also used in an adaptive mesh refinement procedure to give an algorithm that combines mesh movement and refinement The authors discretize the partial differential equations in space using a Galerkin procedure with piecewise linear elements to approximate the solution and quadratic elements to estimate the error A system of ordinary differential equations for mesh velocities are used to control element motions The authors use existing software for stiff ordinary differential equations for the temporal integration of the solution the error estimate and the mesh motion Computational results using a code based on this method are presented for several examples **Handbook of Grid Generation** Joe F. Thompson,Bharat K. Soni,Nigel P. Weatherill,1998-12-29 Handbook of Grid Generation addresses the use of grids meshes in the numerical solutions of partial differential equations by finite elements finite volume finite differences and boundary elements Four parts divide the chapters structured grids unstructured girds surface definition and adaption quality An introduction to each section provides a roadmap through the material This handbook covers Fundamental concepts and approaches Grid generation process Essential mathematical elements from tensor analysis and differential geometry particularly relevant to curves and surfaces Cells of any shape Cartesian structured curvilinear coordinates unstructured tetrahedra unstructured hexahedra or various combinations Separate grids overlaid on one another communicating data through interpolation Moving boundaries and internal interfaces in the field Resolving gradients and controlling solution error Grid generation codes both commercial and freeware as well as representative and illustrative grid configurations Handbook of Grid Generation contains 37 chapters as well as contributions from more than 100 experts from around the world comprehensively evaluating this expanding field and providing a fundamental orientation for practitioners

Moving Finite Element Solution of Systems of Partial Differential Equations in 1-dimension Mohammad Dhjahed Djomehri,1983 *An Implementation of a Moving Finite Element Method* Andrew N. Hryamk,Gregory J. McRae,Arthur W. Westerberg,1984 **Adaptive Computational Methods for Partial Differential Equations** Ivo Babushka,Jagdish Chandra,Joseph E. Flaherty,1983-01-01 List of participants Elliptic equations Parabolic equations Hyperbolic equations Moving Finite Elements M. J. Baines,1985 **31st European Symposium on Computer Aided Process Engineering** Metin Türkay,Rafiqul Gani,2021-07-22 The 31st European Symposium on Computer Aided Process Engineering ESCAPE 31 Volume 50 contains the papers presented at the 31st European Symposium of Computer Aided Process Engineering ESCAPE event held in Istanbul Turkey It is a valuable resource for chemical engineers chemical process engineers researchers in industry and academia students and consultants in the chemical industries Presents findings and discussions from the 31st European Symposium of Computer Aided Process Engineering ESCAPE event **Mathematical Methods for the Magnetohydrodynamics of Liquid Metals** Jean-Frédéric Gerbeau,Claude Le Bris,Tony Lelièvre,2006-08-31 This comprehensive text focuses on mathematical and numerical techniques for the simulation of magnetohydrodynamic phenomena with an emphasis laid on the magnetohydrodynamics of liquid metals and on a prototypical industrial application Aimed at research mathematicians engineers and physicists as well as those working in industry and starting from a good understanding of the physics at play the approach is a highly mathematical one based on the rigorous analysis of the equations at hand and a solid numerical analysis to found the simulations At each stage of the exposition examples of numerical simulations are provided first on academic test cases to illustrate the approach next on benchmarks well documented in the professional literature and finally whenever possible on real industrial cases

Numerical Methods for Problems with Moving Fronts Bruce A. Finlayson,1992 *Uncoupled moving finite elements* Richard Lane Thrasher,1989 Applied mechanics reviews ,1948

Decoding **Moving Finite Elements**: Revealing the Captivating Potential of Verbal Expression

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