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HIGH-ORDER ACCURATE DISCONTINUOUS FINITE ELEMENT SOLUTION OF THE 2D EULER EQUATIONS. F. Bassi* and S. Rebay.† **Dipartimento di Energetica, Università degli Studi di Ancona, Via Brecce Bianche, 60131 Ancona, Italy; †Dipartimento di Ingegneria Meccanica, Università degli Studi di Brescia, Via Branze 38, 25121 Brescia, Italy.*

This paper deals with a high-order accurate discontinuous finite element method for the numerical solution of the Euler equations. The method combines two key ideas which are at the basis of the finite volume and of the finite element method, the physics of wave propagation being accounted for by means of Riemann problems and accuracy being obtained by means of high-order polynomial approximations within elements. We focus our attention on two-dimensional steady-state problems and present higher order accurate (up to fourth-order) discontinuous finite element solutions on unstructured grids of triangles. In particular we show that, in the presence of curved boundaries, a meaningful high-order accurate solution can be obtained only if a corresponding high-order approximation of the geometry is employed. We present numerical solutions of classical test cases computed with linear, quadratic, and cubic elements which illustrate the versatility of the method and the importance of the boundary condition treatment.

A LAGRANGIAN VORTICITY COLLOCATION METHOD FOR VISCOUS, AXISYMMETRIC FLOWS WITH AND WITHOUT SWIRL. J. S. Marshall* and J. R. Grant.† **Department of Mechanical Engineering and Iowa Institute of Hydraulic Research, University of Iowa, Iowa City, Iowa 52242; †Naval Undersea Warfare Center, Newport, Rhode Island 02841.*

This paper presents a new Lagrangian vorticity collocation method for viscous, axisymmetric fluid flows with or without swirl. The velocity calculation is performed using a representation of the vorticity field in terms of Gaussian vortex rings for off-center points and Gaussian vortex blobs along the axis of symmetry. A matrix equation for the element "amplitudes" is obtained via a collocation approach, by fitting the vorticity representation to the known vorticity values at the control points, prior to each velocity evaluation. This matrix equation is solved using an iterative procedure, which both speeds the calculation and filters out "noise" in the element amplitudes. Viscous diffusion is accomplished with use of a diffusion velocity method, in which control points are moved with the sum of the local fluid velocity and an additional "diffusion velocity" that accounts for the effect of viscosity on the spread of vorticity support. Derivatives are obtained by locally fitting a polynomial function to control points about a given control point via a least-square formulation and then differentiating the polynomial. This method is found to maintain high accuracy even for very irregularly spaced control points. The method introduced for viscous diffusion in the paper can also be used for three-dimensional vortex methods in general.

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UNFOLDING SPHERE SIZE DISTRIBUTIONS WITH A DENSITY ESTIMATOR BASED ON TIKHONOV REGULARIZATION. J. Weese,* E. Korat,* D. Maier,* and J. Honerkamp.† **Freiburger Materialforschungszentrum, Stefan-Meier-Strasse 21, D-79104 Freiburg im Breisgau, Germany; †Albert-Ludwigs-Universität Freiburg, Fakultät für Physik, Hermann-Herder-Strasse 3, D-79104 Freiburg im Breisgau, Germany.*

In a large number of measuring and characterization methods, the sphere size distribution of particles embedded in a medium has to be estimated from profile radii observed in cross sections or thin slices. On the one hand, this is a typical problem of density estimation. For that reason, kernel estimators may be applied. On the other hand, the computation of the sphere size distribution from the profile size distribution requires the inversion of an integral equation. In the case of cross sections or infinitely thin slices, this is an ill-posed problem which can be solved with specific methods as, e.g., Tikhonov regularization. In this contribution we propose a method for unfolding the sphere size distribution given a sample of profile radii which combines the advantages of kernel estimators with those of regularization methods. In order to study and test this method, Monte-Carlo simulations have been performed. The results demonstrate that the method is reliable and leads to properly unfolded sphere size distributions. Finally, the method has been applied to experimental data obtained from transmission electron microscopy images of several polymer blends. The results demonstrate that the new method is a valuable tool for data analysis.

CONSERVATIVE MULTIDIMENSIONAL UPWINDING FOR THE STEADY TWO-DIMENSIONAL SHALLOW WATER EQUATIONS. M. E. Hubbard and M. J. Baines. *Department of Mathematics, The University of Reading, P.O. Box 220, Whiteknights, Reading, RG6 6AX, United Kingdom.*

In recent years upwind differencing has gained acceptance as a robust and accurate technique for the numerical approximation of the one-dimensional shallow water equations. In two dimensions the benefits have been less marked due to the reliance of the methods on standard operator splitting techniques. Two conservative genuinely multidimensional upwind schemes are presented which have been adapted from flux balance distribution methods recently proposed for the approximation of steady state solutions of the Euler equations on unstructured triangular grids. A method for dealing with source terms, such as those introduced by modelling bed slope and friction, is also suggested and results are presented for two-dimensional steady state channel flows to illustrate the accuracy and robustness of the new algorithms.

AN EVALUATION OF ROE'S SCHEME GENERALIZATIONS FOR EQUILIBRIUM REAL GAS FLOWS. Lorenzo Mottura, Luigi Vigevano, and Marco Zaccanti. *Dipartimento di Ingegneria Aerospaziale, Politecnico di Milano, Via Golgi 40, 20133 Milan, Italy.*

The extension of Roe's approximate Riemann solver to equilibrium real gas is analyzed by means of a general formulation, allowing us to clarify the inherent nonuniqueness of the average state and the influence of the functional form of the equation of state. Several generalizations of Roe's scheme are then reviewed and their numerical performances are discussed by computing some 2D steady hypersonic flows. The flow solvers are coupled with a newly developed, efficient, and robust procedure for thermochemical air properties evaluation. All of the tested equilibrium solvers achieve very similar results. They are found of comparable numerical efficiency, the higher performances being associated with Vinokur's and Liou's solvers. It is concluded that equilibrium simulations in 2D are by no means less robust than the perfect gas ones, when coupled with the proposed procedure for properties evaluation.