FINITE ELEMENTS VOLUME VI pdf

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The subdivision of a whole domain into simpler parts has several advantages: A typical work out of the method involves 1 dividing the domain of the problem into a collection of subdomains, with each subdomain represented by a set of element equations to the original problem, followed by 2 systematically recombining all sets of element equations into a global system of equations for the final calculation. The global system of equations has known solution techniques, and can be calculated from the initial values of the original problem to obtain a numerical answer. In the first step above, the element equations are simple equations that locally approximate the original complex equations to be studied, where the original equations are often partial differential equations PDE. To explain the approximation in this process, FEM is commonly introduced as a special case of Galerkin method. The process, in mathematical language, is to construct an integral of the inner product of the residual and the weight functions and set the integral to zero. In simple terms, it is a procedure that minimizes the error of approximation by fitting trial functions into the PDE. The residual is the error caused by the trial functions, and the weight functions are polynomial approximation functions that project the residual. The process eliminates all the spatial derivatives from the PDE, thus approximating the PDE locally with a set of ordinary differential equations for transient problems. These equation sets are the element equations. They are linear if the underlying PDE is linear, and vice versa. This spatial transformation includes appropriate orientation adjustments as applied in relation to the reference coordinate system. The process is often carried out by FEM software using coordinate data generated from the subdomains. FEA as applied in engineering is a computational tool for performing engineering analysis. It includes the use of mesh generation techniques for dividing a complex problem into small elements, as well as the use of software program coded with FEM algorithm. In applying FEA, the complex problem is usually a physical system with the underlying physics such as the Euler-Bernoulli beam equation , the heat equation , or the Navier-Stokes equations expressed in either PDE or integral equations , while the divided small elements of the complex problem represent different areas in the physical system. FEA is a good choice for analyzing problems over complicated domains like cars and oil pipelines , when the domain changes as during a solid state reaction with a moving boundary , when the desired precision varies over the entire domain, or when the solution lacks smoothness. FEA simulations provide a valuable resource as they remove multiple instances of creation and testing of hard prototypes for various high fidelity situations. Another example would be in numerical weather prediction , where it is more important to have accurate predictions over developing highly nonlinear phenomena such as tropical cyclones in the atmosphere, or eddies in the ocean rather than relatively calm areas. Colours indicate that the analyst has set material properties for each zone, in this case a conducting wire coil in orange; a ferromagnetic component perhaps iron in light blue; and air in grey. Although the geometry may seem simple, it would be very challenging to calculate the magnetic field for this setup without FEM software, using equations alone. FEM solution to the problem at left, involving a cylindrically shaped magnetic shield. The ferromagnetic cylindrical part is shielding the area inside the cylinder by diverting the magnetic field created by the coil rectangular area on the right. The color represents the amplitude of the magnetic flux density , as indicated by the scale in the inset legend, red being high amplitude. The area inside the cylinder is low amplitude dark blue, with widely spaced lines of magnetic flux , which suggests that the shield is performing as it was designed to. History[edit] While it is difficult to quote a date of the invention of the finite element method, the method originated from the need to solve complex elasticity and structural analysis problems in civil and aeronautical engineering. Its development can be traced back to the work by A. Hrennikoff [4] and R. Courant [5] in the early s. Another pioneer was Ioannis Argyris. In the USSR, the introduction of the practical application of the method is usually connected with name of Leonard Oganesyan. Feng proposed a systematic numerical method for solving partial differential equations. The method was called the finite difference method based on variation principle, which was another independent invention of the finite element method. Although the approaches used by these pioneers are different, they share one essential characteristic: The finite element method obtained its real impetus in the s and s by the developments of J. Argyris with co-workers at the University of Stuttgart , R. Clough with co-workers at UC Berkeley , O. Further impetus was provided in these years by available open source finite element software programs. A finite element method is characterized by a variational formulation , a discretization strategy, one or more solution algorithms and post-processing procedures. Examples of variational formulation are the Galerkin method , the discontinuous Galerkin method, mixed methods, etc. A discretization strategy is understood to mean a clearly defined set of procedures that cover a the creation of finite element meshes, b the definition of basis function on reference elements also called shape functions and c the mapping of reference elements onto the elements of the mesh. Examples of discretization strategies are the h-version, p-version , hp-version , x-FEM , isogeometric analysis , etc. Each discretization strategy has certain advantages and disadvantages. A reasonable criterion in selecting a discretization strategy is to realize nearly optimal performance for the broadest set of mathematical models in a particular model class. There are various numerical solution algorithms that can be classified into two broad categories; direct and iterative solvers. These algorithms are designed to exploit the sparsity of matrices that depend on the choices of variational formulation and discretization strategy. Postprocessing procedures are designed for the extraction of the data of interest from a finite element solution. In order to meet the requirements of solution verification, postprocessors need to provide for a posteriori error estimation in terms of the quantities of interest. When the errors of approximation are larger than what is considered acceptable then the discretization has to be changed either by an automated adaptive process or by action of the analyst. There are some very efficient postprocessors that provide for the realization of superconvergence. Illustrative problems P1 and P2[edit] We will demonstrate the finite element method using two sample problems from which the general method can be extrapolated. It is assumed that the reader is familiar with calculus and linear algebra. P1 is a one-dimensional problem P1.

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2: Control Volume Finite Element Methods for Flow in - InTechOpen - www.enganchecubano.com

Finite Elements: Fluid Mechanics, Vol. www.enganchecubano.com Texas Finite Elements Series. by Oden, J. Tinsley and Graham F. Carey: and a great selection of similar Used, New and Collectible Books available now at www.enganchecubano.com

Next page This technique is not thought of as being a reliability improvement method, yet it can contribute significantly to its enhancement. Finite Element Analysis FEA is a technique of modeling a complex structure into a collection of structural elements that are interconnected at a given number of nodes. The model is subjected to known loads, whereby the displacement of the structure can be determined through a set of mathematical equations that account for the element interactions. The reader is encouraged to read Buchanan and Cook for a more complete and easy understanding of the theoretical aspects of FEA. In commercial use, FEA is a computer-based procedure for analyzing a complex structure by dividing it into a number of smaller, interconnected pieces the "finite elements" , each with easily definable load and deflection characteristics. An example of a point element is a lumped mass element or an element specifically created to represent a particular constraint or loading present at that point. Truss links, rods, beams, pipes, cables, rigid links, springs, and gaps are examples of line elements. This type of element is usually characterized by two grid points or nodes at each end. Membranes, plates, shells and certain types of fluid and thermal elements fall into this category. The surface elements can be triangular or quadrilateral, and thin or thick; accordingly they are characterized by a connectivity of three or more grid points or nodes. Examples of solid elements include wedges, prisms, cubes, parallelepipeds and three-dimensional fluid and thermal elements. Elements in this category are usually defined using six or more grid points or nodes. Combinations of springs, gaps, dampers, electrical conductors, acoustic, fluid, magnetic, mass, superelement, crack tips, radiation links, etc. For example, commonly used elements in the automotive industry body engineering are: However, the two predominant types are nonlinear and dynamic. Geometric Stress less than yield strength Euler elastic buckling Examples: Most of the FEA applications involve this kind of analysis. Examples include joint stiffness and door sag. Examples include door intrusion beam, roof crush, and seat belt pull. Examples include windshield wipers or latch mechanism. Examples include knee bolster crash, front crash, and rear crash. Let us look at these combinations a little more closely: This is the simplest form of analytical application and is used most frequently for a wide range of structures. The desired results are usually the stress contours , deformed geometry, strain energy distribution, unknown reaction forces, and design optimization. This analysis is also relatively simple to perform and is used to calculate critical buckling loads. Caution should be exercised when performing this analysis because it produces analytical results that are not conservative. In other words, the critical buckling load thus calculated is usually higher than the actual load that would be determined through testing. A typical application is hood buckling. This is an extremely useful technique for determining the natural frequencies eigenvalues of components and also the corresponding eigenvectors which represent the modes of deformation. Strictly speaking, this category does not fall under dynamic analysis since the problem is not time dependent. Typical examples include instrument panels, total vehicle or component NVH evaluation, door inner panel flutter, and steering column shake. In general, all nonlinear analysis requires advanced methodology and is not recommended for use by inexperienced analysts. Usually, a graduate degree or several graduate level courses in the theory of elasticity, plasticity, vibrations, and solid and fluid mechanics are required to understand nonlinear behavior. Nonlinear FEA tends to be as much an art as it is a science, and familiarity with the subject structure is essential. Typical examples are seat back distortion, door beam bending rigidity studies, underbody components such as front and rear rails and wheel housings, bumper design, and crush analysis of several components. This FEA category is the most advanced. It involves very complex ideas and techniques and has become practicable only due to the availability of super-high-speed computers. This class of analysis involves all the complexities of nonlinear static analysis as well as additional problems involved with iterative time step selection and contact simulation at impact. Typical applications are related to crash evaluation and energy management. Specification of concerns and expected results Planning of analysis: Making decisions regarding the applicability of FEA, which code to use, and the size and the type of model to be constructed Digitizing: The translation of a drawing into line data that is available to the modeler Modeling: Creating, editing and storing a formatted data file that includes a description of the model geometry, material properties, constraints, applied loading, and desired output Execution: A study of the output to check the validity of the input parameters as well as the solution of the structural problem Feasibility considerations: Utilizing the output to make intelligent technical decisions about the acceptability of the structural design and the scope for design enhancement Parametric studies: Redesign using parametric variation The easiest changes to study are those involving different gages, materials, constraints, and loading. Geometric changes require repetition of steps 3 through 8; the same is true about remodeling of the existing geometry. What type of analysis?

3: Detailed Explanation of the Finite Element Method (FEM)

As one of the premier rare book sites on the Internet, Alibris has thousands of rare books, first editions, and signed books available. With one of the largest book inventories in the world, find the book you are looking for. To help, we provided some of our favorites. With an active marketplace of.

For the vast majority of geometries and problems, these PDEs cannot be solved with analytical methods. Instead, an approximation of the equations can be constructed, typically based upon different types of discretizations. These discretization methods approximate the PDEs with numerical model equations, which can be solved using numerical methods. The solution to the numerical model equations are, in turn, an approximation of the real solution to the PDEs. The finite element method FEM is used to compute such approximations. Take, for example, a function u that may be the dependent variable in a PDE i. The function u can be approximated by a function uh using linear combinations of basis functions according to the following expressions: The figure below illustrates this principle for a 1D problem. Here, the linear basis functions have a value of 1 at their respective nodes and 0 at other nodes. In this case, there are seven elements along the portion of the x-axis, where the function u is defined i. The coefficients are denoted by u0 through u7. One of the benefits of using the finite element method is that it offers great freedom in the selection of discretization, both in the elements that may be used to discretize space and the basis functions. In the figure above, for example, the elements are uniformly distributed over the x-axis, although this does not have to be the case. Smaller elements in a region where the gradient of u is large could also have been applied, as highlighted below. Both of these figures show that the selected linear basis functions include very limited support nonzero only over a narrow interval and overlap along the x-axis. Depending on the problem at hand, other functions may be chosen instead of linear functions. Another benefit of the finite element method is that the theory is well developed. The reason for this is the close relationship between the numerical formulation and the weak formulation of the PDE problem see the section below. For instance, the theory provides useful error estimates, or bounds for the error, when the numerical model equations are solved on a computer. Looking back at the history of FEM, the usefulness of the method was first recognized at the start of the s by Richard Courant, a German-American mathematician. While Courant recognized its application to a range of problems, it took several decades before the approach was applied generally in fields outside of structural mechanics, becoming what it is today. Finite element discretization, stresses, and deformations of a wheel rim in a structural analysis. For example, conservation laws such as the law of conservation of energy, conservation of mass, and conservation of momentum can all be expressed as partial differential equations PDEs. Constitutive relations may also be used to express these laws in terms of variables like temperature, density, velocity, electric potential, and other dependent variables. Differential equations include expressions that determine a small change in a dependent variable with respect to a change in an independent variable x, y, z, t. This small change is also referred to as the derivative of the dependent variable with respect to the independent variable. Say there is a solid with time-varying temperature but negligible variations in space. In this case, the equation for conservation of internal thermal energy may result in an equation for the change of temperature, with a very small change in time, due to a heat source g: Temperature, T, is the dependent variable and time, t, is the independent variable. The function may describe a heat source that varies with temperature and time. The equation is a differential equation expressed in terms of the derivatives of one independent variable t. Such differential equations are known as ordinary differential equations ODEs. In some situations, knowing the temperature at a time t0, called an initial condition, allows for an analytical solution of Eq. Oftentimes, there are variations in time and space. The temperature in the solid at the positions closer to a heat source may, for instance, be slightly higher than elsewhere. Such variations further give rise to a heat flux between the different parts within the solid. In such cases, the conservation of energy can result in a heat transfer equation that expresses the changes in both time and spatial variables x , such as: For a Cartesian coordinate system, the divergence of q is defined as: When a differential equation is expressed in terms of the derivatives of more than one independent variable, it is referred to as a partial differential equation PDE , since each derivative may represent a change in one direction out of several possible directions. In addition to Eq. Such knowledge can be applied in the initial condition and boundary conditions for Eq. In many situations, PDEs cannot be resolved with analytical methods to give the value of the dependent variables at different times and positions. It may, for example, be very difficult or impossible to obtain an analytic expression such as: Rather than solving PDEs analytically, an alternative option is to search for approximate numerical solutions to solve the numerical model equations. The finite element method is exactly this type of method â€" a numerical method for the solution of PDEs. Similar to the thermal energy conservation referenced above, it is possible to derive the equations for the conservation of momentum and mass that form the basis for fluid dynamics. Further, the equations for electromagnetic fields and fluxes can be derived for space- and time-dependent problems, forming systems of PDEs. Basis Functions and Test Functions Assume that the temperature distribution in a heat sink is being studied, given by Eq. The boundary conditions at these boundaries then become: The outward unit normal vector to the boundary surface is denoted by n. Equations 10 to 13 describe the mathematical model for the heat sink, as shown below. The domain equation and boundary conditions for a mathematical model of a heat sink. The next step is to multiply both sides of Eq. A Hilbert space is an infinite-dimensional function space with functions of specific properties. It can be viewed as a collection of functions with certain nice properties, such that these functions can be conveniently manipulated in the same way as ordinary vectors in a vector space. For example, you can form linear combinations of functions in this collection the functions have a well-defined length referred to as norm and you can measure the angle between the functions, just like Euclidean vectors. Indeed, after applying the finite element method on these functions, they are simply converted to ordinary vectors. The finite element method is a systematic way to convert the functions in an infinite dimensional function space to first functions in a finite dimensional function space and then finally ordinary vectors in a vector space that are tractable with numerical methods. The weak formulation is obtained by requiring 14 to hold for all test functions in the test function space instead of Eq. A problem formulation based on Eq. In the so-called Galerkin method, it is assumed that the solution T belongs to the same Hilbert space as the test functions. The relations in 14 and 15 instead only require equality in an integral sense. For example, a discontinuity of a first derivative for the solution is perfectly allowed by the weak formulation since it does not hinder integration. It does, however, introduce a distribution for the second derivative that is not a function in the ordinary sense. As such, the requirement 10 does not make sense at the point of the discontinuity. A distribution can sometimes be integrated, making 14 well defined. It is possible to show that the weak formulation, together with boundary conditions 11 through 13 , is directly related to the solution from the pointwise formulation. And, for cases where the solution is differentiable enough i. This is the first step in the finite element formulation. With the weak formulation, it is possible to discretize the mathematical model equations to obtain the numerical model equations. The Galerkin method â€" one of the many possible finite element method formulations â€" can be used for discretization. First, the discretization implies looking for an approximate solution to Eq. Finite element discretization of the heat sink model from the earlier figure. Once the system is discretized and the boundary conditions are imposed, a system of equations is obtained according to the following expression: The right-hand side is a vector of the dimension 1 to n. If the source function is nonlinear with respect to temperature or if the heat transfer coefficient depends on temperature, then the equation system is also nonlinear and the vector b becomes a nonlinear function of the unknown coefficients Ti. One of the benefits of the finite element method is its ability to select test and basis functions. It is possible to select test and basis functions that are supported over a very small geometrical region. This implies that the integrals in Eq. The support of the test and basis functions is difficult to depict in 3D, but the 2D analogy can be visualized. Assume that there is a 2D geometrical domain and that linear functions of x and y are selected, each with a value of 1 at a point i, but zero at other points k. The next step is to discretize the 2D domain using triangles and depict how two basis functions test or shape functions could appear for two neighboring nodes i and j in a triangular mesh. Tent-shaped linear basis functions that have a value of 1 at the corresponding node and zero on all other nodes. Two base functions that share an element have a basis function overlap. Two neighboring basis functions share two triangular elements. As such, there is some overlap between the two basis functions, as shown above. These contributions form the coefficients for the unknown vector T that correspond to the diagonal components of the system matrix Ajj. Say the two basis functions are now a little further apart. These functions do not share elements but they have one element vertex in common. As the figure below indicates, they do not overlap. Two basis functions that share one element vertex but do not overlap in a 2D domain. When the basis functions overlap, the integrals in Eq. When there is no overlap, the integrals are zero and the contribution to the system matrix is therefore zero as well. This means that each equation in the system of equations for 17 for the nodes 1 to n only gets a few nonzero terms from neighboring nodes that share the same element. The system matrix A in Eq. The solution of the system of algebraic equations gives an approximation of the solution to the PDE. The denser the mesh, the closer the approximate solution gets to the actual solution. The finite element approximation of the temperature field in the heat sink. Time-Dependent Problems The thermal energy balance in the heat sink can be further defined for time-dependent cases.

4: Finite volume method - Wikipedia

TYPES OF FINITE ELEMENTS. The library of finite elements available in general purpose codes can be subdivided into the following categories: Point elements: An example of a point element is a lumped mass element or an element specifically created to represent a particular constraint or loading present at that point.

We call pi the center of polyhedra Vi. Introduction The method of solution for the own problem is based on the control volume finite element approach which has been shown to be particularly well suited for a fast and efficient implementation of the Newton-Raphson linearization technique. The basic idea of the control volume finite element approach is to obtain a discretized equation that mimics the governing mass conservation equation locally. A volume of influence, referred to as a control volume, is assigned to each node. The discretized equation for a given node then consists of a term describing the change in fluid mass storage for that volume which is balanced by the term representing the divergence of the fluid mass flux in the volume. The fluid mass flux will depend on the physical properties associated with the volume and the difference in the value of the primary variable between the node in question and its neighbors. Discretization of the subsurface and the surface flow equations is identical except for the difference in dimensionality. For the sake of clarity, we present in this chapter, a detailed description of the control volume finite element method applied to discretize a simplified prototype continuity equation in Liquid composite molding LCM. The final discretized equations for all subsurface domains and for surface flow are then presented without providing the details of the derivation. Liquid composite molding LCM processes are routinely considered as a viable option to manufacture composite parts. In this process, a fibrous preform is placed in a mold. The mold is sealed and a liquid thermoset resin is injected to impregnate the fibrous preform. All LCM processes involve impregnation of the resin into a bed of fibrous network. The goal is to saturate all the empty spaces between the fibers with the resin before the resin gels and then solidifies. This is an open access chapter distributed under the terms of the Creative Commons Attribution License http: Thus, the entire cycle can be viewed as two separate events, fill and subsequent cure. The mould filling is considered as one of the most critical and complicated stages throughout the entire RTM process. It has a great influence on the performance and quality of the final parts. However, it is hard to understand effects of the filling parameters on the flow front pattern during mold filling. Therefore, it is necessary to understand interrelationship among filling parameters, flow behavior during RTM, and physical properties of the final parts. The present study concerns the numerical modeling of resin transfer molding techniques RTM. From a mechanical point of view, these processes can be treated in the same way as the problems of fluids in porous media. Some of authors use methods based on the systems of curvilinear coordinates adapted to a border. However, this approach becomes limited during divisions or fusion of the flow fronts []. This type of approach was first presented by Wang and others and was adopted in the case of thin shell injection molding [5]. The application of these methods generate several commercial software: However, this numerical approach has some inherent drawbacks. First, the flow front is difficult to define with the exact location because of using fixed mesh system. Mass conservation problems have also been reported with the use of this numerical approach [20,21]. Researchers have addressed these numerical problems and put forward methods to improve the conventional CVFEM method [19, 22]. In this study, the simulation of the resin flow in the RTM process is developed by the control volume finite element method CVFEM coupled with the equation of the free surface location. The equation is solved at each time step using nonconforming linear finite elements on triangles, which allow the conservation of the resin flow rate along interelement boundaries [23]. At each time step, the velocity and pressure in the saturated domain is calculated. The effective velocity is used to update the front position. The filling algorithm determines the time increment needed to fill up completely at least one new element, then the boundary condition is updated and the flow front is advanced for the next iteration. The flow front is refined in an adaptive manner at each time step by using our mesh generator to add new nodes, to get a smoother flow front and reduce the error in the pressure at the flow front of a CVFEM simulation of resin flow in a porous medium. Thus, the position of the flow front, the time-lapse and the rate of the unsaturated zone are calculated at every step. Our results will be compared with the experimental and analytical models in the literature. Resin Transfer Molding 5 On the whole, our study is concerned with the simulation of isothermal filling of moulds in RTM process while adopting the CVFEM and VOF method, taking into account the presence of obstacles and the thickness variation of the reinforcement. The elaborated code allows calculating the position of the injection points and vents, and injection pressure in order to optimize the process parameters. We present a mesh generator for 1D, 2D and 2. Numerical examples are used to validate and assess the applicability of the developed code in the case of anisotropic reinforcements, multilayered, several injection points and the existence of inserts. Continuity equations and Darcy law In RTM process and when filling the mould, the resin flow passes through a bed of fibers, The process of injection in the mould is treated as part of the flows of fluids inside a porous medium. On the basis of partial saturation concept, the mass balance at a point within the domain of an isothermal incompressible fluid flow inside a fiber preform can be expressed as [24]: If the transient term on the left hand side of the above equation is removed saturate case , the following equation for quasi-steady state situation is obtained: Assuming that the resin is incompressible and substituting 4 into 2 gives the governing differential equation of the flow: Two common boundary conditions for the inlet to the mould are either a prescribed pressure condition:

5: FINITE ELEMENT ANALYSIS (FEA) | Six Sigma and Beyond: Design for Six Sigma, Volume VI

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6: Finite element method - Wikipedia

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The finite element method (FEM) is the dominant discretization technique in structural mechanics. The basic concept in the physical interpretation of the FEM is the subdivision.

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In the finite volume method, you are always dealing with fluxes - not so with finite elements. However, the application of finite elements on any geometric shape is the same. Also, the boundary conditions which must be added after the fact for finite volume methods are an integral part of the discretized equations.

FINITE ELEMENTS VOLUME VI pdf

56th Evac. Hospital The arts crafts house Getting started in the modeling/talent industry Model of operational research Research methods in second language acquisition A Culture of Everyday Credit Performance of pavements designed with low-cost materials The Voyage to Colchis. Management and control of quality Snow white and the huntsman book Analysis of the color purple New comparative method Chinaberry Tree (African American Women Writers) Bull! 144 Stupid Statements from the Markets Fallen Prophets Table prayers for meal time Stage setter 8 manual Insurance and risk management notes Victorian Scientist Origami Boxes and More! Mayhem : mystery, UFOs, and cows The Development of Electric Power Transmission A mans house is his art : the Walker Art Centers Idea House Project and the marketing of domestic design If This Is Armageddon Its Very Pretty An economic analysis of alternative revenue generating policies for state financing Federal protection and preservation of wild and scenic rivers is slow and costly Lone Star and the Golden Mesa Work of Brian W. Aldiss Pontius Pilate in history and interpretation Improving the Army Planning, Programming, Budgeting, and Execution System Find differences in two uments Familiar Fire (A Fear Familiar Mystery) Asp.net 4.0 tutorial for beginners with examples Phasing out lead from gasoline in Central and Eastern Europe New Testament Documents Eells family of Dorchester, Massachusetts The decrease in the purchasing power of money. Types, lines, and categories of applicable insurance A Life and Death Decision Grandmother Elsie Wild flowers as they grow