Overview of MSC/DYTRAN Version 1

Roger Keene
Program Manager
The MacNeal-Schwendler Co. Ltd.
United Kingdom

MSC/DYTRAN is a new explicit transient dynamic code designed to solve large problems that involve the interaction of fluids and structure or the extreme deformation of materials. Its release means that MSC has three explicit codes to cover the entire range of transient, nonlinear problems:

MSC/DYNA - MSC/DYNA is intended for the simulation of transient problems dominated by structural dynamics. Typical applications include automotive crash, ship collision, and the heavy landing of aircraft.

MSC/PISCES - MSC/PISCES is a two-dimensional code for the solution of fluid/structure interaction problems and analyses involving the extreme deformation of materials. MSC/PISCES is particularly strong in the defence field for the simulation of ballistics and penetration problems.

MSC/DYTRAN - MSC/DYTRAN is a three-dimensional equivalent of MSC/PISCES designed for applications such as:

- the inflation and unfolding of airbags
- interaction of airbags with the occupant
- bird strike on aircraft
- ballistics
- penetration

MSC/DYTRAN combines the technology of MSC/DYNA and MSC/PISCES in a modern, vectorized and very efficient code structure. It contains a Lagrangian processor to model the structural parts of the model, and an Eulerian processor for modelling fluids and materials undergoing very large deformations.

The Lagrangian processor is essentially the same technology and algorithms that have already been proven in MSC/DYNA. It uses finite elements (solids and shells are available in MSC/DYTRAN Version1) which model a constant mass of material. As the material distorts, the mesh must distort to follow the material. While this is fine for moderate deformations, a Lagrangian finite element mesh is unable to model very large distortions or the flow of material.

The Eulerian processor in MSC/DYTRAN is able to solve these problems. It uses a mesh that is fixed in space and material can move from one element to the next. It is therefore ideal for modelling fluids. A finite volume formulation is used and, unlike many fluids codes, the elements can be of arbitrary shape with general connectivity. MSC/DYTRAN is almost unique in that the complete stress tensor is used within the Euler processor, allowing structural materials like steel or aluminum to be modelled. This is essential for impact and penetration calculations.

The Euler and Lagrange processors can be coupled. This allows forces from the Eulerian fluid to act on the Lagrangian structure, while the motion of the Lagrangian mesh acts as a boundary for the flow of the fluid in the Eulerian part of the model. This coupling is completely general and can undergo arbitrary motions. The coupling surface can also distort by any amount.

All the Lagrangian capabilities of MSC/DYNA are gradually being incorporated into MSC/DYTRAN. Once that task is complete, MSC/DYTRAN will replace MSC/DYNA, offering existing MSC/DYNA users significant new capability.

MSC/DYTRAN Version 1 will be available in the spring/early summer of 1991 on a range of popular computers.

CAPABILITIES OF MSC/DYTRAN VERSION 1

Solution

MSC/DYTRAN is an explicit, transient dynamic code using a central difference time integration scheme. The solution is all in core and vectorized and therefore very efficient. Problem size is limited only by the size of the computer being used.

The Lagrangian processor uses finite element techniques. The Euler processor is first order accurate and uses the OIL algorithm for the transports of material and voids.

Lagrangian Elements

CHEXA, CPENTA and CTETRA Solids: These use one point integration with viscous hourglass control and are the same as those in MSC/DYNA.

CQUAD4 Belytschko-Tsay Shell: This is also the same as in MSC/DYNA. It uses one point integration with viscous hourglass control.

CTRIA3 CO Triangular Shell: Again from MSC/DYNA, this element has one integration point in the plane of the element with a variable number through the thickness.

CTRIA3 Membrane: Mainly used to model the fabric of airbags, this is a simple constant strain triangle with no bending stiffness.

Eulerian Elements

CHEXA, CPENTA and CTETRA Solids: These finite volume based elements can be of arbitrary shape with general connectivity. This greatly simplifies the meshing of complex Eulerian regimes.

Rigid Bodies

Arbitrarily shaped rigid bodies are constructed from quadrilateral and triangular faces that form a closed volume.

Analytical rigid ellipsoids.

Constitutive Models

For Eulerian and solid Lagrangian elements, the complete constitutive model is defined by specifying a material model (shear and yield behavior), an equation of state (pressure/volume characteristic) and a failure model. The following will be available:

Material Models:

- Hydrodynamic (no shear)
- Von-Mises elastoplastic
- Johnson-Cook plasticity with strain rate and thermal effects

Equations of State:

- Elastic
- Ideal Gas
- Polynomial
- JWL high explosive

Failure Models:

- Spalling
- Maximum plastic strain

Shell and membrane elements use a more traditional constitutive model where the complete material behavior is defined. The following will be available initially:

- Elastic
- Von-Mises elastoplastic

Constraints and Loading

In the Lagrangian processor, loading and constraints are usually applied to grid points.

Rigid Wall: This models a rigid boundary of infinite size. Two options exist. In one case, grid points can slide on the wall and separate from it, but cannot penetrate the wall. In the second case, grid points can only slide on the wall, they can neither penetrate nor separate from the wall.

Enforced Motion: The velocity of a grid point in a particular direction can be specified throughout the analysis.

Tied, Coincident Grid Points: Grid points can be tied together in particular directions.

Initial Velocities: The velocity of grid points at the start of the analysis can be defined.

Pressure Loads: Time varying pressure loads can be applied to membrane elements.

Airbag Pressure Definition: A closed volume of membranes can have a pressure applied whose magnitude depends on the volume and temperature of the gas and specified inflow and outflow rates. This can be used to model the gas inside the airbag as the bag inflates. It is simpler, but less accurate, than doing a coupled Euler/Lagrange calculation.

Alternatively, a complete Eulerian calculation of gas dynamics during inflation can be used. The pressure in the Euler meshes are applied to the faces of the membrane elements.

In the Eulerian processor, the loading and boundary conditions on Euler meshes are applied to the faces of the elements.

Wall Boundary: Prevents flow through a face.

Pressure Boundary: Applies a pressure on the face.

Flow Boundary: Defines the mass flow rate, pressure and velocity of material entering the element.

Non-reflecting Boundary: Prevents reflection of stress and shock waves at the boundary.

Interactions

Euler/Lagrange Coupling: This coupling means that the pressures and stresses in the Eulerian mesh act as a load on the Lagrangian mesh. The motion of the surface of the Lagrangian mesh acts as a boundary condition on the flow of material in the Eulerian mesh. The coupling surface can be of arbitrary shape, being defined by the faces of the elements that form the outside of the Lagrange mesh. There is no limit to the amount that the coupling surface can move or deform. Euler/Lagrange coupling works with all types of Lagrange element (solid, shell and membrane) as well as with rigid bodies.

Contact Surfaces: The interaction of parts of the Lagrange mesh is modelled using contact surfaces. These are the same as those in MSC/DYNA and are of three types:

1) Two surface contact, used when two distinct surfaces interact.

2) Single surface contact, used when a surface folds and contacts itself, for example the buckling of sheet metal.

3) Grid points contacting a surface.

The surfaces can be of arbitrary size and shape and can deform and slide relative to each other during the analysis.

MADYMO Coupling: The rigid ellipsoids in MSC/DYTRAN can be coupled to the occupant modelling package MADYMO, produced by TNO in The Netherlands. The two codes run simultaneously and exchange information throughout the analysis. This allows a MADYMO occupant in an automobile for example, to interact with deformable components modelled using MSC/DYTRAN. These components could be airbags, seat belts, steering wheels or the car structure itself.

Rezoning

For problems where the distortions are sufficiently large to make designing a Lagrangian mesh difficult, but too small to require an Eulerian approach, MSC/DYTRAN allows the user to rezone a mesh during the calculation. Once the user has remeshed the problem using MSC/XL or another preprocessor, MSC/DYTRAN automatically maps all the data from the old mesh to the new one and continues the calculation.

Lagrangian elements, Eulerian elements, and rigid bodies can also be removed from the calculation when restarting.

User Subroutines

MSC/DYTRAN allows users to customize the code to their particular applications by the use of user subroutines. These can be used for defining Euler flow boundaries, Lagrange pressure loads, velocity boundary conditions, output of grid points and elements, and the pressure within a closed volume.

User Interface

MSC/NASTRAN Style Input: The input for MSC/DYTRAN is compatible with MSC/DYNA and MSC/NASTRAN. This means that most preprocessors can be used with the code.

Flexible Output: MSC/DYTRAN allows multiple output files to be produced containing only the information required.

Translators: Translators are provided with MSC/DYTRAN to convert the results for postprocessing by:

MSC/XL
I-DEAS
CAEDS
PATRAN
FEMVIEW