MAFELAP 2016

Conference on the Mathematics of Finite Elements and Applications

14–17 June 2016

Mini-Symposium: Development and application of meshless methods

Organisers:
Tom DeVuyst

Abstracts in alphabetical order

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CONTINUUM DAMAGE MECHANICS IN SPH BASED ON PARTICLE INTERACTION AREA

J.C. Campbell, K. Hughes, Rade Vignjevic, N. Djordjevic and T. De Vuyst

Structural Integrity Theme, Brunel University London, UK.
James.Campbell@brunel.ac.uk

The underlying concept of continuum damage mechanics is that mechanical damage is that the effect of damage within a material, occurring at a length scale too small to resolve in the numerical model, is averaged over a volume. Numerically this is represented by a continuous variable that is related to the density of the defects within the material and reduces the effective area over which stresses apply. Meshless methods such as Smooth Particle Hydrodynamics (SPH) are well suited to the application of large material deformation and failure. The SPH momentum equation can be rewritten in terms of a particle-particle interaction area. Damage acts to reduce this area and ultimately lead to material fracture. An implementation of this approach will be presented and discussed. The concept is demonstrated on a 1D flyer plate impact test and the results were compared to experimental data. Numerical results show that the model can recreate the phenomena associated with uniaxial spall to a high degree of accuracy.

SMOOTH PARTICLE HYDRODYNAMICS ANALYSIS OF HIGH-SPEED IMPACT INCLUDING FRACTURE CRITERIA AND FE CONVERSION

R. P.R. Cardoso

Brunel University London, Uxbridge, UB8 3PH London, UK.
Rui.Cardoso@brunel.ac.uk

Smooth Particles Hydrodynamics (SPH) is a very popular method for the numerical modelling of high speed impact (ballistics), where materials are usually subjected to high strain rates and large deformations. In this work, a newly developed SPH method is integrated with different high strain rate constitutive models for the numerical prediction of material degradation and failure during high speed ballistic simulations. The simulations will include contact between particles and finite elements as well as conversion of finite elements into SPH particles for the efficient modelling of large deformations and material separation. The SPH method is based on the use of the Moving Least Square (MLS) method for the SPH basis functions so that at least linear reproducibility is guaranteed. Different fracture criteria and element conversion thresholds will be presented for the conversion of finite elements into SPH particles.

SMOOTHED PARTICLE HYDRODYNAMICS MODELLING OF DYNAMIC FRACTURE AND FRAGMENTATION PROBLEMS.

T. De Vuyst, Rade Vignjevic, K. Hughes, J.C. Campbell and N. Djordjevic

Structural Integrity Theme, Brunel University London., UK.
Tom.DeVuyst@brunel.ac.uk

Research towards predicting the failure and fragmentation growth of explosively and electromagnetically driven metal cylinders and rings explosively within a meshless framework is described. Smoothed Particle Hydrodynamics (SPH), a meshless method, is of particular interest for the accurate prediction of fragmentation and fracture at high strain rate in metals. In combination with a damage model to initiate and propagate damage, the SPH method is able to treat the initiation, propagation, bifurcation and coalescence of cracks in a relatively straightforward manner. A modified Johnson-Cook material model combined with the Lemaitre damage model was used to describe the constitutive behaviour of the metals, while the explosive was modelled using a high explosive burn constitutive model and a JWL equation of state. Contact between explosive and casing are treated using a node to node contact algorithm based on a contact potential. The SPH method was used with both Eulerian and total Lagrangian interpolation kernels In order to correctly model fracture in the total Lagrangian SPH formulation a visibility criterion based on a truncated cone has been developed to stop particles obscured by a failed particle from interacting with other particles. The detailed data from electromagnetically driven ring experiments and fragment mass statistics from explosively driven fragmentation tests is used to evaluate the accuracy of the model predictions. The results demonstrate that this type of model is capable of predicting to good degree of accuracy the number of fragments as well as the fragment mass distribution.

MODELLING OF BIRD STRIKE ON THE ENGINE FAN BLADES USING FE-SPH

N. Djordjevic, Rade Vignjevic, T. De Vuyst, J.C. Campbell and K. Hughes

Structural Integrity Theme, Brunel University London, UK.
Nenad.Djordjevic@brunel.ac.uk

Bird strike is one of the major hazards for aircraft structures, particularly for the jet engines, where the strike can lead to significant power loss and fatal outcomes. Consequently, the key requirement of the damage tolerant design is to ensure survivability of aircraft components under bird strike, which must not lead to immediate loss of performance. The performance of a new jet engine design in the bird strike needs to be demonstrated experimentally in the certification process, but significant part of the blade design process is nowadays dominated by more cost effective numerical simulation tools. The main aim of the work presented here was simulation of bird strikes on lightweight engine blades. The simulations were performed with an in-house developed Smoothed Particle Hydrodynamics (SPH) code coupled with a transient nonlinear Finite Element (FE) code (Lawrence Livermore National Laboratory - DYNA3D), where the bird was modelled with SPH particles and the blades with the FE mesh. The key aspect of the analysis was modelling of contact between the bird and the blade, including the particle to node and the particle to surface contact algorithms, which are both available in the code. This was followed by parametric studies of the bird shape, the impact location and the impact timing. Two lightweight blade designs were considered in this work: a titanium-metallic blade and a carbon fibre composite blade. Simulation results were compared and validated in terms of the extent of damage induced in the blade and its final deformed shape recovered from the bird strike test.

MODELLING TRANSIENT FLUID LOADING ON FLEXIBLE STRUCTURES

K. Hughes, J.C. Campbell, N. Djordjevic, T. De Vuyst and Rade Vignjevic

Structural Integrity Theme, Brunel University London, UK
Kevin.Hughes@brunel.ac.uk

Structural response to water impact is important for several areas, including the aerospace and automotive industries. Liquid sloshing in tanks is important of manoeuver and crash behaviour and additionally aircraft must be designed to cope with ditching. The goal is a reliable technique for predicting the structural response to transient and extreme fluid loading. This is a complex problem, potentially involving the interaction of non-linear fluid behaviour with non-linear structural behaviour. This paper discussed the coupled FE/SPH approach for modelling fluid interaction with structures. The capabilities of the method are illustrated through comparison of model results with experimental data for sloshing and impact on water. Current challenges with respect to engineering application of this approach will be discussed.

SPH AS A NONLOCAL REGULARISATION METHOD FOR INSTABILITIES DUE TO STRAIN-SOFTENING

N. Djordjevic, Rade Vignjevic[a], T. De Vuyst, J.C. Campbell and K. Hughes

Structural Integrity Theme, Brunel University London, UK.
[a]v.rade@brunel.ac.uk

Meshless methods, such as Smoothed Particle Hydrodynamics (SPH), are of particular interest for the accurate prediction of failure including fragmentation and fracture. Within the framework of continuum damage mechanics (CDM) material mechanical properties are degraded locally with evolution of damage. These local models evaluate state and internal variables at points or particles with a limited ability to take into account the length scales (characteristic lengths) of the effects taking place at a sub continuum scale [1].

The presented work investigated the strain-softening effects in the SPH spatial discretisation combined with local and nonlocal CDM damage models. The simple uniaxial wave propagation in presence of damage induced material softening for which Bazant et al. [2] derived an exact solution was used in this investigation. The simulations were performed with the in-house SPH code MCM ("Meshless Continuum Mechanics").

The strain softening related problems observed by Bazant et. al. were not present in the total Lagrangean formulation of SPH [3] due to the nonlocal character of the SPH method. It was established that stress wave propagation continues in the presence of strain-softening and the waves continue to propagate within the damage localisation zone unlike in the FE simulation. Furthermore, it was demonstrated that the smoothing length represents characteristic length for the material considered and has to be defined with caution when modelling damage and failure.

References

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