8th. World Congress on Computational Mechanics (WCCM8)
5th. European Congress on Computational Methods in Applied Sciences and Engineering (ECCOMAS 2008)
June 30 – July 5, 2008
Venice, Italy

A MIXED EULERIAN-LAGRANGIAN FORMULATION FOR THE COMPUTATIONAL MODELLING OF EXTRUSION PROCESSES

***Alison J. Williams[1], T. Nick Croft[1], Avril K. Slone[1] and Mark Cross[1]**

[1] Centre for Civil and Computational Engineering
Swansea University
Singleton Park
SWANSEA SA2 8PP
UK
Alison.j.williams@swan.ac.uk

Key Words: *Forming Processes, Multiphysics Problems, Euler-Lagrange computational Methods, High Performance Computing*

ABSTRACT

Computational modelling of forming processes has been a major activity for well over 20 years in the computational engineering community. It is a challenging class of problems because it involves the interaction of a number of physical phenomena and the stretching of conventional numerical methods to their limits. In particular, the conventional formulation uses a Lagrangian finite element approach, which though effective for small strain problems, presents more challenges when trying to capture the large deformation of the work-piece within a reasonably rigid die. The extreme deformation of the work-piece may lead to re-meshing requirements and although this process may be automated, it is also a further overhead on what is already an expensive computational task. Nevertheless, the approach is entirely functional and combined with thermal effects provides a serviceable basis as a commercial simulation tool. Indeed, this approach has been embedded within a number of simulation tools that have been commercialised, the most notable of which are FORGE3 [1] and DEFORM [2]. However, the computational cost of the above Lagrangian approach is so significant that it becomes a natural candidate for being implemented on parallel clusters. Unfortunately, because the search algorithms in the contact analysis procedures are not readily parallelised, then the potential for parallel scalability is limited.

Alternatively, since even in the Lagrangian route, the work-piece is assumed to behave plastically (i.e. the elastic behaviour is neglected), others have taken the alternative Eulerian route whereby the flow of the metal through a rigid die is considered on a fixed ‘flow’ mesh. Although this works well and can easily embed thermal effects it is less flexible in that the die is assumed to be rigid and often the flow is assumed as steady. A simulation tool which uses this approach is superFORGE [3] which employs finite volume methods more typical of computational fluid dynamics (CFD) codes.

This paper describes an approach which uses a combined Eulerian-Lagrangian approach to capturing the interaction between the work-piece and a deformable die together with thermal effects, with an initial focus upon extrusion. This approach models the work-piece as a plastic 'fluid' and uses free surface techniques to capture transient effects, especially during the start-up phases of the process. The interaction between the work-piece and the Lagrangian die is then modelled as a fluid-structure interaction problem using the approach of Slone et al [4-5]. The benefit of this approach is that it not only captures all the phenomena involved in the simulation, but is also amenable to being parallelised by utilising the group solution strategy described by Williams et al [6].

In this paper the resulting computational model, which is implemented within the PHYSICA multi-physics simulation tool [7], is evaluated on both an emerging extrusion benchmark problems [8] and also on a fully functional test problem involving the thermal-fluid-structure model running on a parallel cluster. The performance on the benchmark problem is competitive with published solutions, Table 1, and, as can be seen from Table 2 below the parallel scalability on the test problem is very encouraging, indicating that the simulation technology is a viable tool for extrusion modelling especially, but also for more general forming processes.

Table 1 Comparison of exit velocities (m/s)

Bore location	Kleiner & Schikorra[9]	This work
Right	.0272	.0258
Top	.023	.0239
Middle	.022	.0219
Left	.0214	.0218
bottom	.0184	.0198

Table 2 Parallel simulation results

Processors	Run time (hours)	Speed-up
1	81.9	1
4	18.3	4.48
8	10.2	8.03
12	7.5	10.92
16	6.1	13.43

REFERENCES

[1] FORGE3, see http://www.transvalor.com

[2] DEFORM, see http://www.deform.com

[3] superFORGE, see http://www.mscsoftware.com

[4] A K Slone, *Dynamic fluid-structure interaction using finite Volume unstructured mesh techniques*, PhD Thesis, University of Greenwich, London, UK, 2000

[5] A.K. Slone, C.Bailey, K.A. Pericleous and M. Cross, "Dynamic fluid structure interaction using Finite Volume Unstructured Mesh procedures", *Computers and Structures*, Vol. **80**, 371-390, 2002

[6] A J Williams, T N Croft and M Cross, "A group based solution strategy for multi-physics simulations in parallel", *Applied Math Modelling*, Vol. **30**, 656-674, 2006

[7] PHYSICA, see http://www.physica.co.uk

[8] Extrusion Zurich 2005, see http://www.ivp.eth.ch/extrusion05

[9] M Kleiner and M Schikorra, Institute of Forming Technology and Lightweight Construction, University of Dortmund, Germany, private communication.