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

Analysis of Plastic Pipes Subjected to Impact Ruptures

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Key words: *crack identification, FE analysis, polypropylene pipes, brittle, laboratory*

Current standards drive the industrial producers toward new experimentation of their products against the ruptures due to impact occurrences. Pipes made of plastic are elements which are subjected to such events during their use but also during transportation and installation [1].

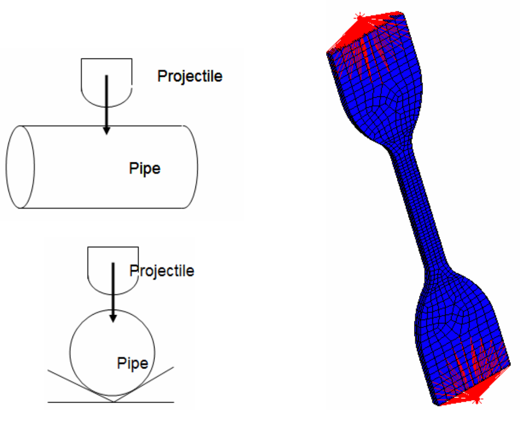
This work presents a methodology for analysing polypropylene pipes available on the market subjected to impact failures and characterized by brittle behaviour at low temperature (0°C). The numerical simulations consist in three-dimensional finite element approach [2, 3] supported by laboratory experiments aimed: to the identification of the material characteristics and to the validation of the numerical analyses (F. a-b). The low temperature and the tests velocity are basic parameters to drive the material response in different ways: experimentally, they are taken into account by a thermal chamber and by a suitable tuning of the testing machine actuator.

The physical problem of a body subjected to an impact load is characterized by several nonlinearities, which must be captured by the numerical model. A commercial finite element code is used to achieve three-dimensional numerical models of pipe prototypes (diam. 75mm thick 2.5mm, diam. 50mm thick 2mm). The implementation involves the nonlinear behavior of the polypropylene material. The structural dynamic equilibrium is found considering the deformed shape of the connection in large displacement and deformation conditions (F. c-d). The friction contribution is also implemented.

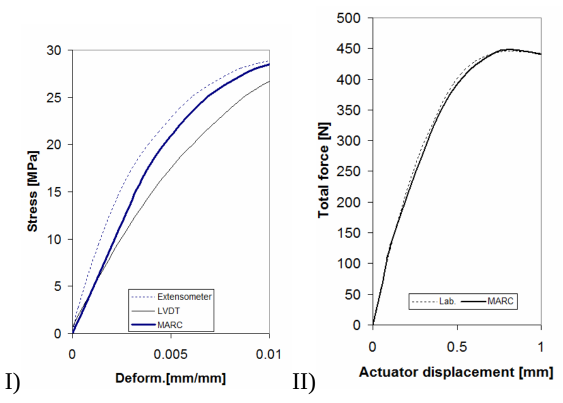
The limit state of cracking of a brittle material is usually estimated as its elastic limit. Following the Galileo-Rankine-Navier criterion, the principal maximum and minimum stress have to be internal to the elastic interval [σ_c, σ_t], or in general form

$$\sigma_c \le S_a \le \sigma_t ; \qquad a=I,II,III$$

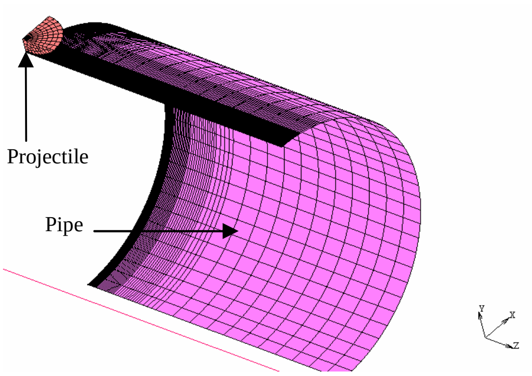
where σ_c and σ_t are the compression and tension limits of the stress in a mono-axial test and S_a are the principal stresses [4]. It is applied in the numerical analyses to identificate the crack occurrence in the prototypes under impacts. A further development will implement an original FE methodology able to follow the fracture path evolution in time and space.



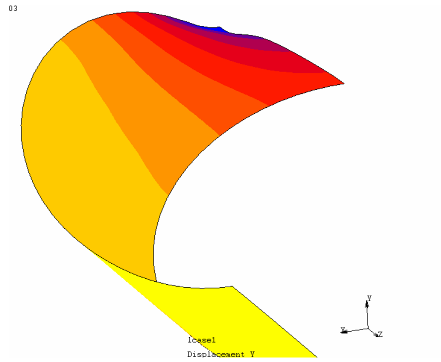
a) Laboratory conditions and specimen model



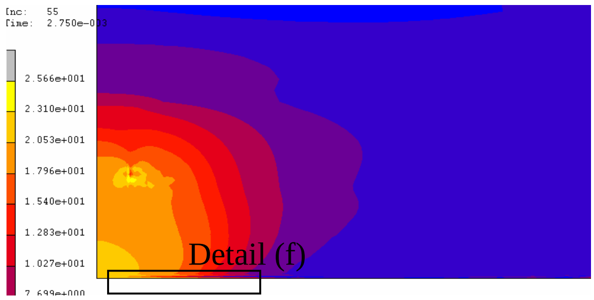
b) Mono-axial test 0°C: (I) calc. stress –meas. strain – (II) meas. force – meas. displ.



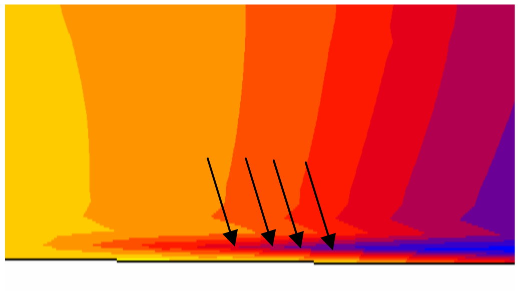
c) 3D symmetric mesh



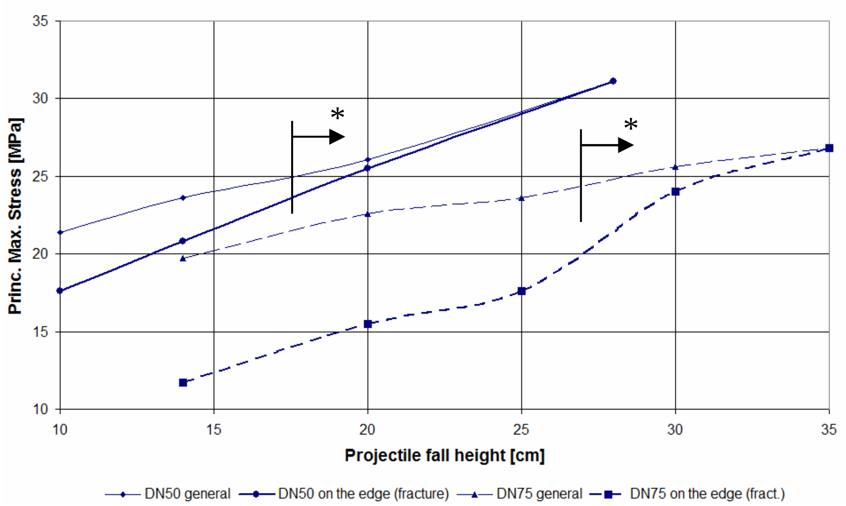
d) Deformed shape



e) Results: diam. 75mm princ. max stress – impact area



f) Crack detail



g) Comparison: numerical and lab tests 0°C (* fall height from which the prototypes begin to show ruptures)

The numerical results match the observations of the laboratory tests on real scale prototypes and the theoretical assumptions. The critical stress of fracture is close to 25 MPa (F. e-f-g). Finally, so as to prevent unwanted impact ruptures, an enhancement of the material compound should be intended for a reduction of the longitudinal elastic modulus or for an increment of the elastic limit, this resulting, respectively, in additional flexibility and material strength.

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