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NUMERICAL STUDY ON BALLISTIC PHENOMENA - PART TWO

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ABSTRACT

The study of ballistic phenomena (interior ballistics, exterior ballistics and terminal ballistics) is an activity that involves the use of complex and at the same time very expensive equipment. Also, another aspect worth taking into account is the existence of risks when it comes to investigating the phenomena in this area.

The use of numerical methods for making the pre-digital tests can be seen as a logical and inexpensive approach. Furthermore, besides these advantages, the simulations of various ballistic phenomena allow for an otherwise impossible observation of different sizes and details regarding the polygon tests. In the case studied in this paper, the numerical modelling of the phenomenon of the charge of water propulsion allows for, as an example, the average speed evaluation of the whole amount of water, while in the case of polygon tests only the speed of peak flow value may be shown.

This paper is a numerical study on disrupting agent propulsion (internal ballistics), the speed water flow development and its distribution within the flow (the balancing kickback agent) being observed.

KEYWORDS: numerical modelling, ballistic phenomena

1. Case study

This paper was a numerical study on disrupting agent propulsion (internal ballistics), the speed water flow development and its distribution within the flow (the balancing kickback agent) being observed.

Thus, considering the geometrical and structural characteristics of the pipe and the mechanical characteristics of the disruption agent, the modeling and mesh parts were carried out.

Following the mesh of the structures involved in the water propulsion phenomenon, 169011 Euler type items, 2840 Lagrange type items and 24570 SPH items were obtained [14]. The schematization of the shaped assembly is shown in Fig. 1.

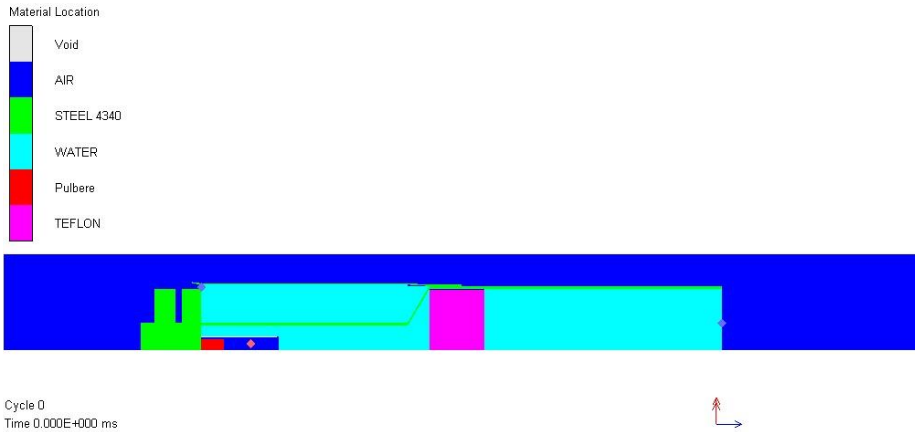


Fig. 1. *MEF Model*

The numerical simulation of propulsion was performed in AUTODYN v15.0, the type of analysis being the one stated.

The materials used were taken from the library and, for the powder, the model described in [17] was adopted. The material behavior is described by the following equations:

- ➢ AIR
- Density – 0.001225 g/cm^3;
- State equation of ideal gas type
  - Gamma: 1.4;
  - Adiabatic constant: 0;
  - Reference temperature: 288.2 K;
  - Specific heat: 717.599 J/kgK.
- ➢ WATER
- Density – 0.998 g/cm^3;
- State equation of shock type
  - Gruneisen coefficient: 0;
  - C1 Parameter: 1.647e3;
  - S1 Parameter: 1.921.
- ➢ TEFLON
- Density – 2.153 g/cm^3;
- State equation of shock type
  - Gruneisen coefficient: 0.59;
  - C1 Parameter: 1.841e3;
  - S1 Parameter: 1.707.
- ➢ POWDER
- Density – 1.86 g/cm^3;
- State equation of Powder Burn (Beta) type

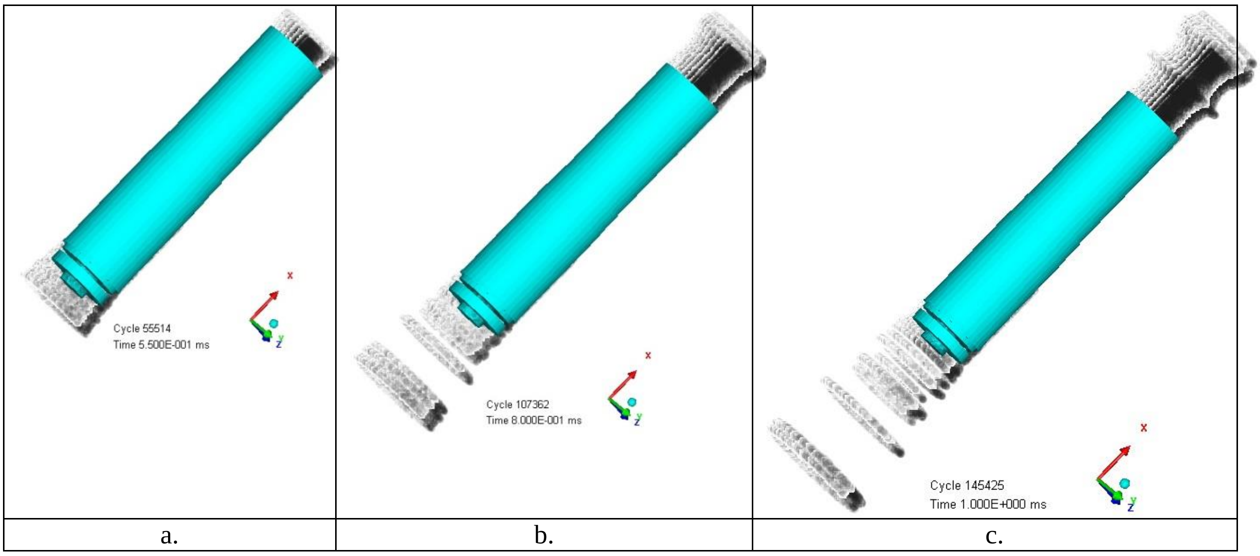
- EOS for solid phase - Linear type (Volume elasticity modulus: 1.35e7 kPa, Reference temperature: 293 K);

- EOS for reactive phase - Exponential type (G=52.169998; c=0.5; C1=500; C2=0; D=1.0033; e=1.8185e6 kJ/m^3; p1=1e-5kPa; p2=2.5e6; p3=5e6; p4=7.5e6; p5=1e7; p6=1.25e7; p7=1.5e7; p8=1.75e7; p9=2e7; p10=1e9; H1=0,0071; H2=2,0432; H3=3,8692; H4=5.6236; H5=7.3329; H6=9.0095; H7=10.6606; H8=12,2906; H9=13,9029; H10=515,278015; ρ1=1e-6; ρ2=1; ρ3=2; ρ4=3; ρ5=4; ρ6=5; ρ7=6; ρ8=7; ρ9=8; ρ10=9; γ1..γ10=1);

- Von Mises resistance model
  - G=1.38e6kPa; σ_c= 2e3kPa.
- ➢ Steel 4340 type
- Density – 7.83 g/cm^3;
- State equation of Linear type
  - Volume elasticity modulus: 1.59e8 kPa,
  - Reference temperature: 300K;
  - Specific heat: 477 J/kgK;
- Johnson-Cook resistance model
  - G=8.18e7kPa;
  - A= 7.92e5 kPa; B=5.1e5 kPa; n=0.26; C=0.014; m=1.03; T_t=1.793e3; $d\varepsilon_o/dt=1s^{-1}$.

Another key element in defining the parameters of the simulation was the definition of contacts between the three parts of the model (pipe, piston and agent of disruption).

The water dispersing mode is shown in Fig. 2.



a. b. c.

***Fig. 2.** Water dispersing mode in time*

The variation of the average speed of both water loads used by the disruptor is shown in Fig. 3 and Fig. 4.

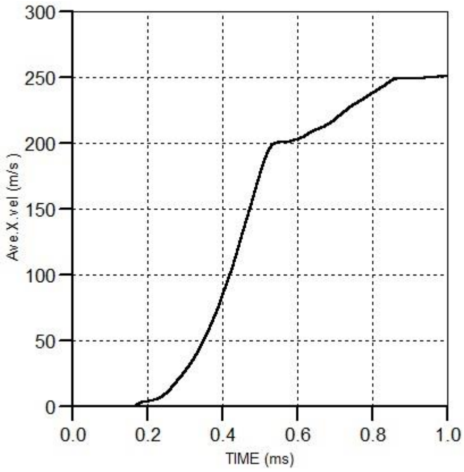


Fig. 3. *Average speed of the water (disrupting agent)*

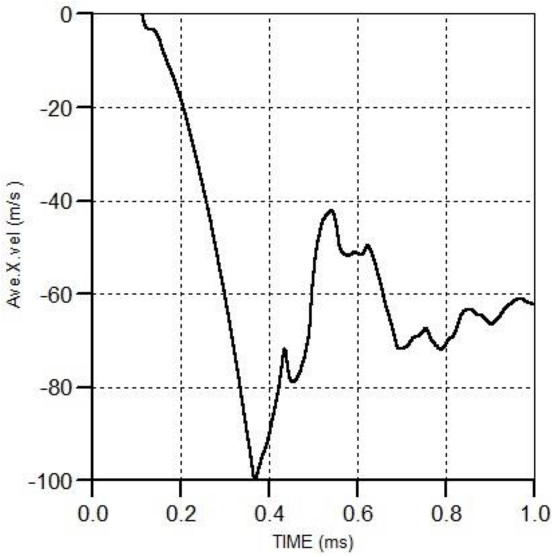


Fig. 4. *Average water speed (balancing agent kickback)*

Although the average speed chart of the disrupting agent and of the annulling agent of the kickback indicates a value of 250m/s, respectively, 62m/s, inside the flow there are also particles that record higher values of the speed (Fig. 5 and Fig. 6).

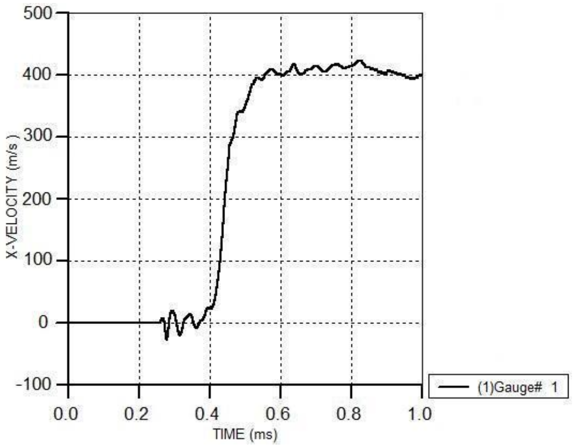


Fig. 5. *Evolution of the peak speed flow of the disruptor agent*

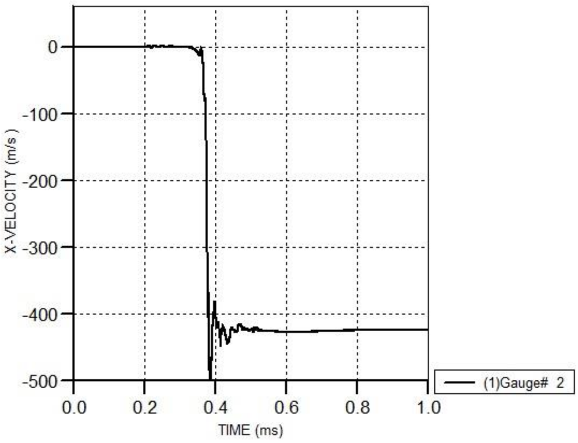


Fig. 6. *Evolution of the peak speed flow for water kickback compensation*

2. Conclusions

From those presented in the numerical modelling of the water propulsion phenomenon it results that the numerical approach is an easy way to achieve a detailed investigation and reduced costs.

The use of the SPH method allows for the numerical modelling of the phenomenon without the danger of blocking the problem because of the characteristic large deformations.

The analysis of the water speed field during covering 120mm highlights an average speed of the disrupting agent of 251m/s and a speed of the recoil agent of 62m/s. Also, the simulation shows a loss of flow coherence because of the water interaction with the adjacent environment (air). The flow peak speed presents a decrease after reaching a maximum value due to the interaction with air.

The comparative analysis of the numerical simulation results with the experimental results shows a good agreement in terms of the peak speed flow.

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