PERFORMANCE OF KINETIC ENERGY PROJECTILE - NUMERICAL AND EXPERIMENTAL STUDY

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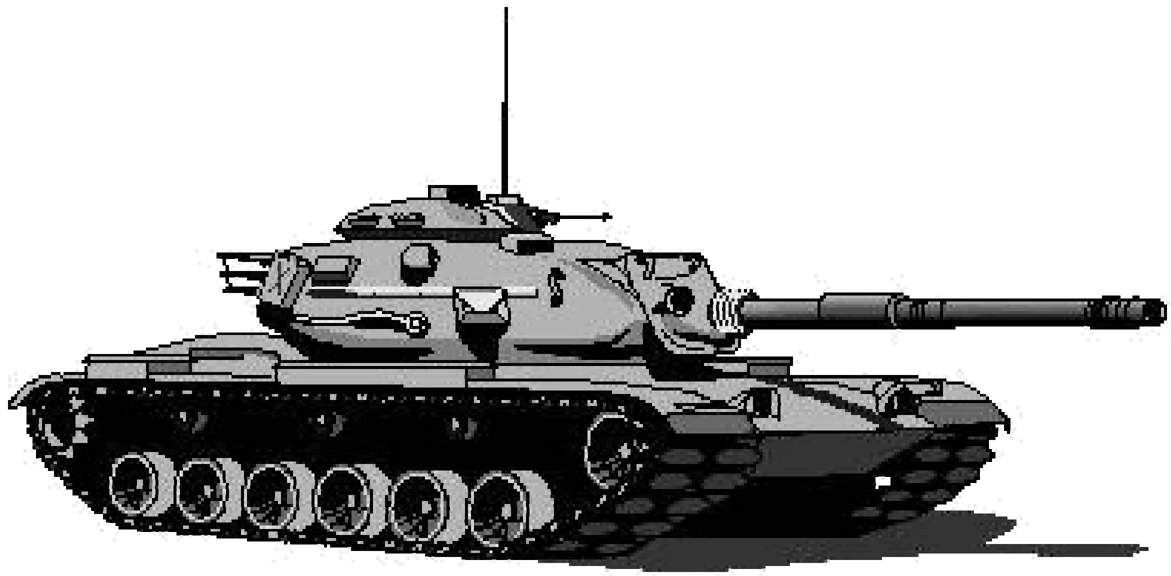
Effect of Yaw and Obliquity on Penetration

- High velocity kinetic energy long rods are one of the most important munitions of the main battle tank.

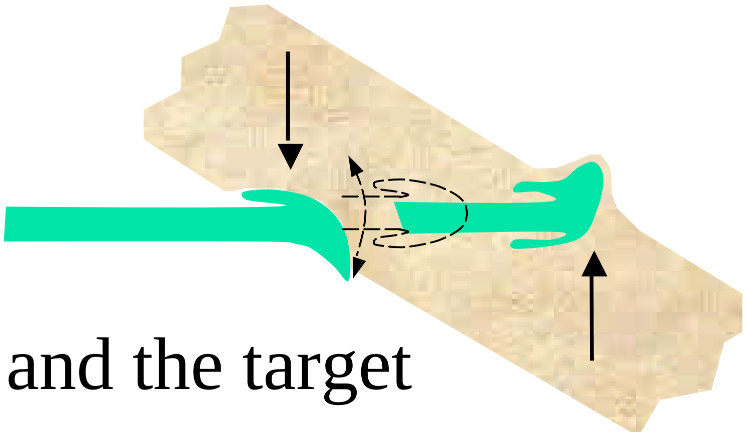


Passive armor

- One way to protect a tank against a kinetic energy long rod is to configure a series of thin plates as passive armor.
- These plates are generally oblique.
- This target is capable of breaking the rod.

Effect of Yaw and Obliquity on Penetration

- The penetration process of a rod while penetrating a thin and oblique target is characterized by the following factors:
  - erosion at the nose of the rod (large plastic strain)
  - rotation and bending of the rod
  - long rod breakage
  - interaction between the broken parts and the target



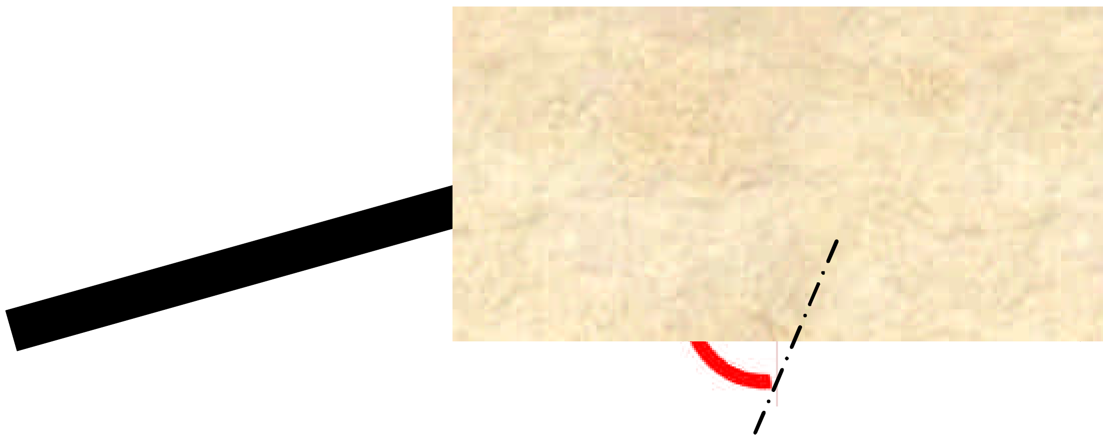
- Yaw worsens the above phenomena

The goals of the present work

- To build a numerical simulation of the penetration process.
- Validation of the numerical model with experimental results.
- Using the model to study the influence of the initial yaw on projectile penetrability.
- Using the numerical model to design an improved projectile.

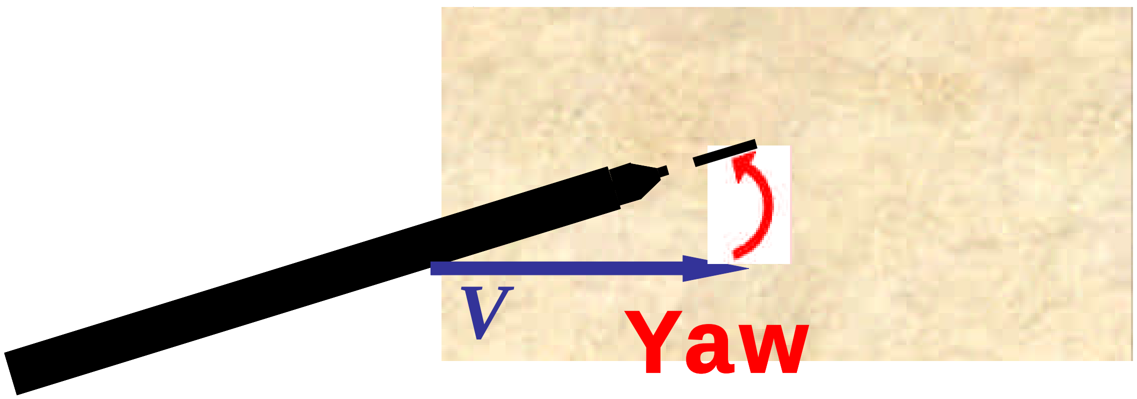
Def

Obliquity is the angle between the velocity vector of the rod and the normal to the target.

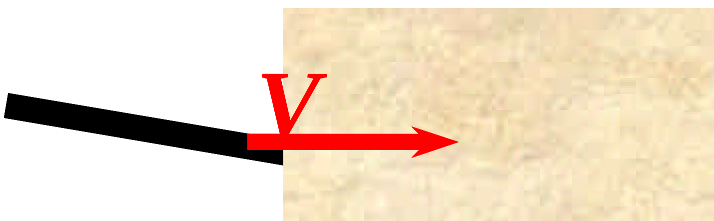


Def

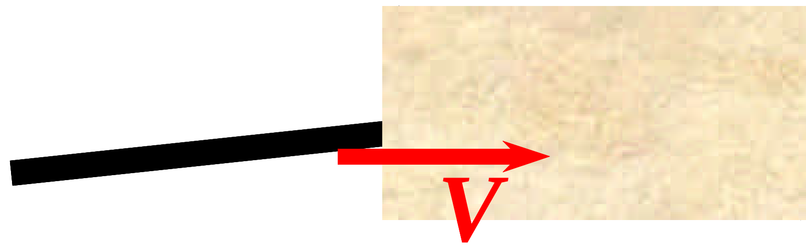
Yaw is the angle between the velocity vector direction of the rod and it's axis of symmetry.



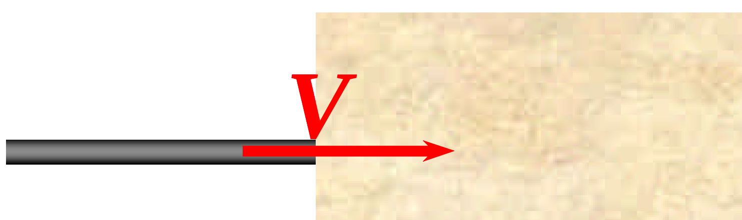
Initial Yaw Sign



Negative initial yaw angle



Positive initial yaw angle

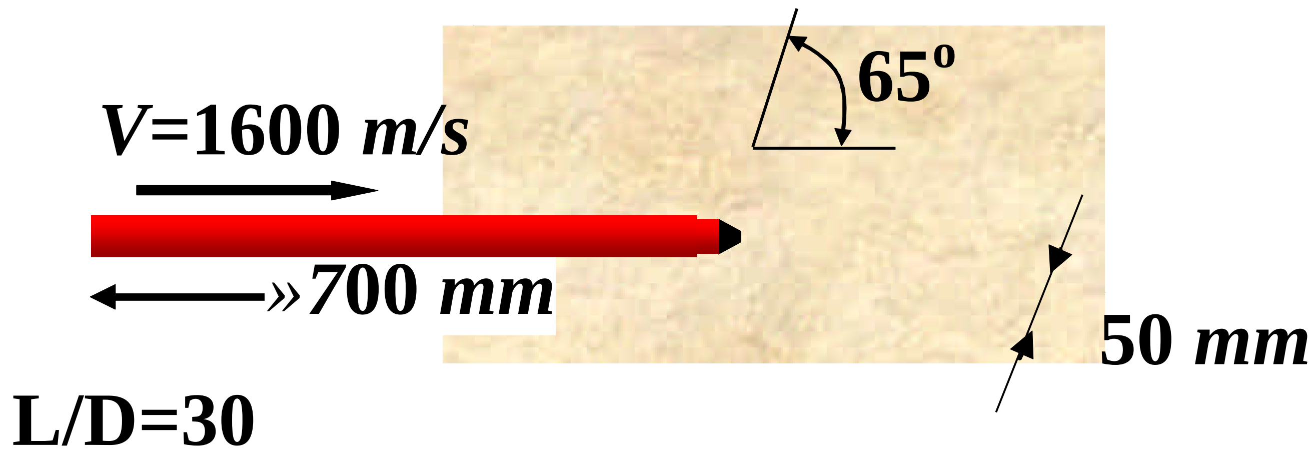


Zero initial yaw angle

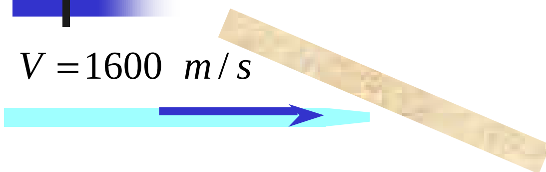
EXPERIMENTS

Schematic of the Experimental Set-up

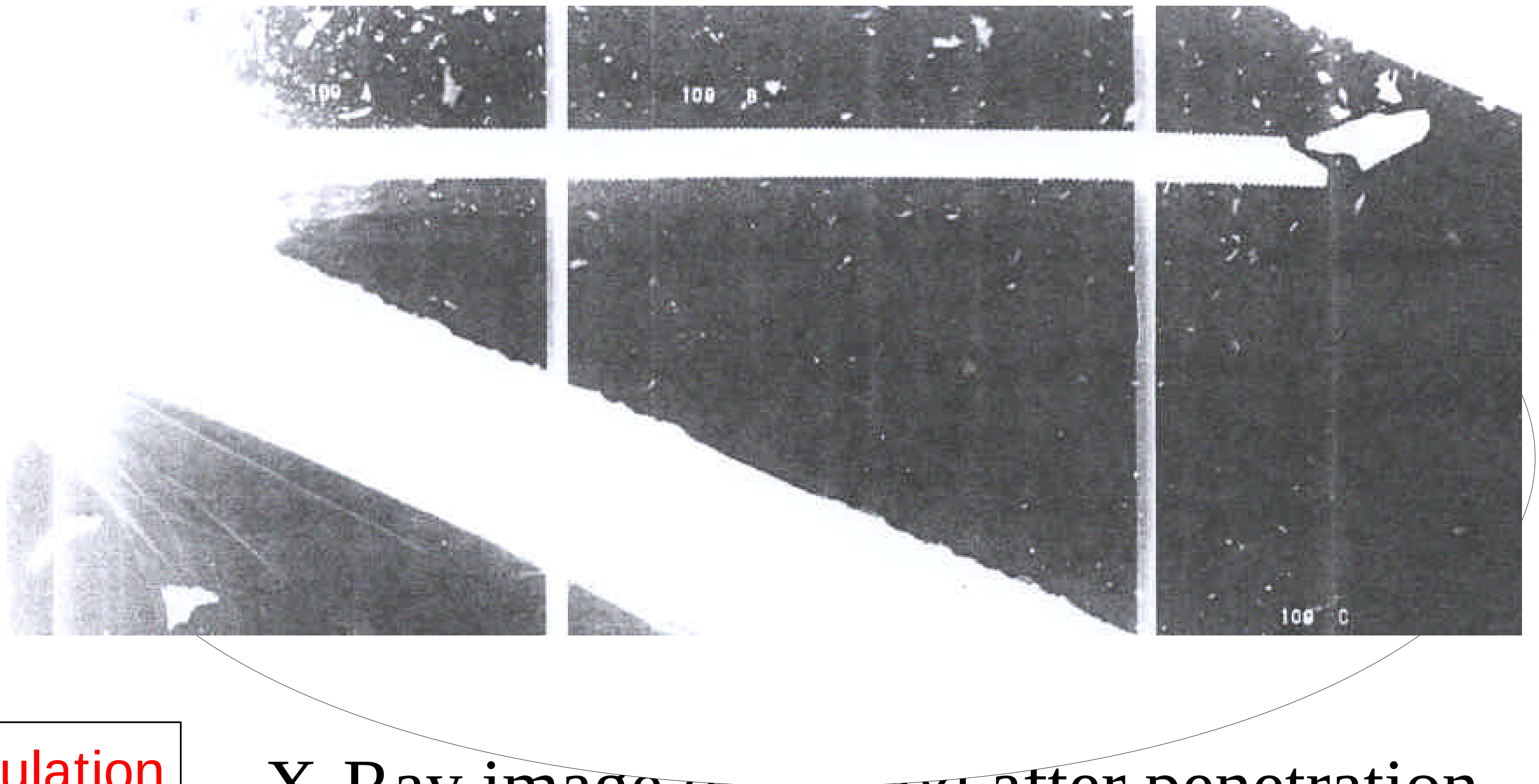
- The tungsten-alloy long rod penetrates the thin steel target



Experimental Results



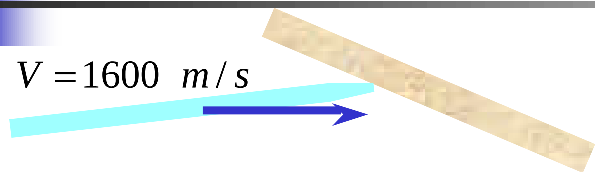
Initial yaw ≈ 0°



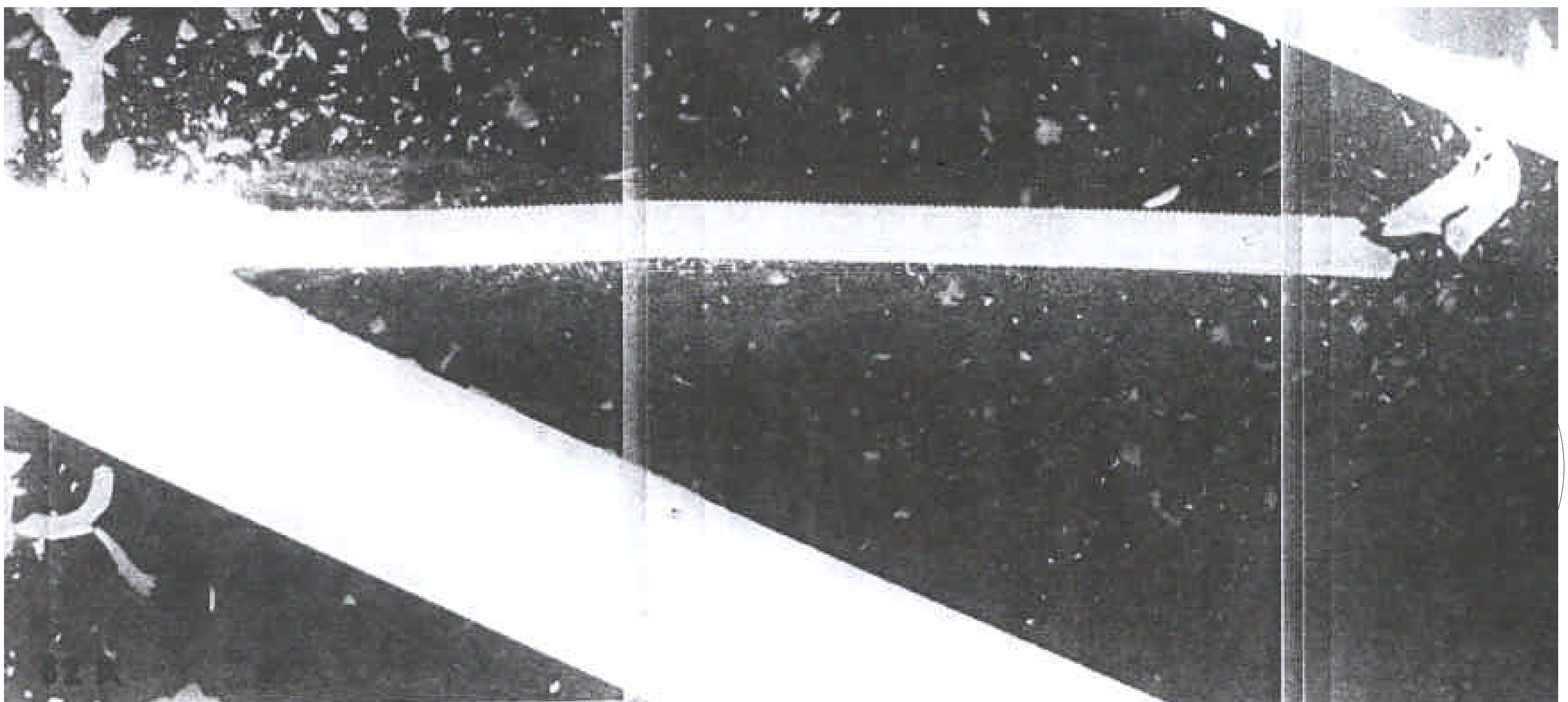
simulation

X-Ray image of the rod after penetration

Experimental Results



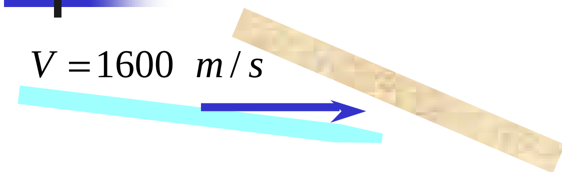
Initial yaw ≈ 1°



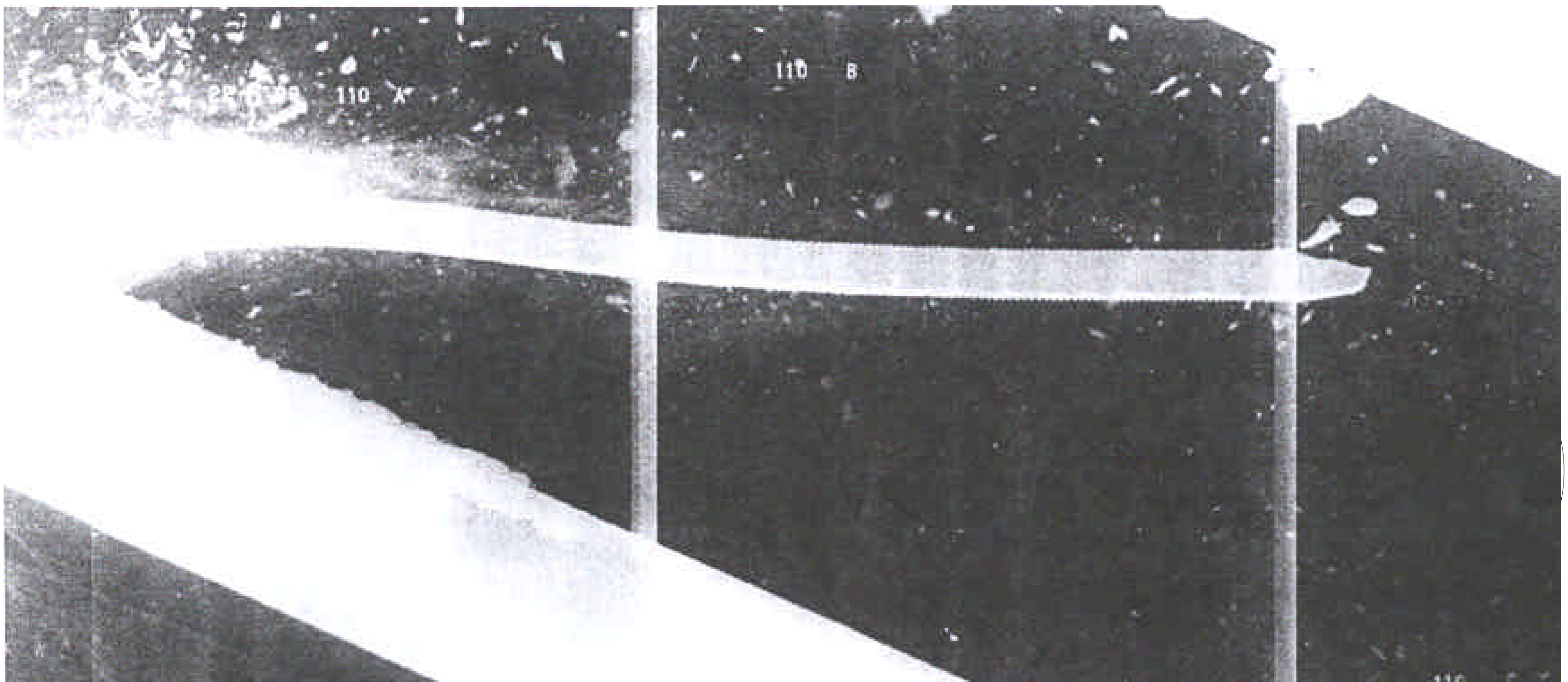
X-Ray image of the rod after penetration

simulation

Experimental Results



Initial yaw ≈ -1°



simulation

X-Ray image of the rod after penetration

Experimental Results

It is apparent that:

- the rod was bent and its nose was broken
- for a negative initial yaw angle the rod bends up
- for a positive initial yaw the rod bends down
- for a zero initial yaw the bending is minimal

NUMERICAL SIMULATION

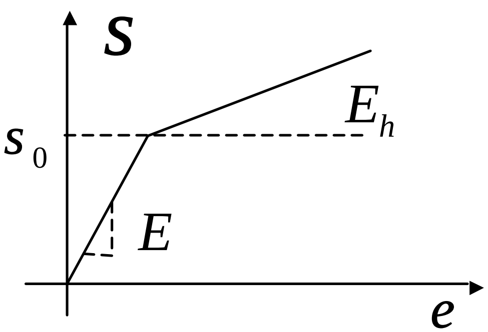
Numerical Simulation

A three-dimensional time-dependent finite element numerical simulation (MSC/DYTRAN) was performed in order to emulate the penetration process of the rod during and after target penetration .

Numerical Simulation

- Lagrangian explicit model.
- adaptive contacts to model the rod - target interaction
- a nonlinear, plastic material description with isotropic hardening:

$$s_y = s_0 + \frac{E\ \ E_h}{E - E_h} e_p$$



- a polynomial equation of state:

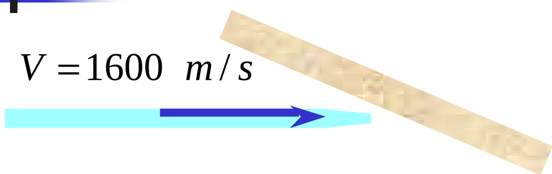
$$p = \begin{cases} a_1 m + a_2 m^2 + a_3 m^3 + \left(b_0 + b_1 m + b_2 m^2 + b_3 m^3\right) r_0 e & m > 0 \\ a_1 m + \left(b_0 + b_1 m\right) r_0 e & m \le 0 \end{cases}, m = \frac{r}{r_0} - 1$$

Numerical Simulation

A failure criterion model in the form of a user written subroutine was added to the MSC/DYTRAN code:

- it depends upon the state of the material in the element (stress, strain, pressure …)
- it is based on two types of material failure:
  - erosion failure
  - static maximum plastic strain failure

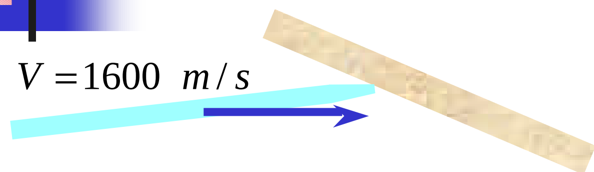
Numerical Simulation



Initial yaw = 0°

Experiment

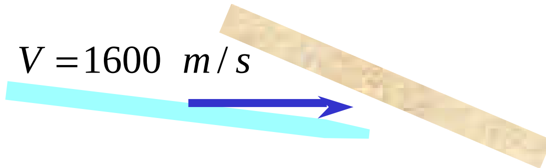
Numerical Simulation



Initial yaw = 1°

Experiment

Numerical Simulation



Initial yaw = -1°

Experiment

Numerical Simulation

The bending process:

- enlarges the hole crater in the target
- decreases the rod velocity
- diverts the direction of the penetrator

In addition, for none zero initial yaw values:

- the side of the rod pointing in the direction of its velocity is damaged. (This side is in greater contact with the target because of the velocity direction).

Numerical Simulation

- The overall results are a weakening of the rod and a decrease in its ability to penetrate a series of plates following the original thin plate target.
- For large yaw angles the bending of the long rod will cause it to break into several pieces.