CONTINUOUS SOLVENT-FREE EXTRUSION OF PROPELLANT FOR 35 MM CALIBRE AMMUNITION

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OVERVIEW

- Introduction
- Approach
- Propellant composition
- Rheological modelling and closed vessel testing
- Propellant grain geometry
- Preliminary propellant manufacturing and testing
- Processing with a 30mm co-rotating twin screw extruder
- Propellant characterization
- Firing tests
- Conclusions

INTRODUCTION

- Aim of the project: evaluation of new 35 mm calibre ammunition performance
- In-house testing (TNO Laboratory for Ballistic Research)

- Previously manufactured DB for 35 mm:
  - DB propellant composition
  - 45 mm continuous co-rotating twin-screw extruder
  - 10 wt% solvent

- New DB propellant with equal performance
  - Comparable composition based on JA-2 replacement
  - Solvent-free
  - 30 mm continuous co-rotating twin-screw extruder

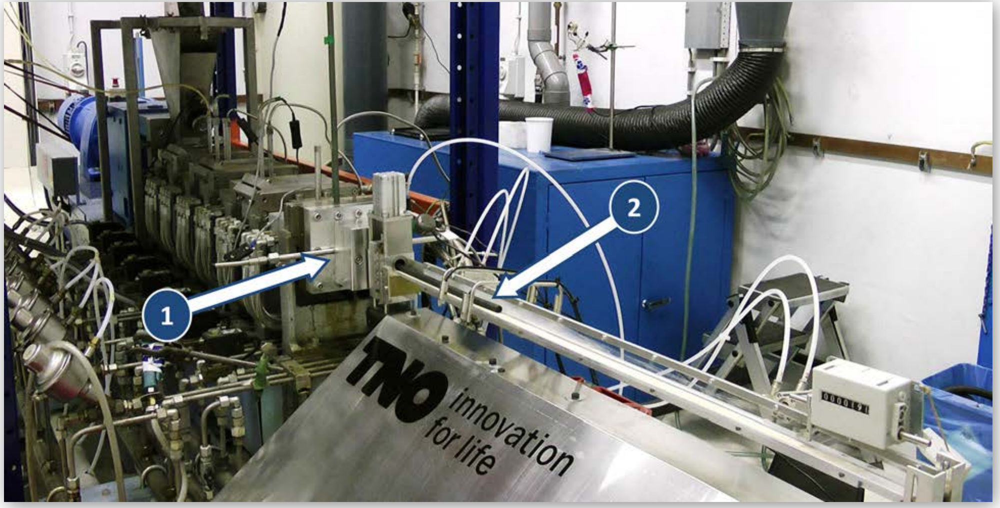
INTRODUCTION

- Current 35 mm ammunition

	Projectile weight [kg]	Projectile velocity [m/s]	Propellant weight [kg]	Kinetic energy [kJ]
HE	0.550	1180	0.340	383
FAPDS	0.400	1400	0.375	392
KETF	0.750	1050	0.340	413

INTRODUCTION

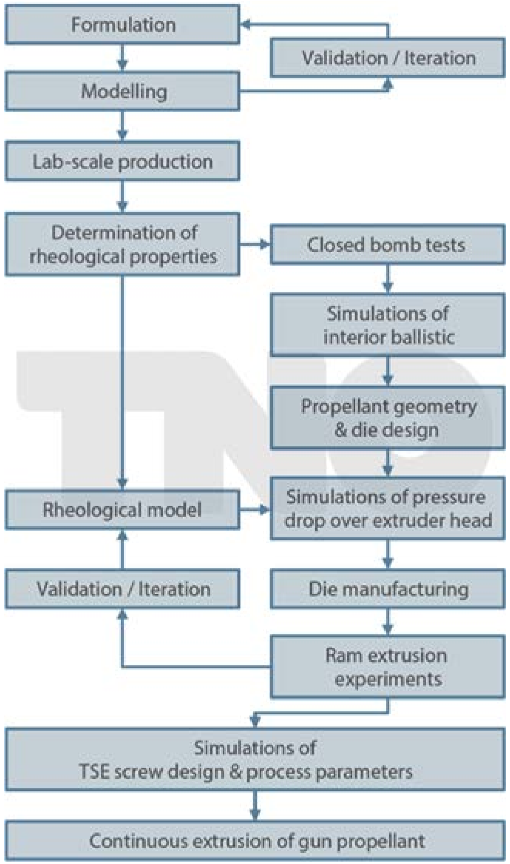
- Previous work ARDEC/TNO:
  ‘*Definition of a JA-2 Equivalent Propellant to be Produced by Continuous Solventless Extrusion*’, Journal of Applied Mechanics, May 2013
- 120 mm calibre
- Propellant grain:
  - Shape: 19-perf
  - Diameter: 11.6 mm
- Produced with 45 mm co-rotating twin-screw extruder (TSE)
  - 10 – 15 kg/h
  - Single die



1: extruder head
2: extruded propellant strand

APPROACH

- TNO propellant development approach
- Thermodynamic-, burning-, and rheological properties known from 120 mm development
- IB simulations
  - Small grain diameter required: ~ 5 mm
  - Development of new die design
- Ram extrusion experiments to validate burning properties (small scale: < 1 kg)
- Determination of TSE screw design and process parameters
- Continuous extrusion batch



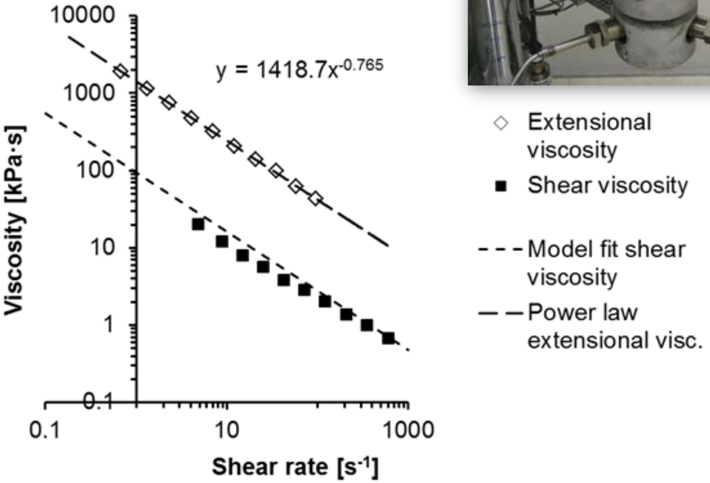
PROPELLANT COMPOSITION

- JA-2 equivalent composition
- Slightly higher content of blasting oils (less than some German tank propellants)
- Tuning mechanical properties (viscosity; flow behaviour in extruder) by addition of green plasticizer
- Non-energetic plasticizer reduces flame temperature
  - Force ~1100 J/g
  - Flame temperature ~3000 K

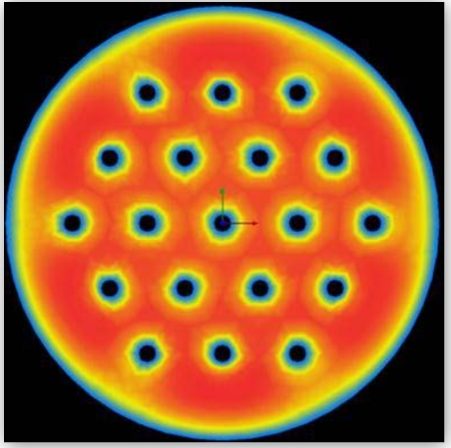
RHEOLOGICAL CHARACTERIZATION

- Safe TSE operation requires reliable prediction of:
  - Pressure drop over extruder head and die
  - Temperatures and pressures along extruder

- Flow of propellant paste through a die is characterized by using a double barrel capillary rheometer
  - Shear viscosity
  - Extensional viscosity

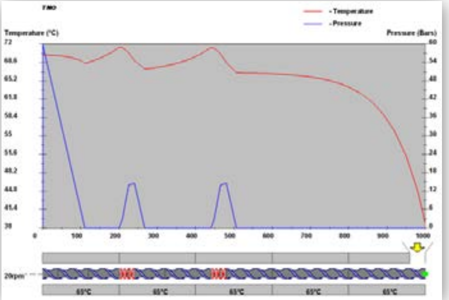


RHEOLOGICAL MODELLING



Flow pattern in die (red: highest paste velocity, blue: lowest velocity)

- Pressure drop over die: commercially available 2D-FEM simulation software
- Extruder head: conical entry part and capillary part of the die (determining final propellant shape; cylindrical, slotted, hexagonal, rosette)
- TSE screw configuration and process parameters determined by commercially available software

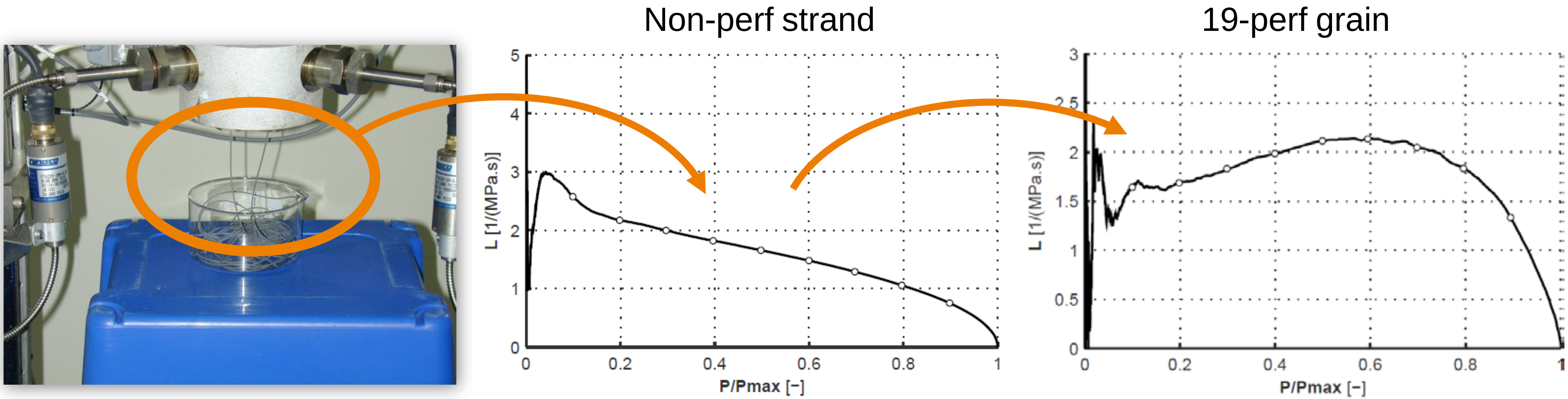


TSE internal conditions for typical screw configuration

TSE screws with transport, compacting and kneading elements

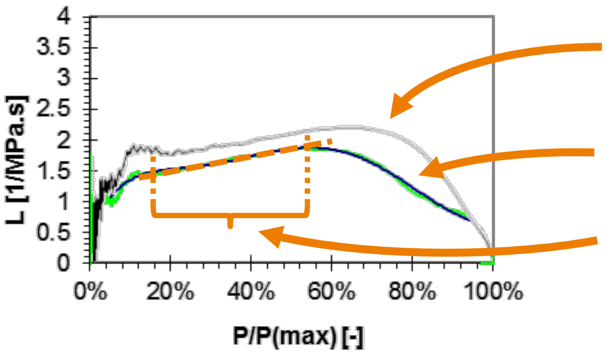
PROPELLANT GRAIN GEOMETRY

- Cylindrical 19-perf grain geometry
- Propellant burn rate determined from closed vessel tests with non-perforated strands (from rheometer)
- Websize 19-perf grains determined by IB simulations



PRELIMINARY PROPELLANT

- Die manufacturing
- Validation pressure drop by small scale ram extrusion (< 1 kg)
- Closed bomb testing



Previous batch (produced with 10 wt% solvent)
$L_{av} = 2.05\ MPa^{-1}\ s^{-1}$

Test batch (unequal inner and outer websizes)

Data used for calculation of burn rate and correction of grain geometry

- Propellant grain geometry optimization / die adjustment (high progressivity = equal websizes)

PROCESSING WITH A 30 MM CO-ROTATING TWIN SCREW EXTRUDER (TSE)


30 mm TSE

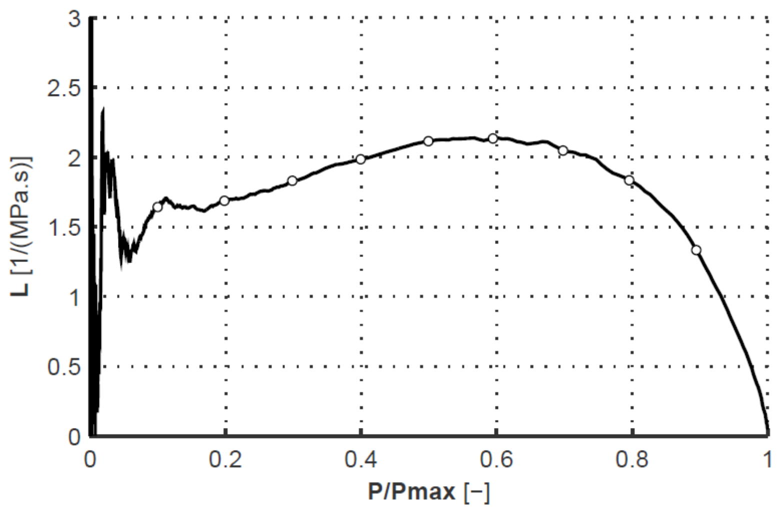
Final DB 35 mm propellant


Screws of 30 mm TSE after process

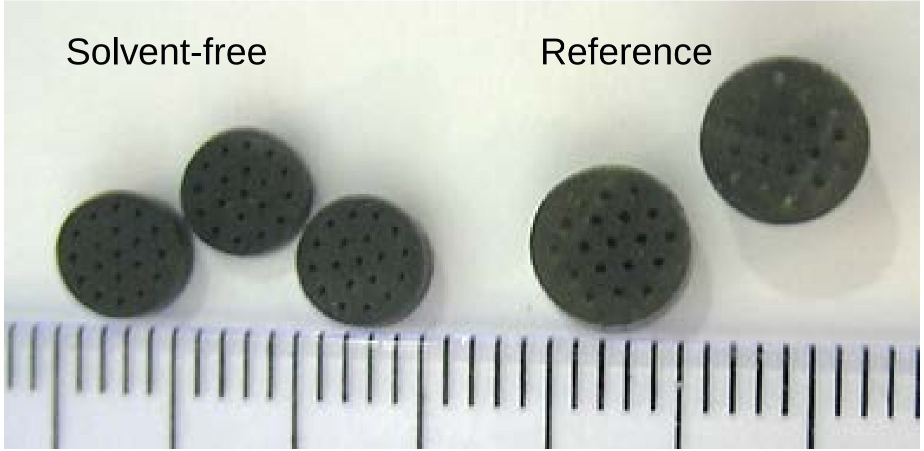
45 mm TSE

CHARACTERIZATION OF THE EXTRUDED PROPELLANT

- Dynamic vivacity: $L_{(0.3...0.7)} = 2.03\ MPa^{-1}s^{-1}$
  Expected: $L_{(0.3...0.7)} = 2.05\ MPa^{-1}s^{-1}$

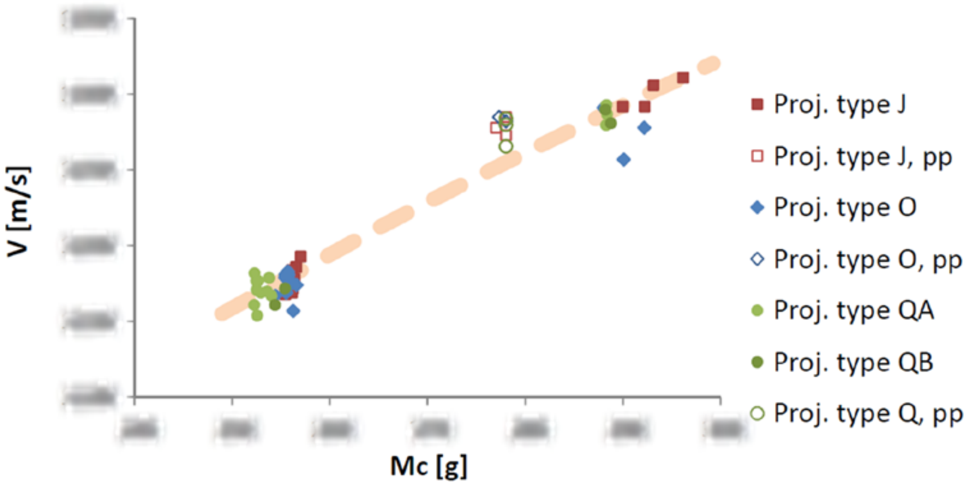


- Diameter: 5.1 mm
- Websize: 0.6 mm
- Perf. diameter: 0.3 mm



FIRING TESTS

- Various projectile types
- Small variations in projectile mass (M_c)
- Equal performance as previous propellant batch (‘pp’; manufactured using solvent)
- Larger dispersion at low charge mass



CONCLUSIONS

- The composition and grain geometry of a DB propellant were determined by interior ballistic calculations.
- Subsequently, the conditions for the manufacturing of this propellant were determined using rheological properties of the propellant paste.
- The double base propellant was successfully manufactured by solvent-free extrusion using a 30mm co-rotating twin screw extruder.
- The obtained extrusion conditions were in good agreement with simulations.
- The propellant dimensions and density were very close to the theoretically expected values.
- Burn properties and gun performance equal to those of previous propellant batch produced using solvent.

THANK YOU FOR YOUR ATTENTION