Development of a prototype propelling charge for a large caliber gun

Extrusion processing and modeling at TNO-PML

TNO Prins Maurits Laboratory

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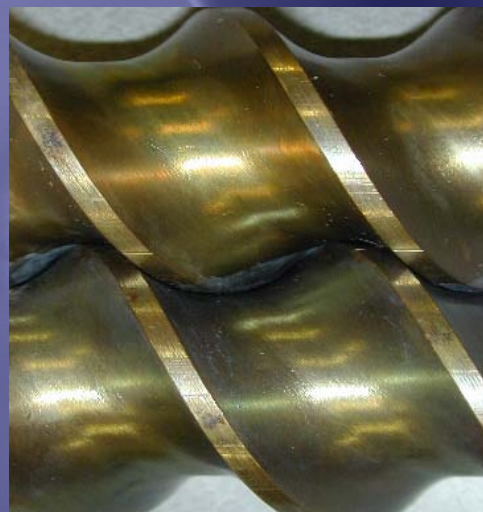

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TNO Prins Maurits Laboratory

Principal mission

Support the Netherlands' armed forces in building and maintaining a cost-effective, strong defence by providing scientific and technical advice in areas such as:

- **Chemical & Biological Protection**
- **Munitions and Explosion safety**
- **Weapons and Weapon Platforms**

Civil spin-off in Space, Transport and Process Industry

Pyrotechnics & Energetic Materials

- Internal ballistics and gun propellants
- Rocket propellants and crystallisation of energetic materials
- Pyrotechnics and ignition systems
- Gasgenerators
- Castable and extrudeable PBXs
- Life time prediction and stability of energetic materials

Advanced gun Propellant development

Facilities:

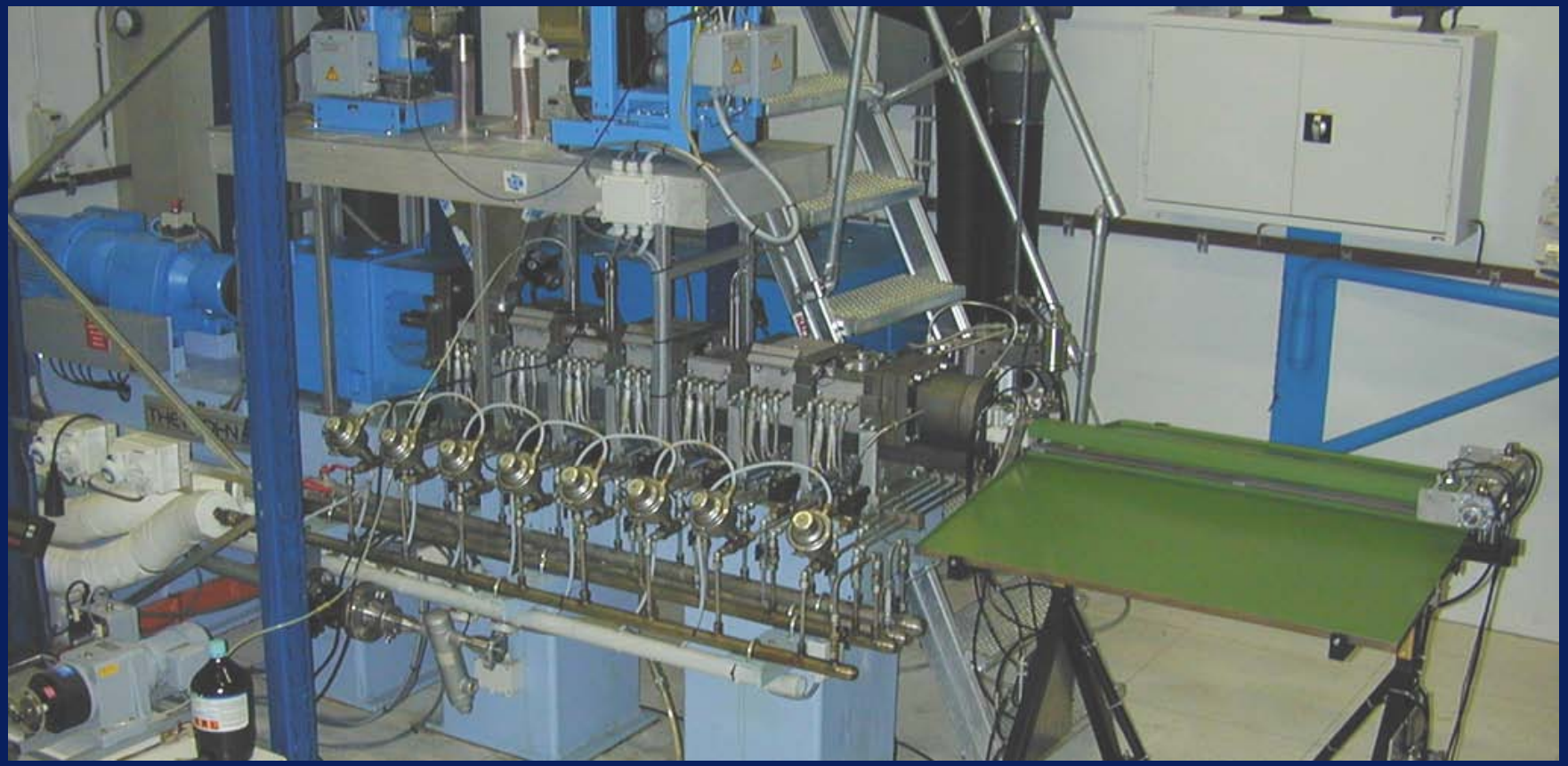
- Modeling
- Lab scale production
- Semi production scale
- Analysis
- Scale up / Prototyping

Goals

Better performance of gun system:

- High impetus
- Reduced erosivity (Low flame temperature, gas composition)
- High safety level (IM)
- Ignition system and design (plasma, pyrotechnic)
- Charge design

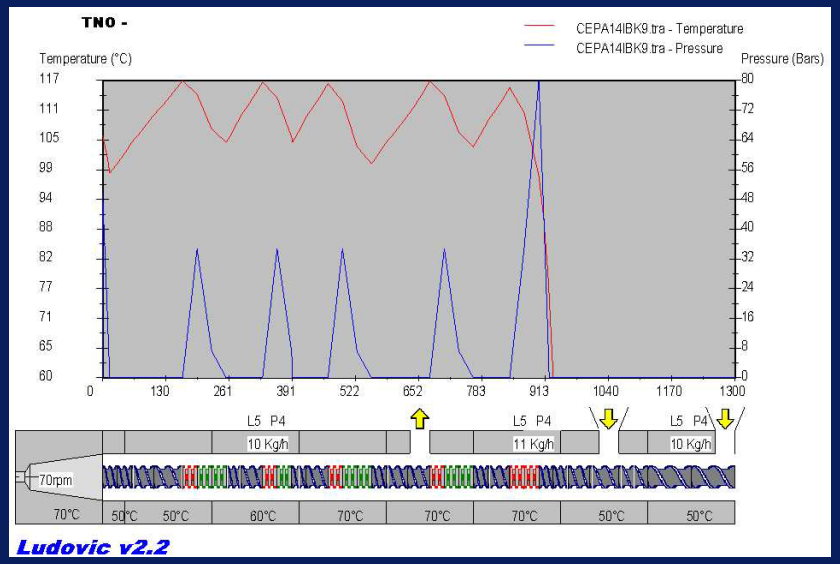
Equipment: 45 mm co-rotating double screw extruder

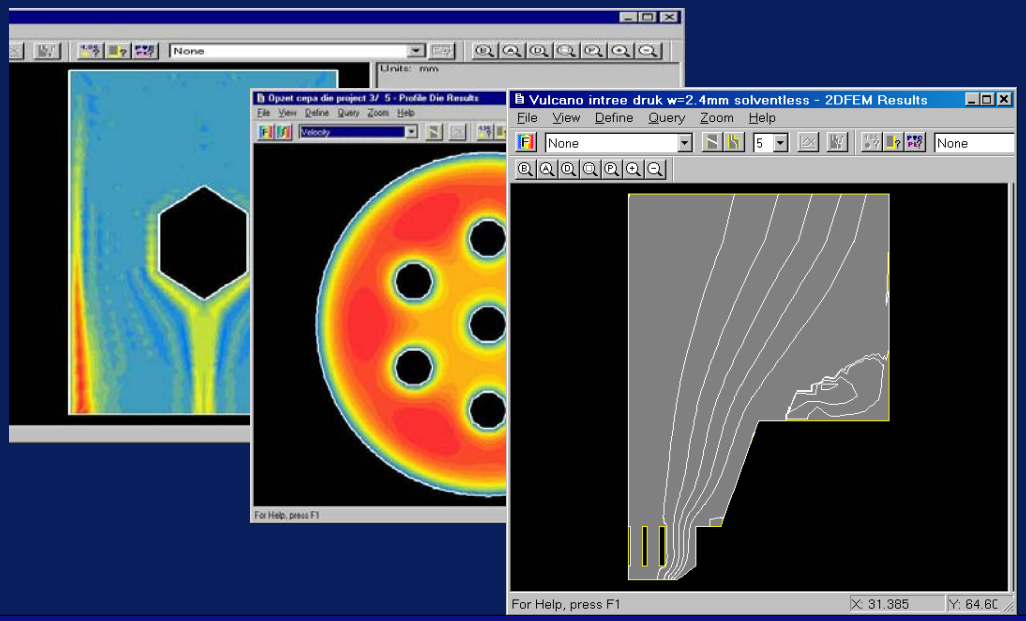


Simulation

Processing condition limits for safe processing:

- **Pressure**
- **Temperature**
- **Friction**
- **No dead spots**





Why simulation?

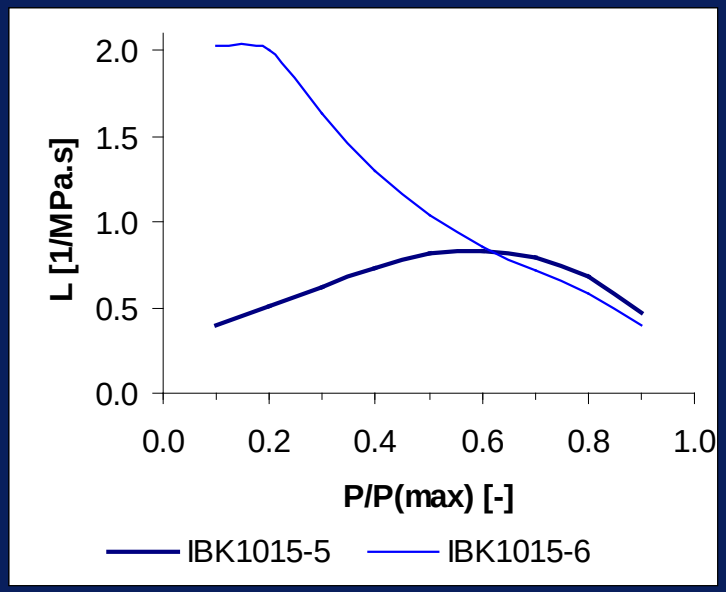
- **Understand the black box**
- **Safe to process this material?**
- **“Desk study”**

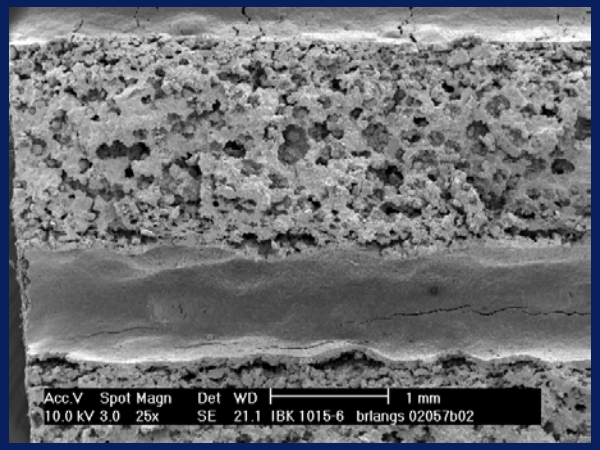
Early achievements

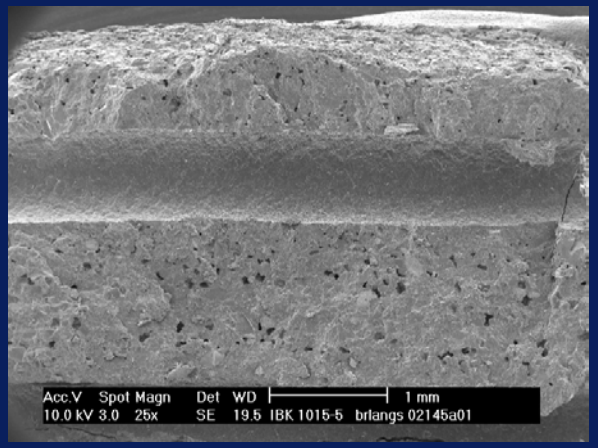
Reducing porosity in composite propellant

Causes of porosity:

- Use of solvents
- Air entrapment in raw material
- Partial flow behavior

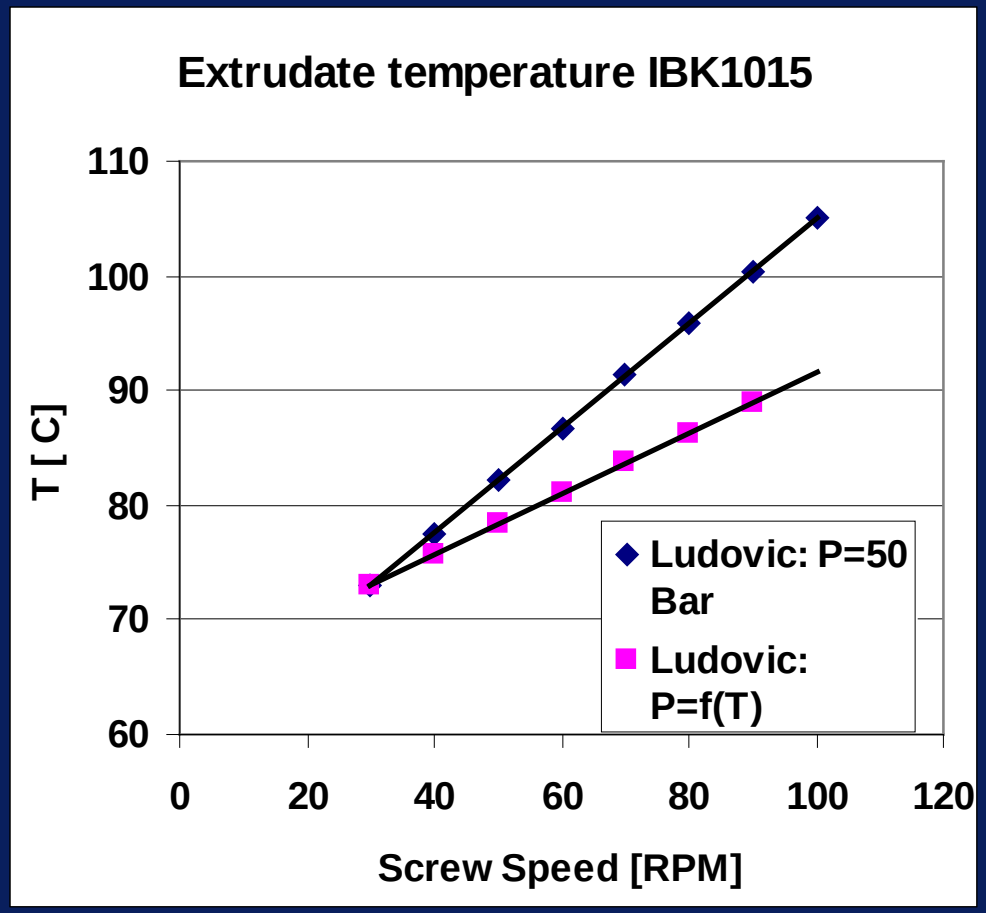






Early achievements

Reducing porosity in composite propellant



Results:

- T extrudate constant (Over heating)
- Reduced porosity (More homogenious por.)

Goals

Goals achieved in past:

- **Partially understanding of the black box**
- **Indication whether process is safe for this material**
- **Optimization by identifying trends and steering parameters**

Goals set for future

- **Better/complete understanding of the black box**
- **Better estimation of P and T of process**
- **Reduce number of experiments (esp. large scale)**
- **(Reduce waste)**
- **Identify/optimize the process using “desk study”**

Prototype propelling charge for large caliber munition

Goal:

- **High muzzle velocity of new projectile using conventional MB propellant**

Requirements:

- **Optimal charge design and ignition**
- **Optimal propellant design and burn rate**
- **Reproducible grain shape and formulation**

Means:

- **Testing of different charge concepts**
- **Testing different propellant grain geometries**
- **Utilize extrusion technique for high reproducibility (quality)**

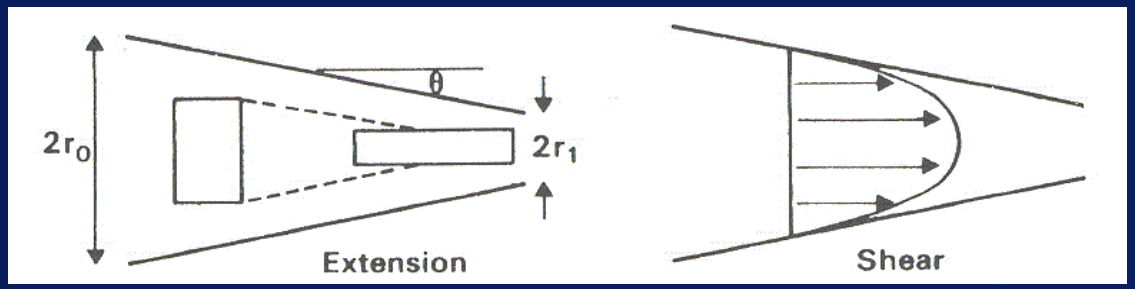
Formulation ⇔ Rheology ⇔ Processing (⇔ Mechanical prop.)

- Investigation of effects of T, plasticizers and additives on rheology
- Rheological model(s) describing these effects
- Desk study of ideal formulation and processing conditions
- Future: mechanical relations to formulation or rheological models

Result: Development of solventless composite propellant

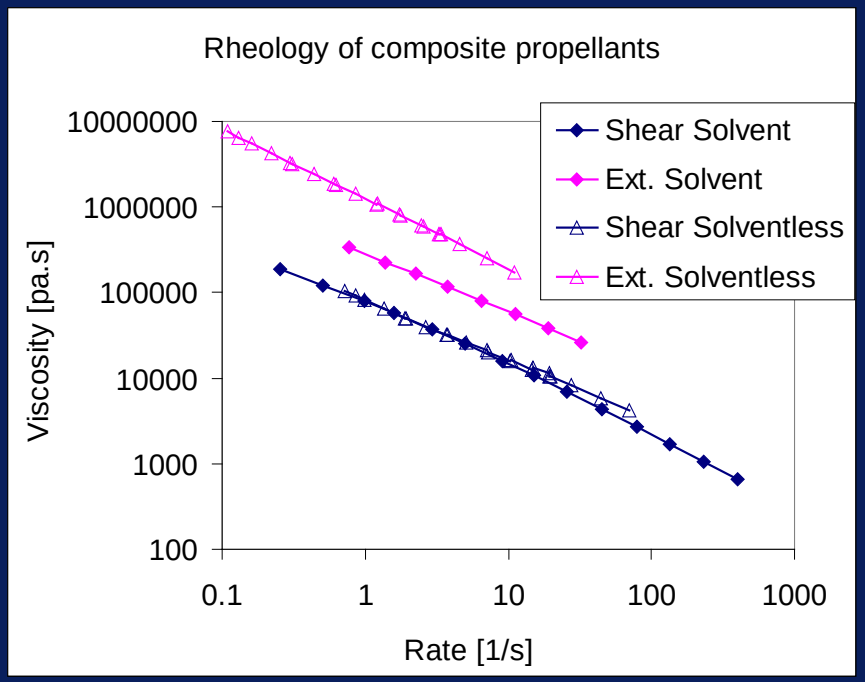
Rheology

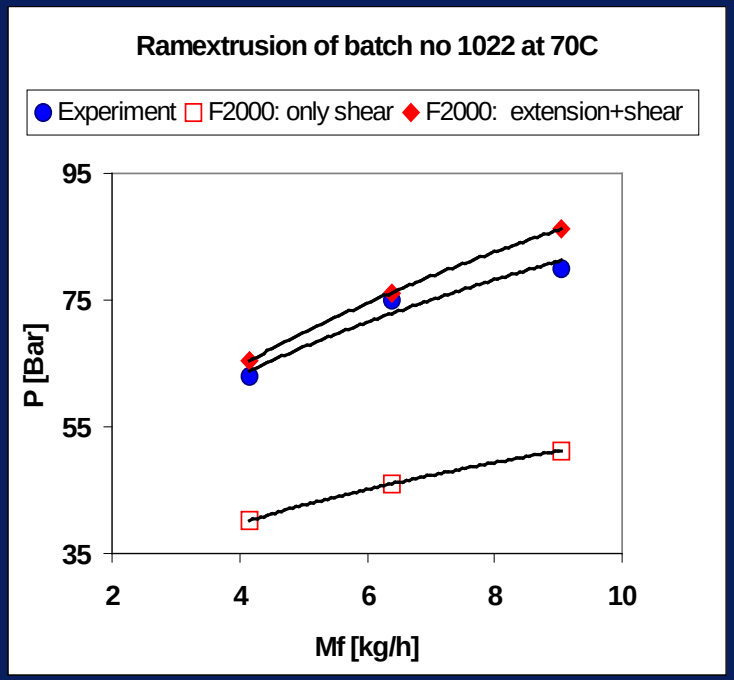
Elastic behaviour



Formulations showing elastic behavior under normal processing conditions:

- **NC based propellant compositions**
- **Solventless composite propellant compositions**
- **Ammo/Bamo compositions (Explosives/propellants)**





Rheology

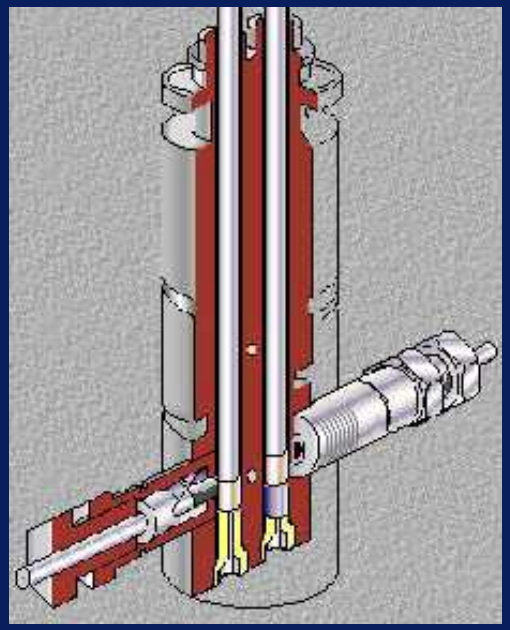
Rheology of MB pastes

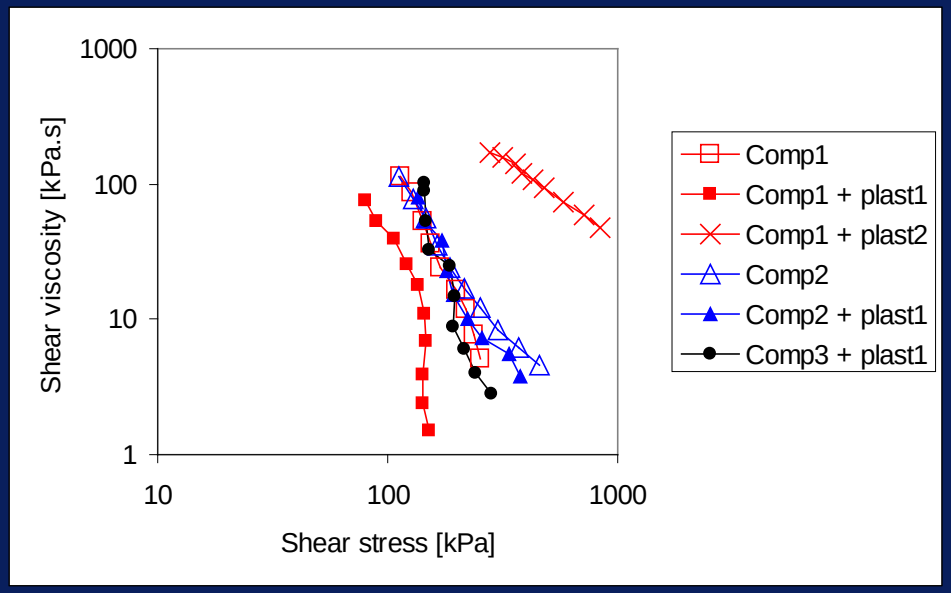
Formulation:

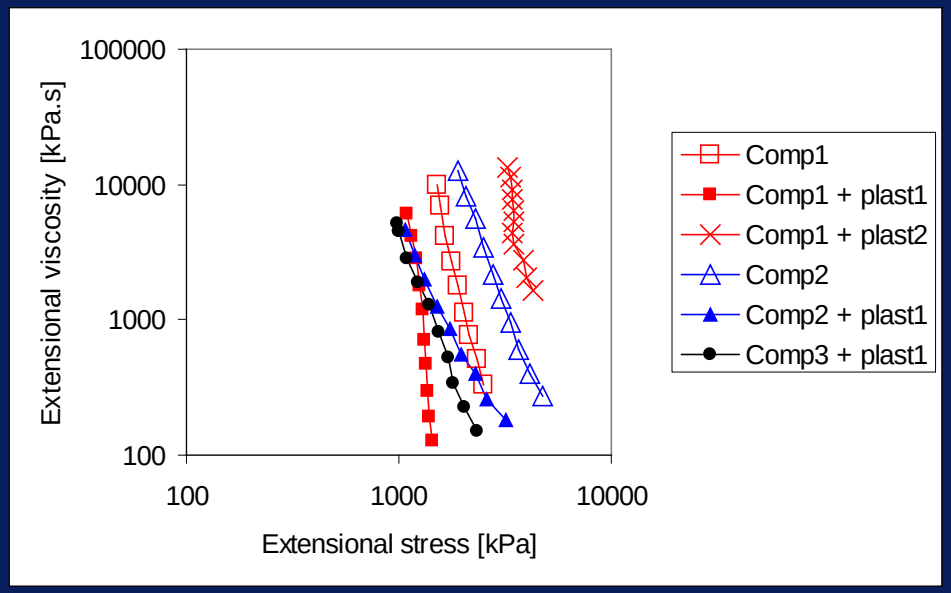
- **Plasticizers: NG, DEGDN, inert**
- **Additives NQ, K2SO4, etc.**

Rheology:

- **Effect on shear and elastic behavior**

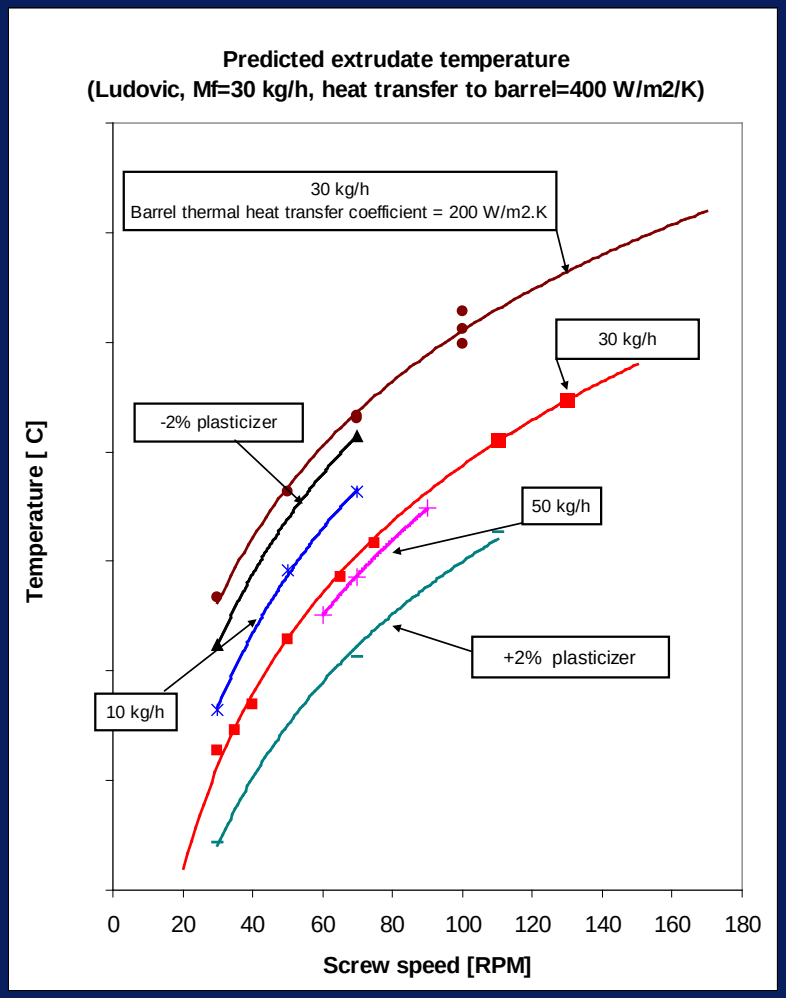


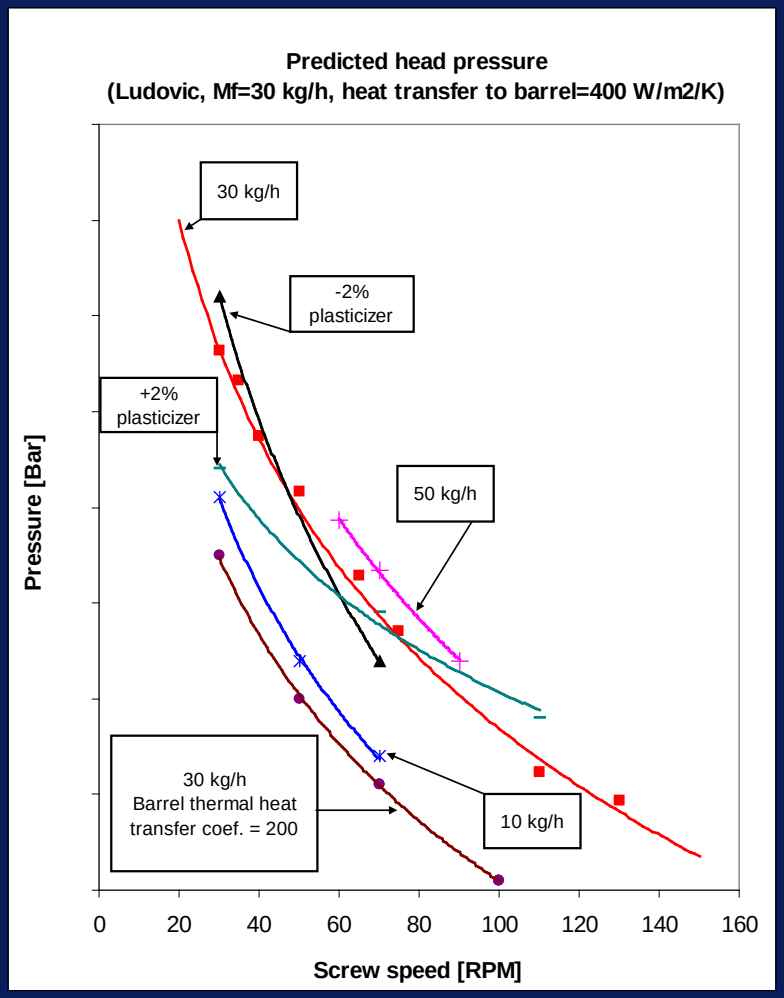




Processing

Desk study MB propellant using simulation software

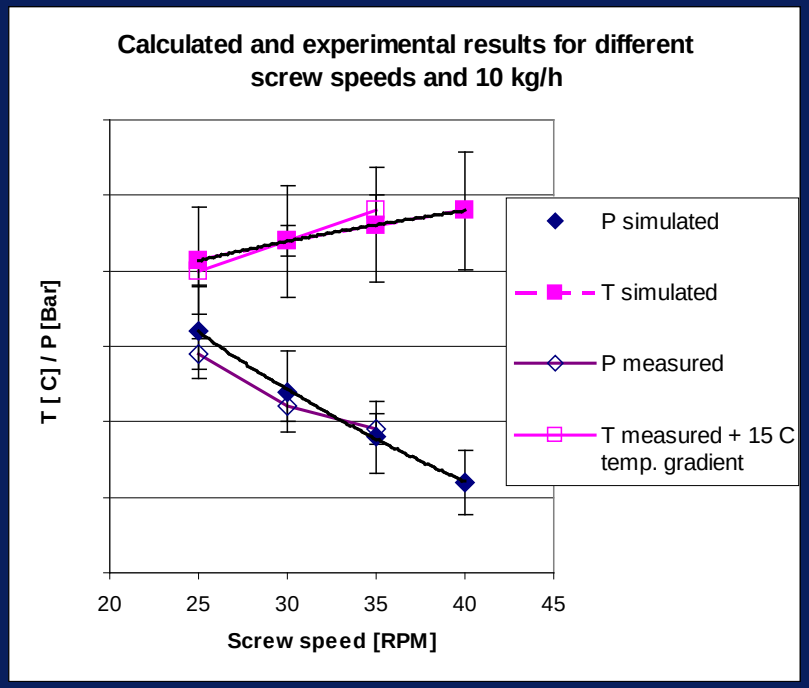


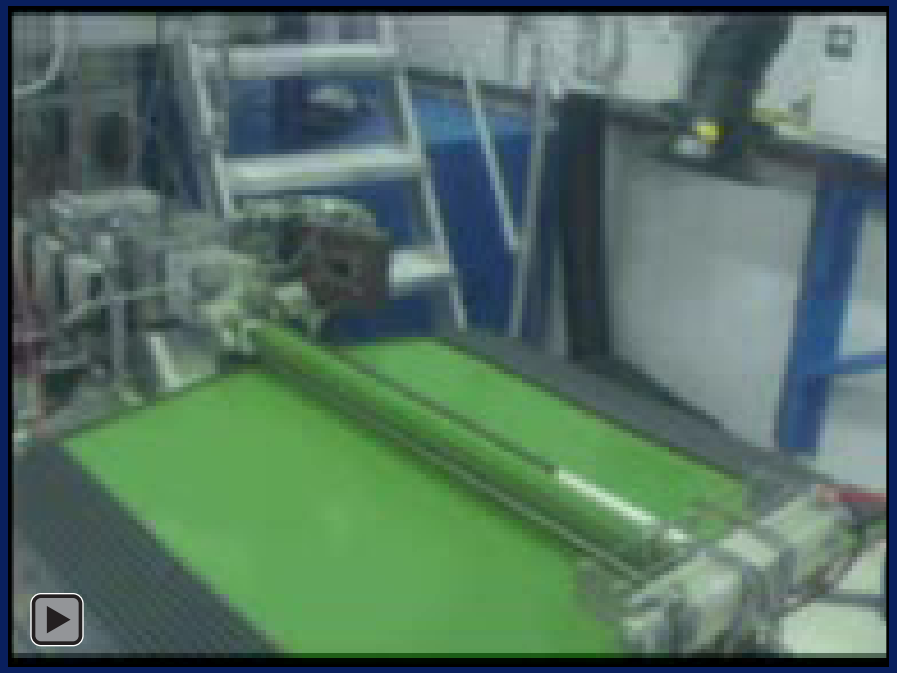


Processing

Experimental results MB propellant

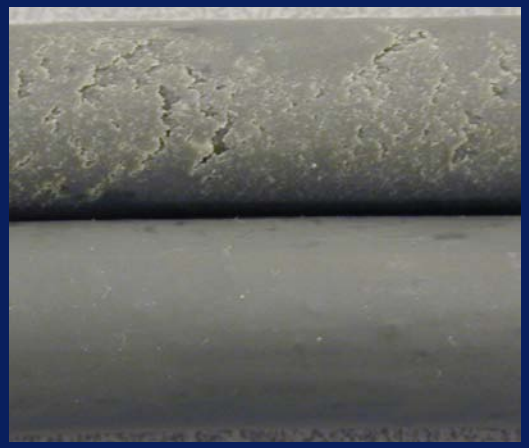
- Better rheological model and better simulation approach results into very good estimations
- Desk study: Optimization of processing conditions
- (Ram-)extrusion batch – validity models





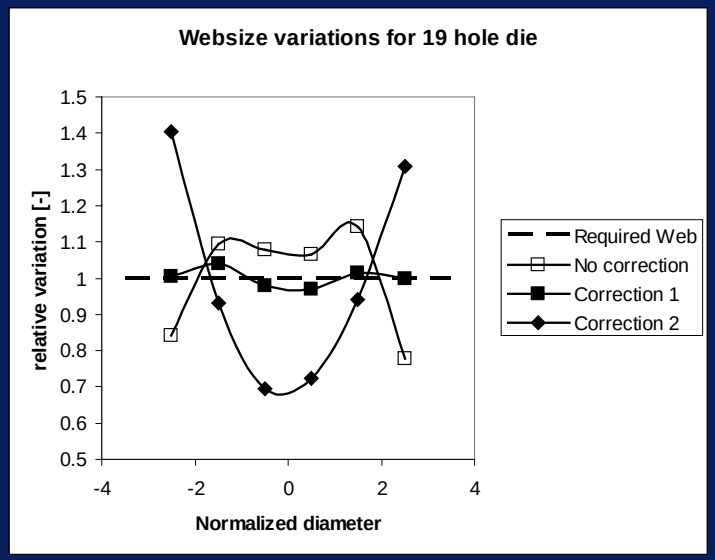
Results

Processing NC propellant –die design

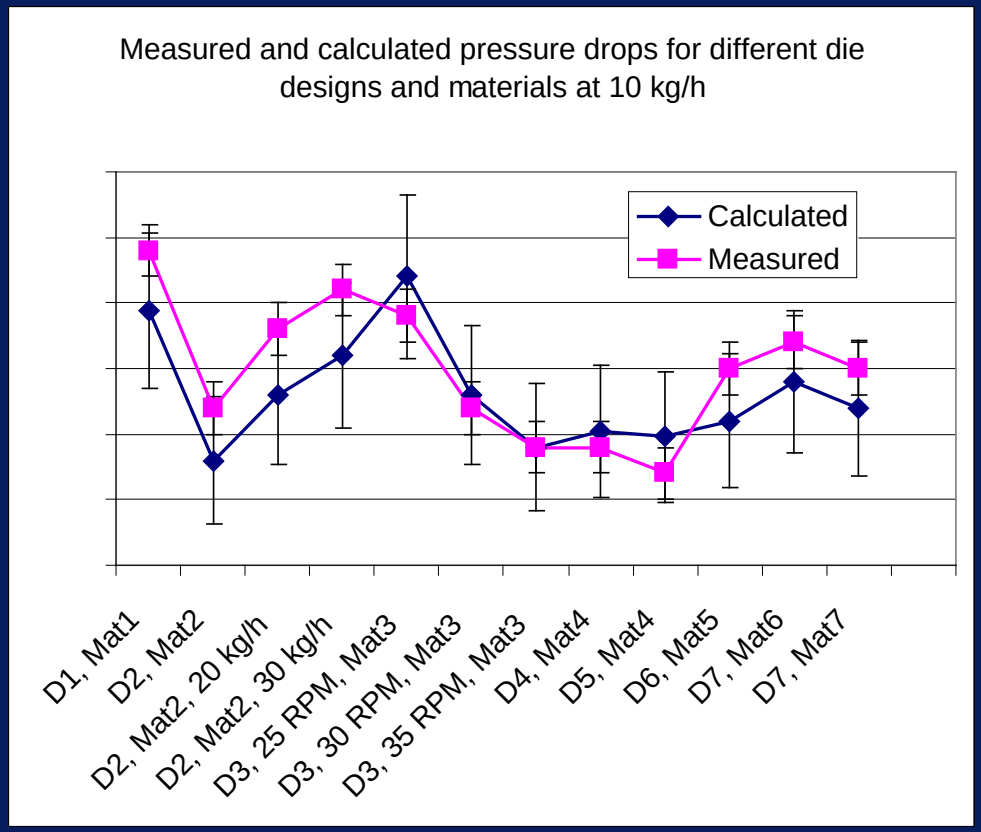


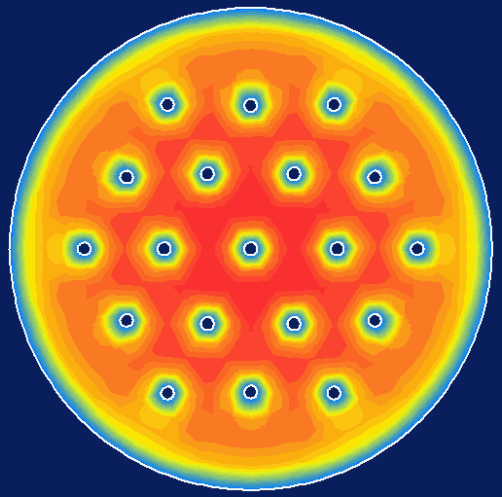
Task:
- Different geometries
- Different compositions (rheology)

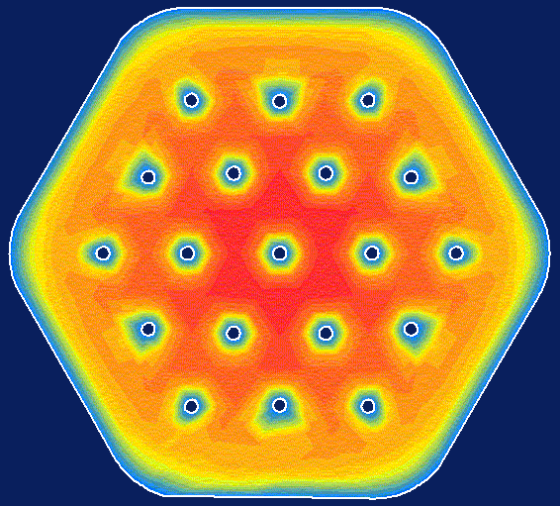
Optimization:
- Correct pressure drop
- Smooth outer surface
- Websize distribution, etc.



Different die designs



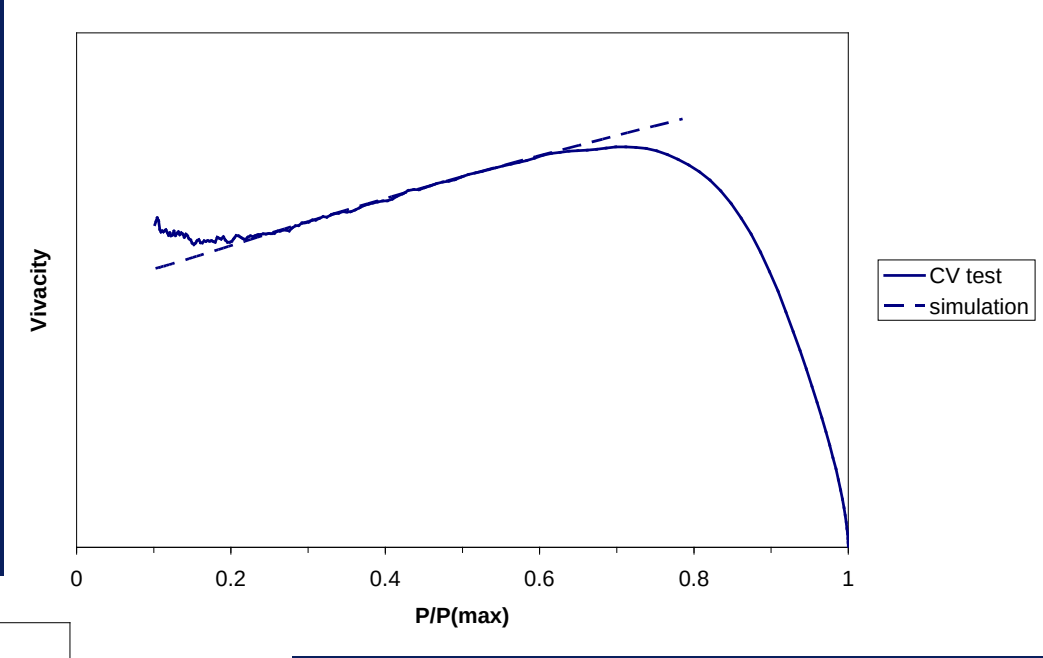


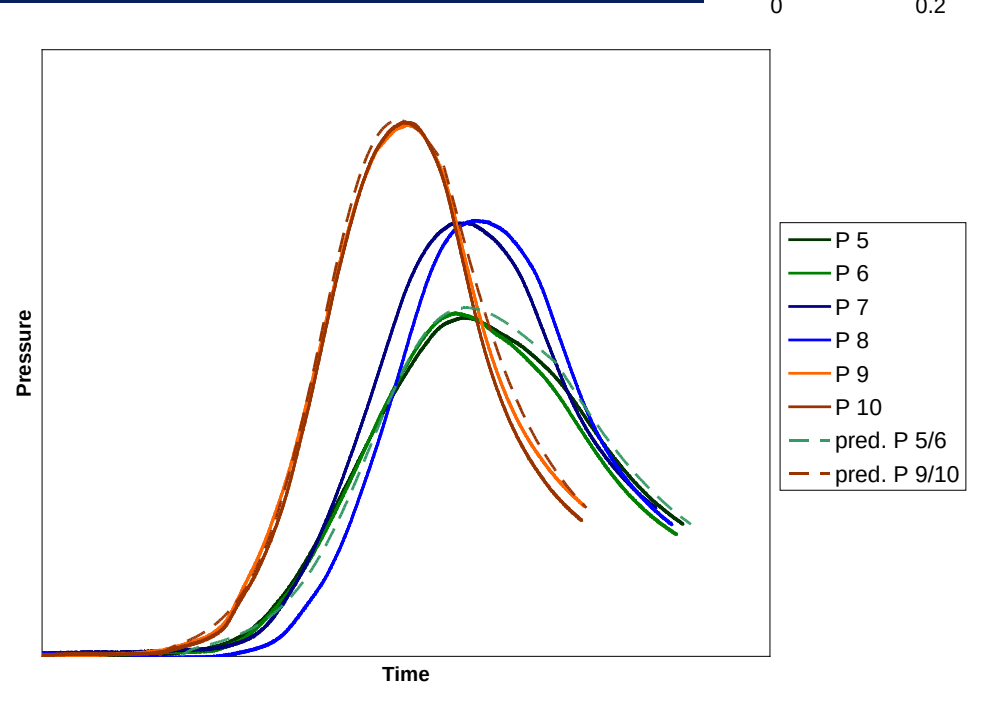


Calculated and measured results differ less than 10%which is considered acceptable

CV-test and Firing results

Produced propellant shows good progressivity





Firing results show good reproducibility and is as expected from calculated performance using TIBalCo

Present

materials produced using extruder

Materials	Total produced mass [kg]
Double base (NG and DEGDN)	300
Triple Base	700
Composite propellants	50
Flares/pyrotechnics	20
PBX	30

Future

Technology

- High performance propellants (MB and composite propellants)
  - Reduced temperature dependency
  - Higher progressivety
  - Different extrusion processes
- New IR-Flare composition (www.irflare.com)
- Desk study:
  1. Processing on smaller and larger machines (TNO-industry)
  2. Cost (in-) efficiency of batch and extrusion
  3. Feasibility processing medium caliber propellants

Conclusions

- Extrusion simulations give valuable insight into process
- If rheological model is acurate, the estimated values are within 10% of experimental values
- NC double and triple base propellants can be shaped successfully using a co-rotating double screw extruder
- TNO developed prototype propelling charge for large caliber ammunition succesfully
- Technology level of extrusion is high
- Technology will develop further depending on projects and market perspective

Discussion/Questions?