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Development of a cast plastic bonded explosive with high CL20 content

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SNPE MATÉRIAUX ÉNERGÉTIQUES GROUPE SNPE

SUMMARY

- Objectives
- Theoretical performances
- Formulation parameters
  - Binder optimization
  - Process optimization
  - Influence of the particle size of CL20
- Characterization
  - Mechanical properties
  - Sensitivity and vulnerability properties
  - Performance properties
- Conclusions

OBJECTIVES

- Since the 90's, SNPE has developed a new family of cast plastic bonded explosive compositions more powerful and based on CL20.
- The objective is to obtain a content higher than 90 % of CL20 in order to increase the performance.
- Until now, explosive compositions including an important content of CL20 led to a high level of viscosity.
- Low levels of viscosity have been obtained thanks to works of optimization of the formulation and using a process without volatile organic compounds.

THEORETICAL PERFORMANCES

CHEETAH calculations

Compositions	ORA 86B	LX 14	CL20-1	CL20-2
HMX	86	95.5		
CL20			91	92
Non energetic binder	14	4.5	9	8
Density (g/cm^3)	1.686	1.870	1.840	1.861
D cm/µs	0.7800	0.8800	0.8659	0.8790
P_{cj} Mbar	0.2517	0.3532	0.3448	0.3580
Cylinder expansion energy kJ/cm^3 (V/V_0= 7)	0.0695	0.0872	0.0877	0.0901

A loading of 92 % CL20 is necessary to obtain the performance of a composition including 95 % HMX (LX14)

FORMULATION AND PROCESS PARAMETERS

- The low viscosity of composition with a high content of CL20 (≥ 91 %) is obtained by associating several main factors:
  - Choice of ingredients of the binder
  - Influence of the manufacturing process
  - Morphology and particle size distribution of CL20

FORMULATION PARAMETERS:
Binder System Optimization

Influence of the ingredients

Composition	1	2	3
CL20	91%		
Binder HTPB Plasticizer Curing agent	100 DOZ IPDI	100 P0 IPDI	100 P0 MDCI
Temperature	60℃		
Viscosity at the end of mix (kP)	**22**	**16**	**15**
Yield point (Pa)	-	**2700**	**800**

The choice of plasticizers contribute to reduce the viscosity and the MDCI led to a significant reduction of the yield point of the mixing at the end of mix for the same viscosity

FORMULATION PARAMETERS:
Binder System Optimization

Plasticizers	P0	P1	P3	P5	P6	P7	P8
Viscosity before curing agent (kP)	6.8	4.0	6.0	12.8	22.0	5.6	3.7
Viscosity at the end of mix (kP)	8.4	4.0	6.0	16.8	24.0	12.0	12.0

The P1 plasticizer is the most favourable, the measured viscosity was 4 kP before and after curing agent.

FORMULATION PARAMETERS:
Process Optimization

Influence of the temperature on the viscosity at the end of mix

Two mixing temperatures were tested: 60°C and 70°C.

Composition	6	7
CL20	91%	
Binder HTPB Plasticizer Curing agent	 100 P0 MDCI	 100 P0 MDCI
Temperature	60°C	70°C
Viscosity at the end of mix (kP)	15	8,4

The increase of temperature from 60 to 70°C improves the viscosity.

FORMULATION PARAMETERS:
Process Optimization

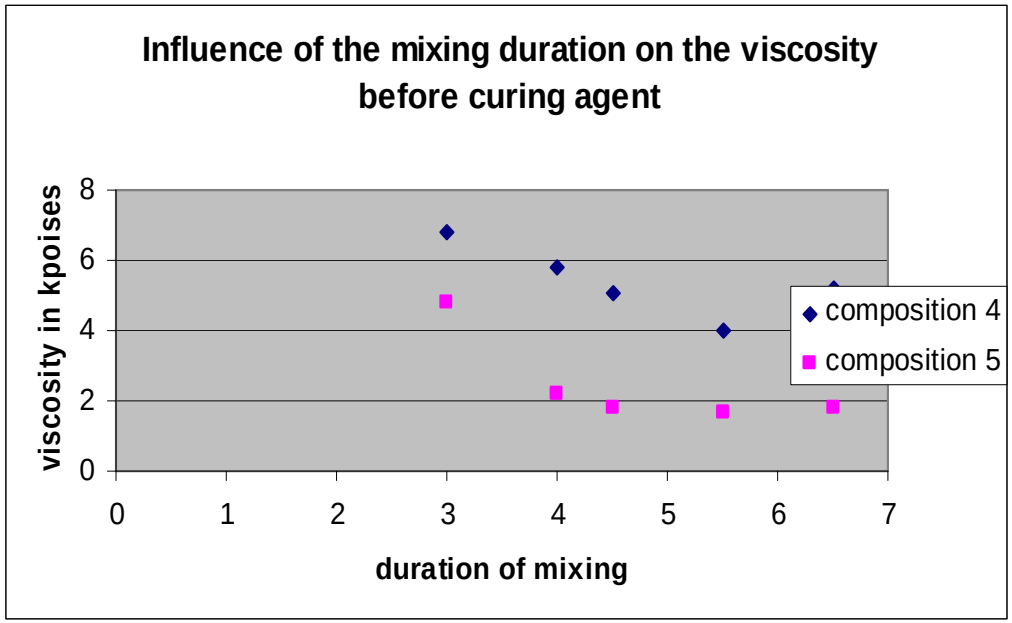
Influence of mixing duration

Compositions	4	5
Binder HTPB	100	100
Plasticizer	P0	P1
Curing agent	MDCI	MDCI
CL20	91%	

Ingredients of the composition

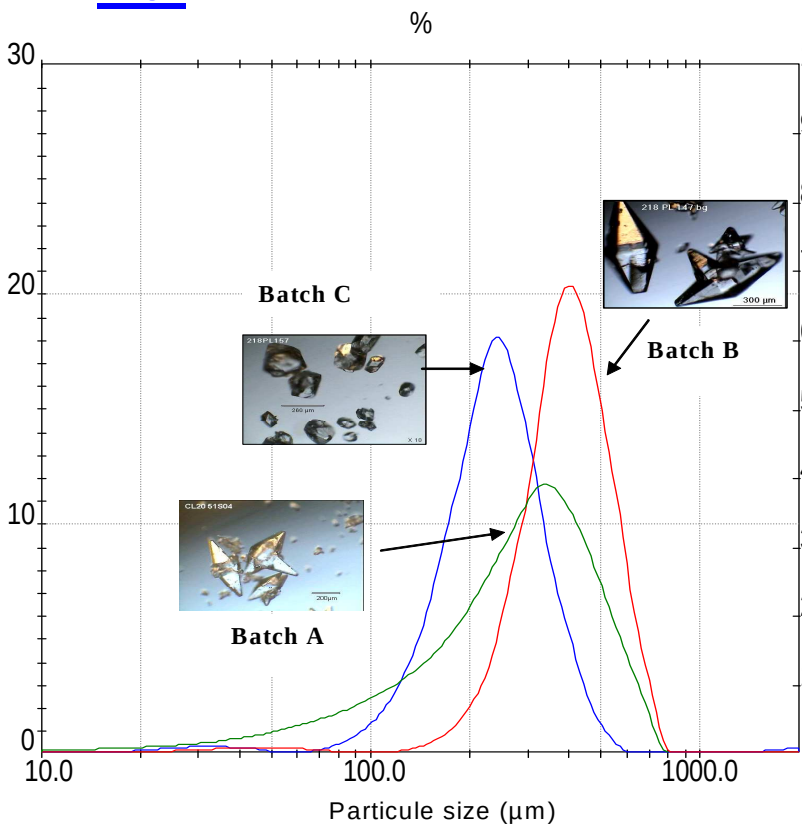
Temperature of mixing 70°C

An optimum after 5 hours of mixing and then the mixing hardens and viscosity is worsened.



FORMULATION PARAMETERS:
Influence of the particle size of CL20

- ***Evaluation of different batches of CL20 in the HTPB compositions at two high contents of CL20: 91 % and 92 %.***



Their median particle diameters are
between 280 and 400 µm.

CL20 batch		A		B		C	
CL20 composition (%)		91	**92**	91	92	91	92
Viscosity (kP)	Before curing agent	4	**3.2**	5.2	7.2	5.6	12.8
	At the end of mixing	4	**8**	5.2	12	5.2	17.6

CHARACTERIZATION

Mechanical properties at 20°C, crosshead of 50 mm/min

	Sm (MPa)	E (MPa)	eb (%)
91% CL20 + 9% inert binder	1.25	22	8
92% CL20 + 8% inert binder	1.6	41	5
ORA86B HMX (86%) - PE Binder	1.6	68	3

Suitable mechanical properties taking into account the high content of CL20.

CHARACTERIZATION

Sensitivity Tests

	CL20	91% CL20 + 9% inert binder	92% CL20 + 8% inert binder*	ORA 86B
Friction sensitivity (BAM) according to AOP 7 STANAG 4487A	≤ 3 J	9 J	12 J	11 J
Impact sensitivity (BAM) according to AOP 7 STANAG 4489 C	65-75 N	151 N	12 Positive trials / 30 @ 353 N	220 N
Ignition Temperature STANAG 4491	225°C	NA	198°C	245°C

***After binder optimization**

The composition with high content of CL20 (92 %) presents a good behaviour in sensitivity.

CHARACTERIZATION

French Large Scale Gap Tests

	CL20	91% CL20 + 9% inert binder	ORA 86B
Number of cards*	> 360	195	160
P in Kbar in acetate barrier	7.2	31.6	44.1

Cards thickness = 0,19 mm

Sensitivity is moderate comparatively to the sensitivity of neat CL20

CHARACTERIZATION

Vulnerability – Impact bullet

The mock-up was SNPE design.
The characteristics were:

- **Steel case thickness : 20 mm**
- **Static burst pressure: 140 MPa**
- **Volume: 1.1 L of explosive composition**
- **Bullet velocity : 870 m/s**

Type of reaction:
pneumatic deflagration (assimilated to a type IV)
21 % of product has been recovered.

CHARACTERIZATION

Detonation velocity

Compositions	ORA 86B HMX (86%)	91% CL20 + 9% inert binder	92% CL20 + 8% inert binder	LX14 HMX (95,5%)
Detonation Velocity* (m/s)	8362	8850	9052	8840

* non confined cylindrical sample (30 mm diameter)

At 92 % of CL20, the measured detonation velocity is higher than the calculated value with Cheetah 2.0 code (+3 % comparatively to calculations).
D_v is higher than LX14 one (+2.4% / to the LX14).

CONCLUSIONS

- New more powerful cast plastic bonded explosive compositions based on CL20 have been developed and partially characterized.
- The best formulation has filler content of 92 % in weight.
- Main features of work formulation are:
  - The choice of the suitable plasticizers and the nature of curing agent allowed to decrease the viscosity and to increase the content of CL20.
  - The duration and temperature of process are also very important.
  - The selected process is solvent free .
  - Low end of mix viscosity : < 8 kP.
- Good safety properties taking into account their high content of CL20.
- High performances → detonation velocity 9052 m/s