



Eutectic Sugar Propellant Research, Part II

Rev. 2011/09/19

Solubility of sugar alcohols in water

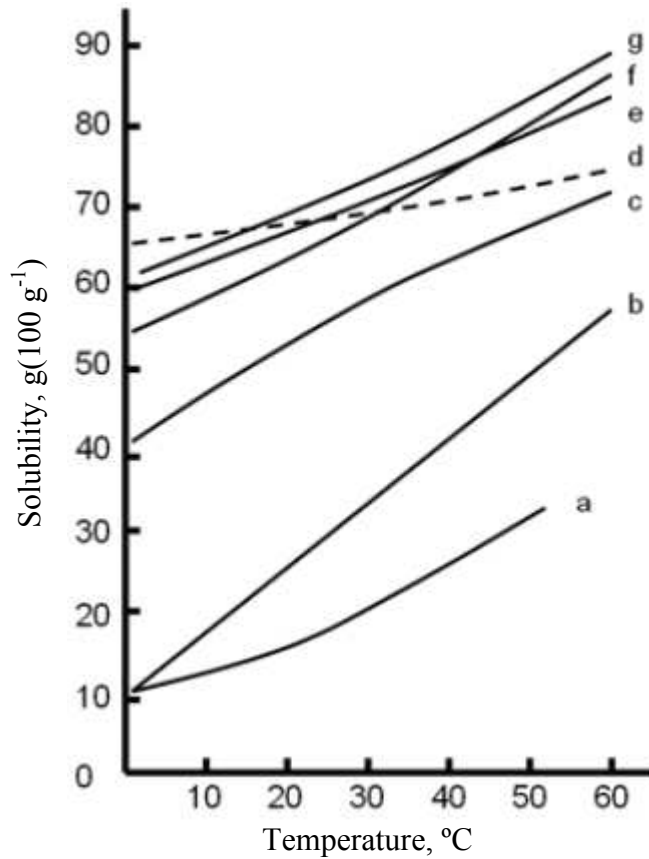


Fig 1 (a) D-Mannitol; (b) Isomalt; (c); Lactitol; (d) Sucrose; (e) Maltitol; (f) Xylitol; (g) Sorbitol^[1]

Eutectic KNO₃-NaNO₃-Mannitol propellant

Mannitol is very less hygroscopic due to its low solubility in water. The melting point of mannitol is 165-169°C. Mannitol and sorbitol have the same energy value of 10,08kJ/g.

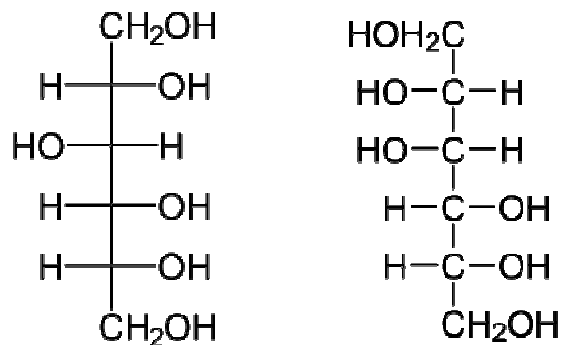


Fig. 2 Structural formula of D-Sorbitol and D-Mannitol

As a eutectic mixture of KNO_3 and NaNO_3 has a melting point of approx. 220°C and mannitol a melting point of approx. 170°C , the heating and cooling curves are similar, which is preferable to avoid inner tension during curing.

Eutectic KNO_3 - NaNO_3 -Mannitol propellant was prepared with the same method, described on part 1 of 'Eutectic Sugar Propellant Research' [2]. It was observed that the solution of KNO_3 - NaNO_3 and mannitol turned not brownish like with sorbitol. The propellant has a ceramic like structure and color after curing. As already observed with sorbitol, also KNO_3 , NaNO_3 and mannitol seem to build a ternary eutectic system. The KNO_3 - NaNO_3 -Mannitol propellant was still completely liquid at 170°C .



Fig. 3 Chunks of eutectic KNO_3 - NaNO_3 -Mannitol propellant starting to cure

Experiment:

5.45g KNO_3 crystals, 4.55g NaNO_3 crystals and 5.4g D-mannitol crystals were mixed in a Borosilicate glass beaker and then heated up with a laboratory heating plate with temperature sensor and thermostat. At a temperature of 173°C , the loose mixture of the 3 solid substances was completely liquefied, which confirms the assumption, that KNO_3 , NaNO_3 and D-mannitol are building a ternary eutectic system. This discovery makes it

now very easy to manufacture eutectic KNO_3 - NaNO_3 -Mannitol or -Sorbitol propellant. The 3 solid substances just need to be physically mixed and then heated up to the eutectic temperature, which liquefies the mixture completely. The propellant can be directly prepared and heated in the mold if necessary.

The eutectic KNO_3 - NaNO_3 -Mannitol propellant is quite hard. I was not able to break a 4cm long piece with a weight of 7g into half by my hands. A drop test from 1m height on a concrete surface was performed, which broke the 4cm long propellant piece finally into two pieces.

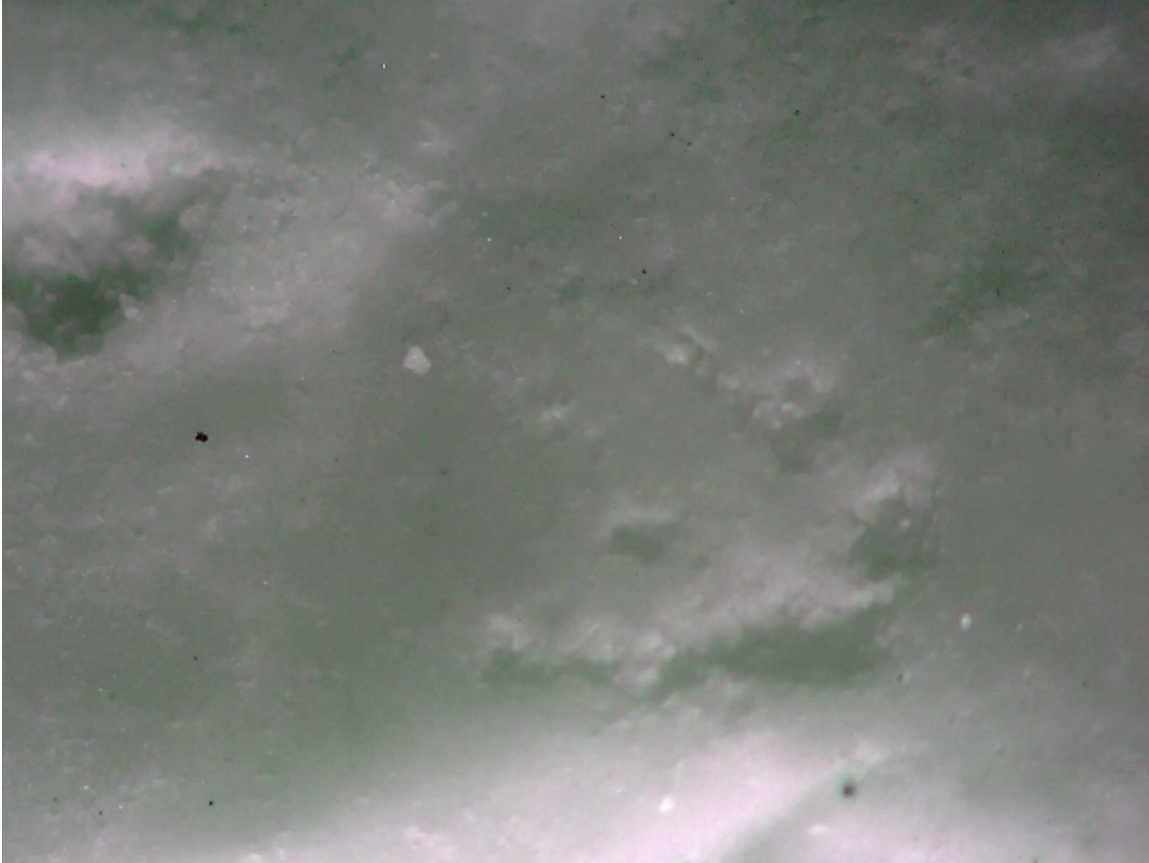


Fig. 4 Surface of eutectic KNO_3 - NaNO_3 -Mannitol propellant --- picture taken with a digital microscope, 200x magnification

The combustion behavior of eutectic KNO_3 - NaNO_3 -Mannitol propellant differs from KNO_3 - NaNO_3 -Sorbitol. Using sorbitol, the propellant burns with a lot of white-yellow flames and very less smoke. Using mannitol, the propellant burns with a lot of white smoke and less yellow flames.

Combustion test video of a piece of KNO_3 - NaNO_3 -Mannitol propellant:
<http://www.youtube.com/watch?v=RaGtKXsKAuo>

Hygroscopy study

The weight increase by hygroscopy on a piece of eutectic KNO_3 - NaNO_3 -Mannitol propellant was observed over several days, starting one hour after manufacturing:

Date/time	Ambient temperature (°C)	Humidity (%)	Weight (g)	Remark
2011-9-17 9:14 AM	32	70	1.94	
2011-9-17 4:32 PM	32	59	1.95	
2011-9-17 9:16 PM	29	78	1.94	
2011-9-18 9:14 AM	26	69	1.94	
2011-9-18 9:17 PM	25	64	1.94	
2011-9-19 9:20 AM	21	75	1.94	

Conclusion:

After 12h KNO_3 - NaNO_3 -Mannitol propellant had still not gained any weight by hygroscopy, while KNSB (made by 'slurry' method) and eutectic KNO_3 - NaNO_3 -Sorbitol propellant with similar surface and weight had already gained a weight of 50-60% by water and a consistency like 'ice cream' at same conditions mentioned in table above.

After 24h KNSB and eutectic KNO_3 - NaNO_3 -Sorbitol propellant turned into a useless puddle but the KNO_3 - NaNO_3 -Mannitol propellant was still bone dry.

After 48h the propellant had still not gained any weight by water.

Therefore eutectic KNO_3 - NaNO_3 -Mannitol propellant is to prefer toward all other eutectic oxidizer salt/sugar alcohol mixtures regarding hygroscopy but should be reinforced by fibers (see next chapter) to reduce its brittleness when cast in larger dimensions. The same method can be applied using other sugar alcohols as fuel as well.

Reinforcement of the propellant by fibers

The state of matter of the propellant during manufacturing is liquid. This gives us the great opportunity to use fibers to reinforce the propellant. Carbon, cellulose, plastic fibers come into consideration. Preferable are fibers which are combustible and acting as a secondary fuel besides the reinforcement effect. Carbon fiber fabrics or carbon fiber veils can be bought in many shops online, for example:

<http://www.shopmaninc.com/carbonpage.html>

http://www.fibreglast.com/product/Carbon_Fiber_Veil_1064/155

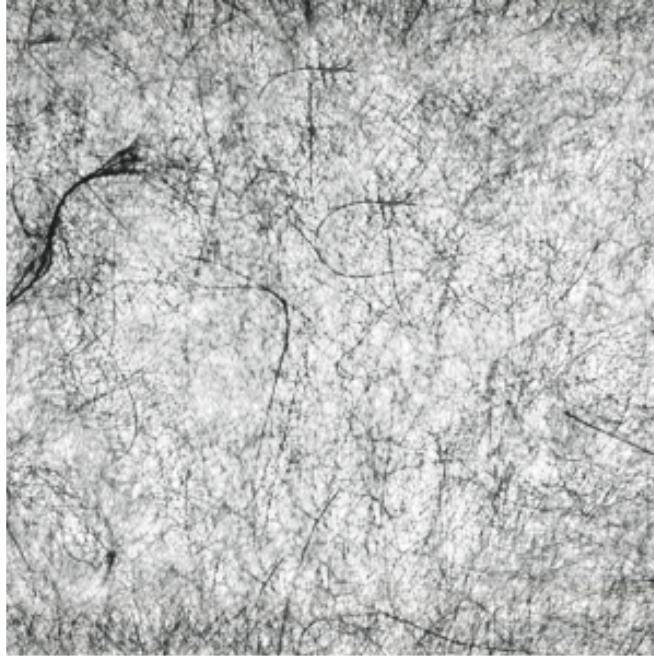


Fig. 5 None woven graphite veil construction allows a resin-rich surface that increases chemical stability and reduces the risk of micro-cracks forming in the composite surface

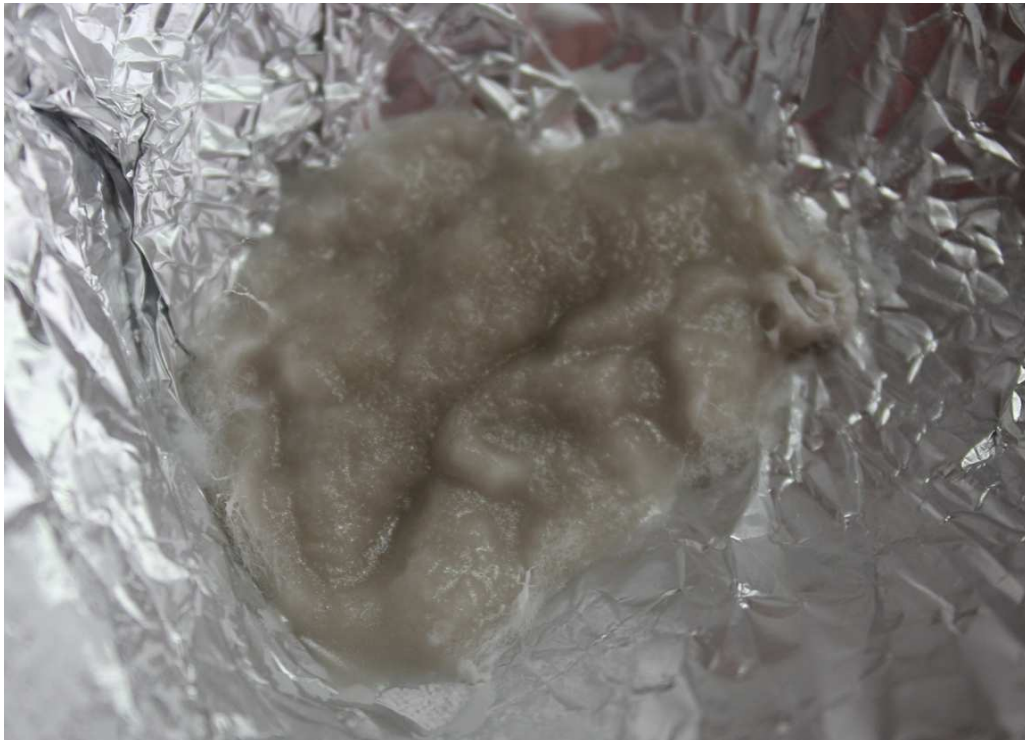


Fig. 6 KNO_3 - $NaNO_3$ -Mannitol propellant reinforced by cotton fibers, just cast
Experiment:

15g liquid KNO_3 - NaNO_3 -Mannitol propellant was poured over some loose cosmetic cotton. After curing (2h) a drop test from 1m height on a concrete surface was performed. The cotton fiber reinforced propellant showed not any damage.



Fig. 7 KNO_3 - NaNO_3 -Mannitol propellant reinforced by cotton fibers, after curing

Combustion test video of cotton fiber reinforced KNO_3 - NaNO_3 -Mannitol propellant:
<http://www.youtube.com/watch?v=Lyc9JU1KK-g>

References

[1] <http://mediatum.ub.tum.de/doc/982130/982130.pdf>

[2] http://www.sugarshot.org/downloads/eutectic_sugar_propellant_research_pt1.pdf