NEW TYPE STRAWS: PROPERTIES AND QUALITY

A. Volkov

1. Technology of straw production:
   a) standard;
   b) ultrasonic welding.
2. Welding tools.
3. Straw quality control.
4. Mechanical properties:
   a) stress – strain dependence;
   b) tension relaxation.
5. Behavior of pretense straw in vacuum:
   a) equilibrium equation;
   b) overpressure influence.
6. Poisson`s ratio measurements:
   a) measurement procedure;
   b) influence of straw tension.

Conclusion

Corresponding author: A. Volkov e-male: adv@jinr.ru

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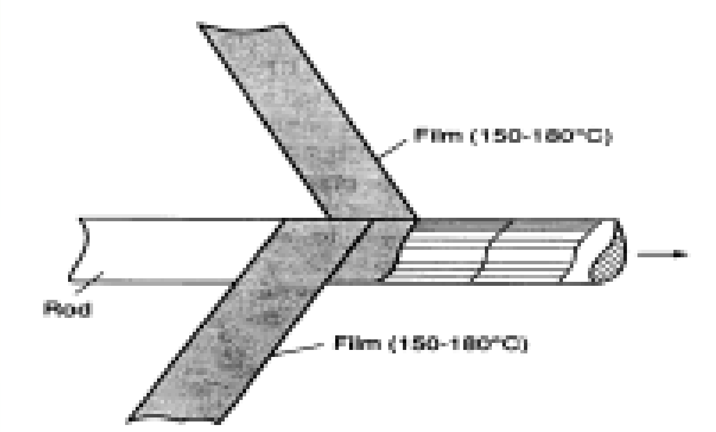
WINDING TECHNOLOGY OF STRAW PRODUCTION



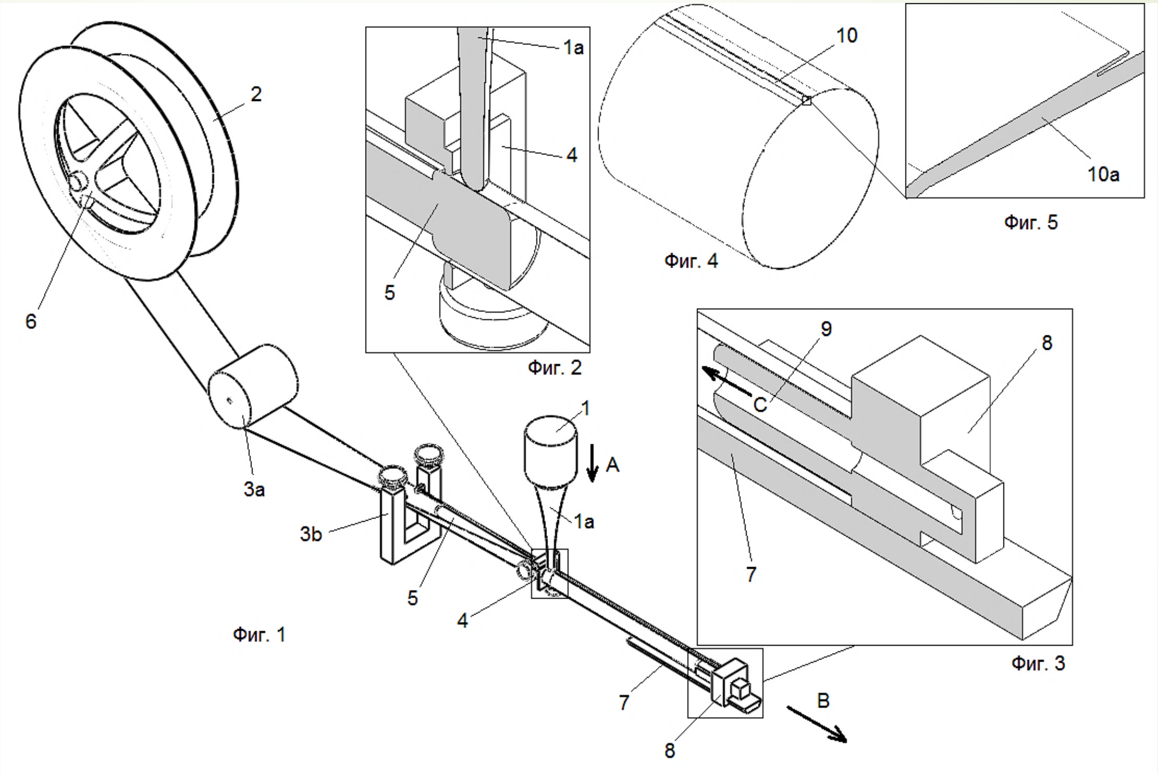
Thickness is two layers of film + glue layer.

Glue provides increased straw creep

Compared to creep of film`s material.

Film is heated to 50 – 70 degree.

WELDING TECHNOLOGY OF STRAW PRODUCTION

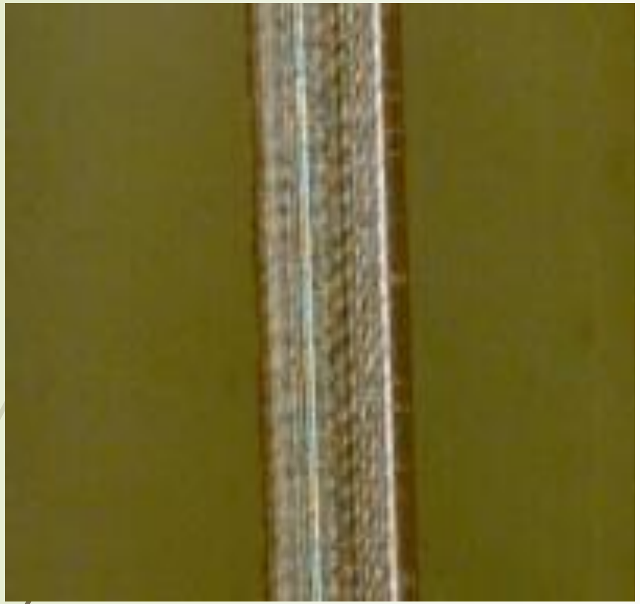


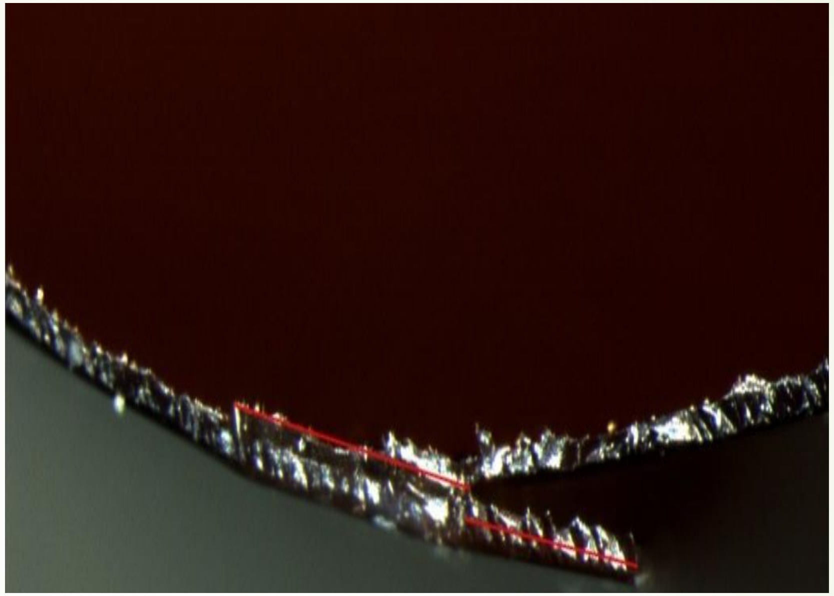
Block – scheme of welding machine.
Welding element – sonotrode, 1a.

WELDING TECHNOLOGY 0F STRAW PRODUCTION

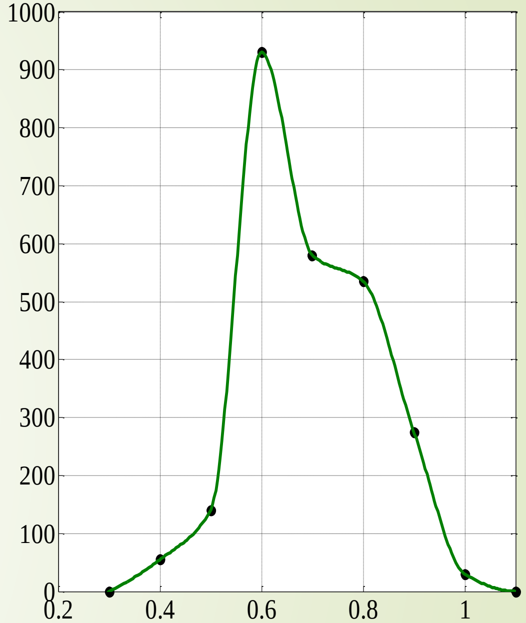
Mass production of straws

QUALITY CONTROL OF 36 μm STRAWS: WELDING





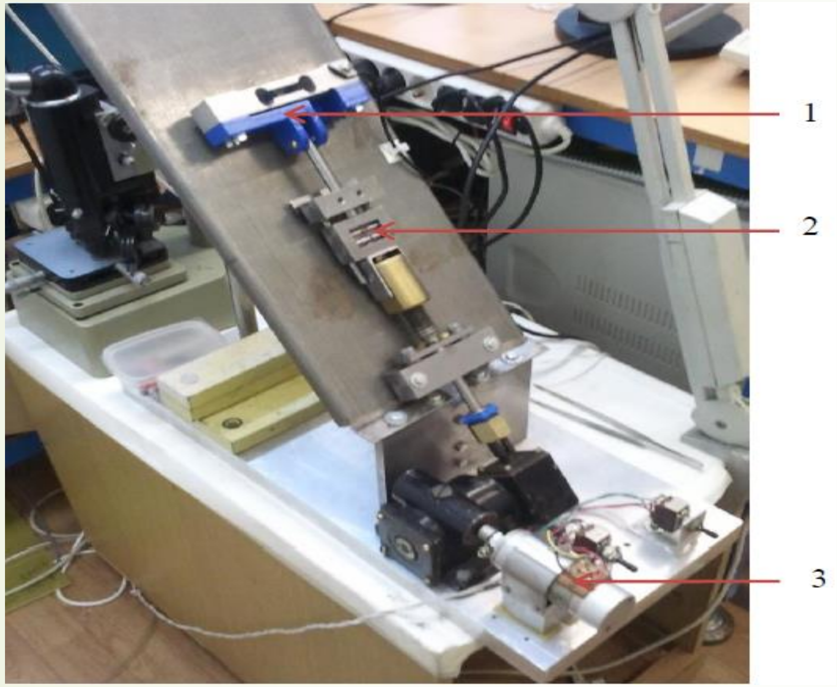
View of the seam



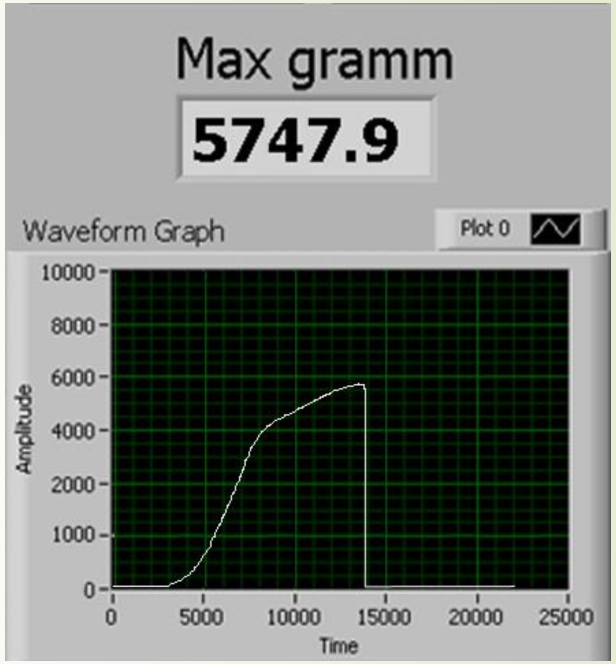
Seam width distribution

During welding metallization in the weld aria is destroyed.
Seam width distribution is presented in the mode of debugging the welding parameters.
Final distribution of seam width is less then 1 mm.

QUALITY CONTROL: SEAM BREAKING FORCE



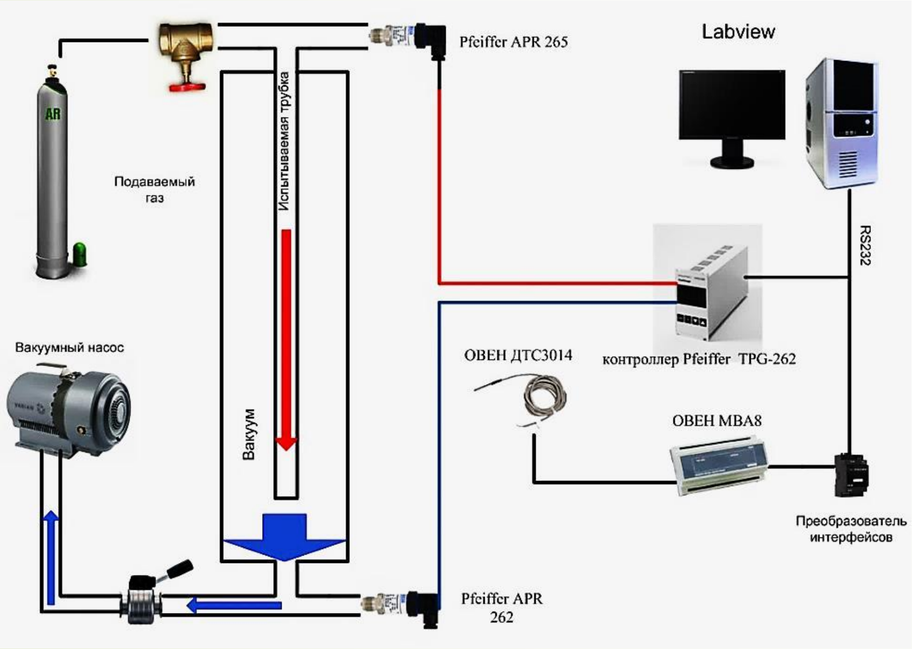
Test bench for checking of seam breaking force:
1 – stress gauge, 2 – sample,
3 – tensioning mechanism



User interface for data presentation. Requirements – breaking force should be higher then 4 kg.

GAS LEAK CONTROL

Test bench for gas leak investigation

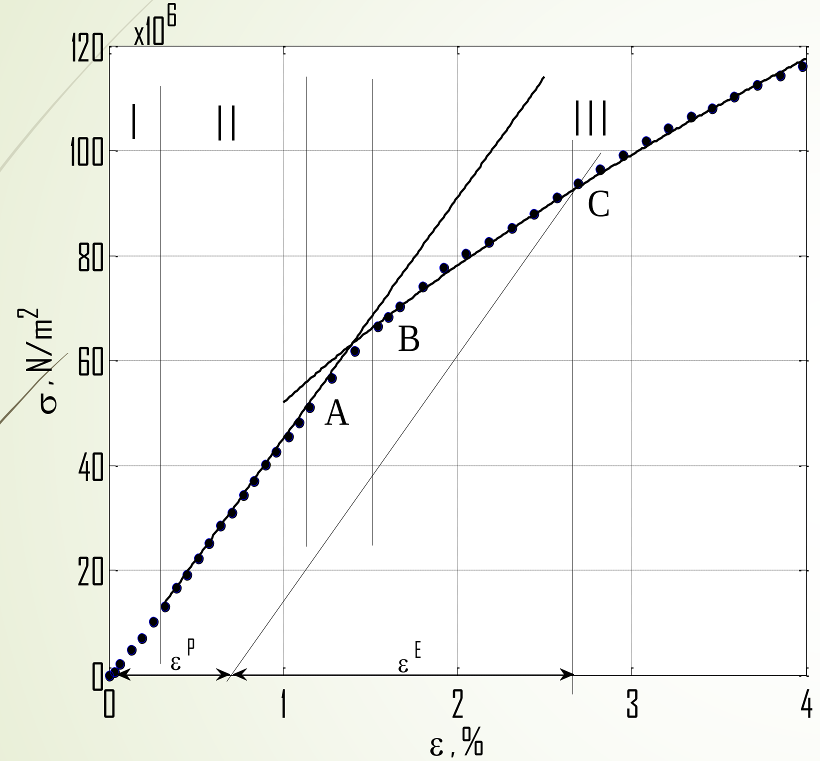


Gas leak of straw 2.5 m. long:
Leakage at overpressure 1 atm. Is
$3 \cdot 10^{-4}\ cm^3/min$

One month gas leak test at overpressure 1.5 atm.
Leakage is $5 \cdot 10^{-3}\ cm^3/min$

MECHANICAL PROPERTIES OF STRAW

Stress - strain dependence



Young`s module is $E = 4.6 \cdot 10^9 \frac{N}{m^2}$

Elastic deformation is described by

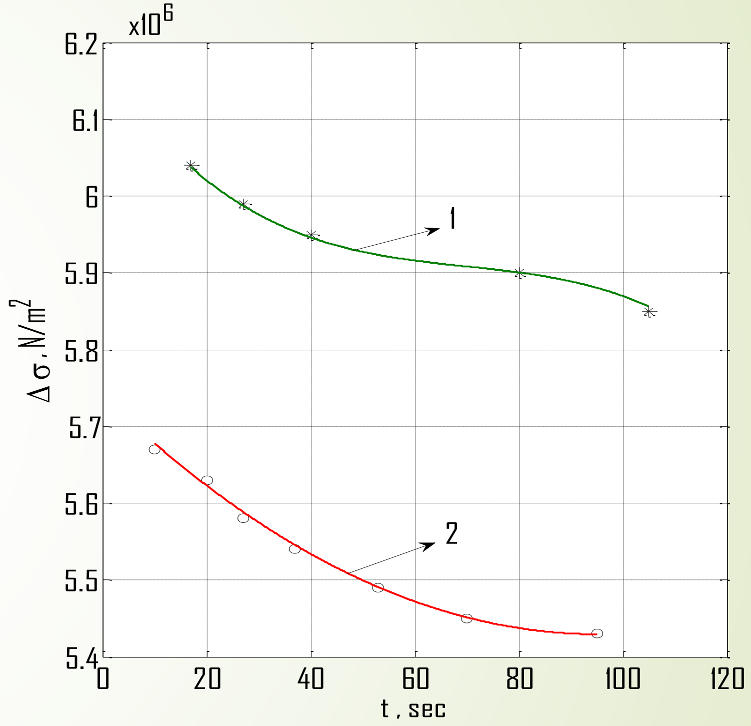
$$\sigma = \varepsilon E$$

Plastic deformation is described by

$$\sigma = C\varepsilon^n$$

For used straws C = 51.87; n = 0.59

Tension relaxation



1 – stress rate $2.56 \cdot 10^{-3}$ $\%/sec$;

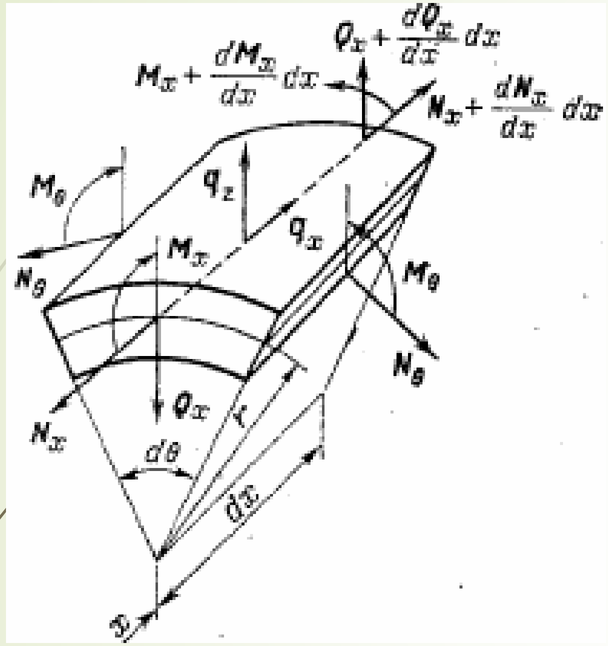
2 - stress rate $8.52 \cdot 10^{-4}$ $\%/sec$.

Relaxation can be approximated by:

$$\Delta\sigma = Ae^{-t/\tau}.$$

Relaxation constant $\tau = 45\ min$ for line 1 and $\tau \approx 30\ min$ for line 2.

BEHAVIOR PRETENSE STRAW IN VACUUM



Equilibrium equation of straw

$$\frac{d^4w}{d^4x} + 4\beta^4 w = \frac{1}{D}\left(q_z - \frac{\mu}{r}N_x\right) \longrightarrow \frac{d^4w}{d^4x} + 4\beta^4 w = \frac{1}{D}\left(P - \frac{\mu}{2\pi r^2}T_0\right)$$

Equilibrium equation describes the change of a straw radius w along the X axis under applied forces: tension T_0 and overpressure in vacuum P

Solution of homogenous equation $\frac{d^4w}{d^4x} + 4\beta^4 w = 0$

$$w(x) = \frac{e^{-\beta x}[\beta M_x(\sin\beta x - \cos\beta x) - Q_0\cos\beta x]}{2\beta^3 D}$$

$$D = Eh^3/12(1-\mu^2)$$

$$\beta^4 = 3(1-\mu^2)/r^2h^2$$

E – Young`s modulus;
μ - Poisson`s ratio,
h – thickness of straw.

$$M_x = -D\left(\frac{d^2w}{dx^2}\right)_{x=0} = M_0 = \frac{P}{2\beta^2}\ ;\ M_\theta = \mu M_x;\ Q_0 = -D\left(\frac{d^3w}{dx^3}\right)_{x=0} = -\frac{P}{\beta}$$

$$(w)_{x=0,L} = -\frac{1}{2\beta^3 D}(\beta M_0 + Q_0)$$

Moments M_x, M_θ , and shear force Q_0 affect only the ends of a straws about 2 mm length.

BEHAVIOR OF PRETENSE STRAW IN VACUUM

Partial solution of the equation:
P – overpressure, T_0 - pretension
At atmospheric pressure

$$w_1(x) = \frac{1}{4\beta^4 D}\left(P - \frac{\mu}{2\pi r^2}T_0\right)$$

Change of a straw tension

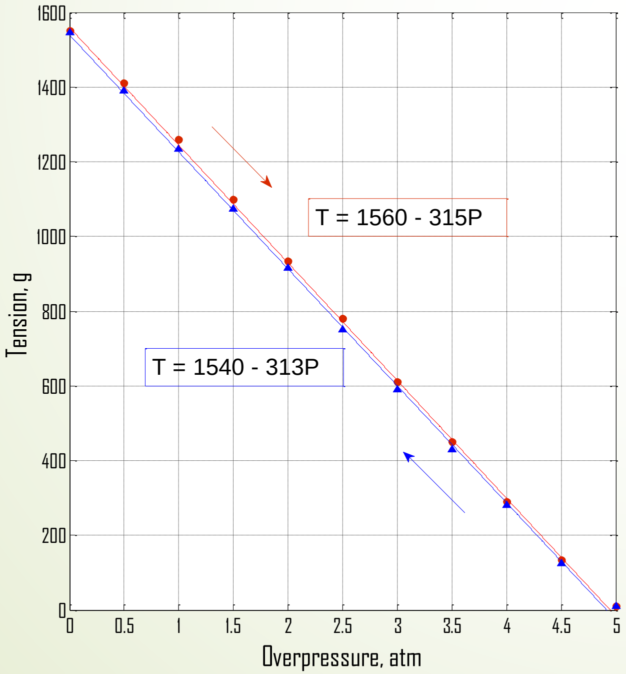
$$\sigma_m = \sigma_{T_0} - \mu P \qquad T_m = T_0 - \mu F_P$$

T_m - tension at overpressure; $F_P = 1\, atm. \cdot kg/cm^2$.

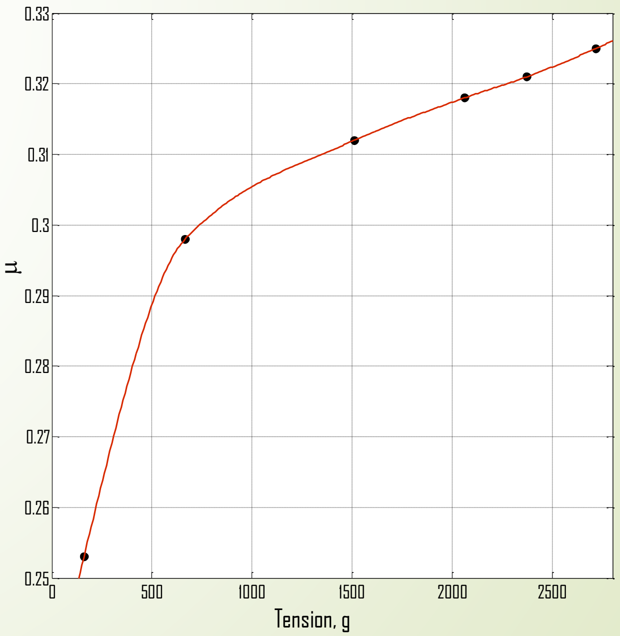
Pretension compensates influence of pressure

At $T_0 = 2\pi r^2 P/\mu$ → $w_1(x) = 0$

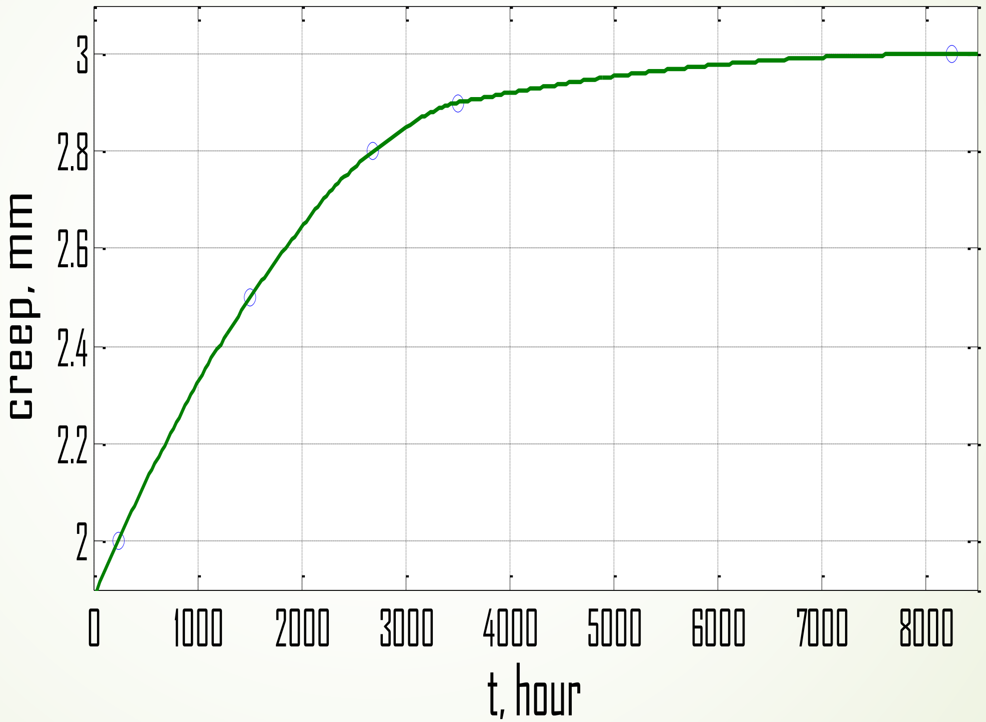
Tension vs. overpressure



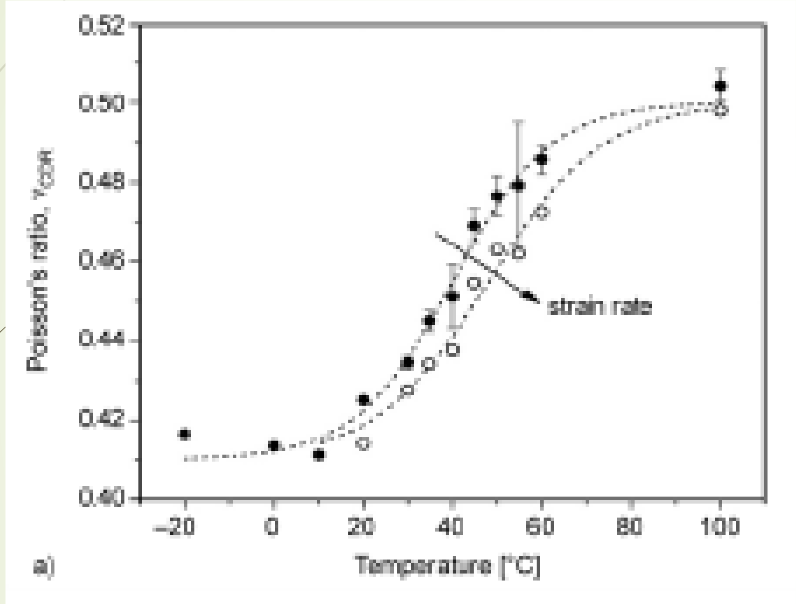
Poisson`s ratio vs. tension

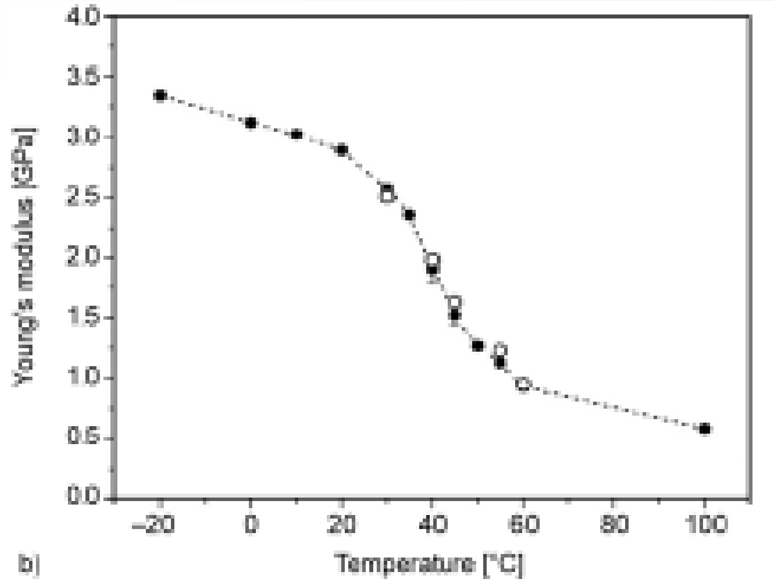


CREEP OF STRAW L = 86 cm, $T_0 = 2350g$



TEMPERATURE EFFECT ON THE STRAW PROPERTIES





● - deformation rate 0.003 1/sec

○ - deformation rate 0.05 1/sec

Stability of straw`s mechanical properties is observed
In the temperature range 15 ± degrees.

CONCLUSION

At JINR there is equipment for production of high-quality straws up to 5 meters long by method of ultrasonic welding.

Manufacturing techniques of straws 20 and 36 micron thick are debugged. It is offered to create at JINR second line of straw production for COMET experiment.

Solution of the straw equilibrium equation is received. It allows to estimate straw behavior at influence of tension and overpressure. Overpressure causes a rotation of self-supporting straws.

The behavior of straws in vacuum is investigated. Straw tension falls on 310 g/atm. for welded and 220 g/atm. for winded types of straw.

The new method of Poisson`s ratio measurement for produced straws is implemented. Method is non-destructive and high accuracy.

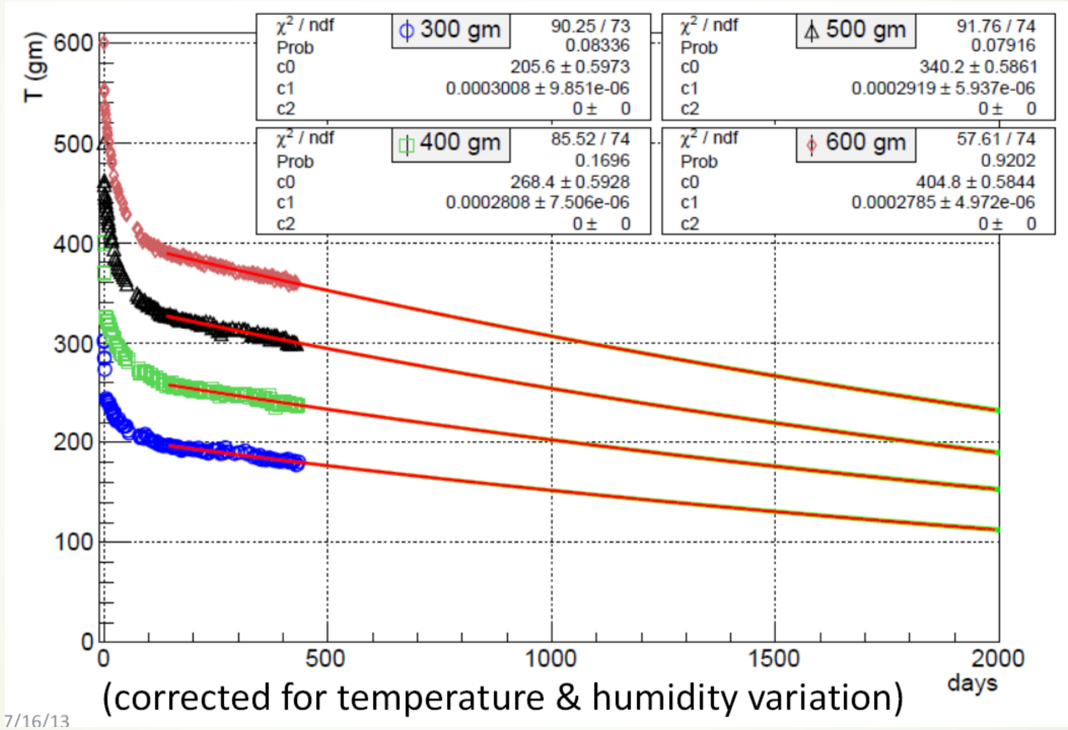
The optimal working temperature of straws in experiment is considered.

REFERENCES

1. N. I. Azorskii et al. The device for production of cylindrical tubes. Patent RF 2555693
2. N. I. Azorskii et al. The drift tubes new type working in vacuum: production technology and quality control. JINR Preprint P – 13 – 2016 – 33.
3 I. M. Ward, J. Sweeney. An introduction to mechanical properties of solid polymers. John Wiley & Sons, Ltd., 2004
4 C. R. Calladine. Theory of shell structures. Cambridge University Press, 1983.
5. И. А. Биргер, Р. Р. Мавлютов. Сопротивление материалов. Наука, 1986
6. S. Timoshenko. Theory of plate and shells. McGraw-Hill Book Co., 1959
7. C. H. Mott and C. M. Roland. Limits to Poisson`s ratio in isotropic materials – general results for arbitrary deformation. Chemistry Division, Naval Research Laboratory, Code 6120, Washington DC 20375-5342.
8. S. Pandini, A. Pegoretti. Time and temperature effects on Poisson`s ratio of poly(butylene terephthalate). eXPRESS Polymer Letters Vol. 5, No. 8, 2011
9. Alexander Mendelson. Plasticity: theory and application. The MacMillan Company, New York, 1968

THANK YOU FOR ATTENSION

Creep of winded straw – data of experiment Mu2E



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