5. RUBBER HEAT MACHINE.

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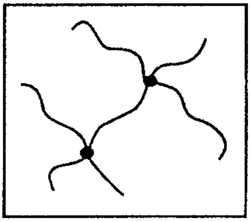


Fig1.Scheme of polymer's net

As known, matter which we call rubber, which became widespread because it's property of highelasticity, is a highmolecular polymer, molecules of which are connected by atoms of sulphur. By this elastic net happens, which has ability for big deformations without destruction of connections.

Experimentally determined, that rubber warms up during stretching, and decreases length by the heating. This phenomenon is called effect of Goule-Hooke. But why this happens? And why rubber has stiffness? For answering on these questions is better to look this on one polymer chain, which consist of big numbers of molecules. If on this chain do not acts any external force, the R can take any values from -L to L, where L – is length of the chain, <R> will be equal to zero. But to stretch the rubber we need to use some force f. Then of course R again will be possible to take any values from -L to L but <R> will not be zero. If to move <R> we used some force means this chain has some kind of stiffness. In case of solid body all is simple: stretching the body we are increasing distance between molecules, by this happens increasing of molecules attraction's potential energy. But rubber has no such potential energy like solid bodies.

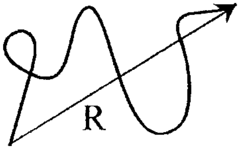


Fig2.Scheme of polymer's chain

If process is isothermic, our work goes on the heating up of the external medium, and potential energy of rubber dont changes. This phenomenon can be described with the entropy, like the ideal gaze.

$$dU = \delta Q + \delta A \quad (1) \qquad dU = TdS + \delta A \quad (2) \qquad T = const \quad (3)$$

So if we know probability of rubber's condition we can calculate entropy thought well known formula(5), where P – is probability.

$$S = k\ln P \quad (4) \qquad \delta A = -TdS \quad (5) \qquad P = Ce^{\left(-\frac{3R^2}{2Nl^2}\right)} \quad (6)$$

If entropy decreases means that work was done on the rubber, if it increases means that work was done by rubber. For comparing the tendentious of the theoretical rubber with experiment is better to determine formula for force, because it is rather simple to measure force, but not energy. According to the formula of potential energy we can get equation for force(7).

$$\vec{F} = \frac{3kT}{Nl^2}\vec{R} \qquad (7)$$

As we can see force is directly proportional to the R and T. On first look this formula looks like Hook's law, but this is incorrect, because in this formula there is no relative length.

We made experiment as shown on the picture. The rubber was

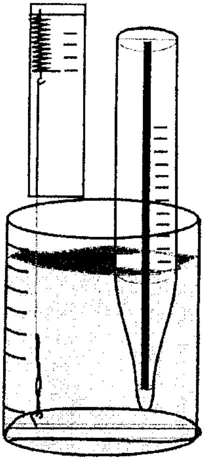
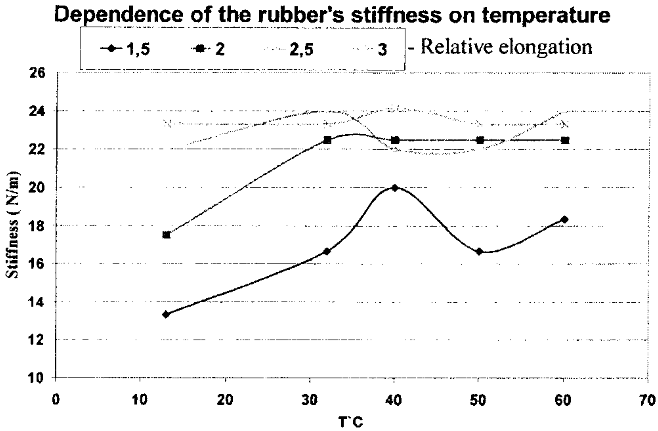
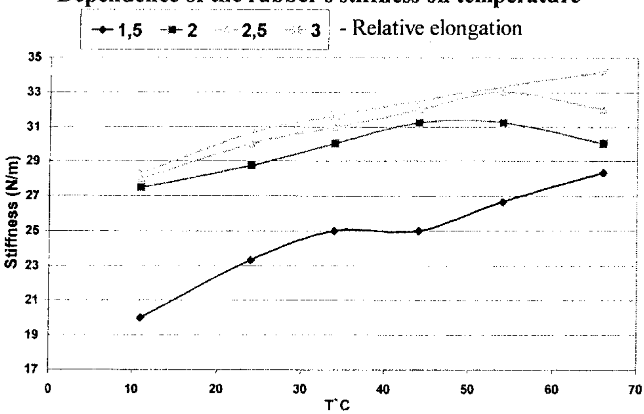


Fig3.Picture of the experiment





placed into the water. Warming up the water we got different temperatures of rubber. On these graphs you can see depending of the stiffness of rubber on temperature by different lengths. The rubber is not ideal linear because the rubber is not clear and chains are displaced random. And also you can see that after some temperatureby the big lengths happens decreasing of the stiffness. This happens because happens destruction of the rubber.

We made rubber heat machine ,which consist of external ring, internal wheel on the axe and 32 rubbers tented between these two wheels. Also there is lamp which works as the heater. Principle of it's work is very simple : Rubbers which are near the lamp are heating up, and by this happens increasing of it's force, by this happens displacement the mass center of the wheel relatively to the rotation axe and by the force of gravity happens the rotation of the wheel. After some turns the rotation

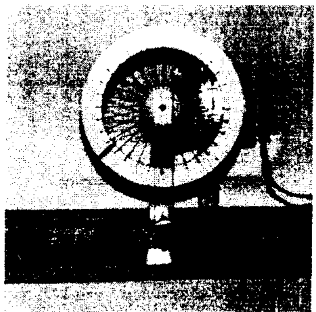


Fig4.Photo of rubber heat machine

becomes uniform. So there we have friction force's moment and gravity force moment. Sum of the moments most be zero. The moment of friction can be measured experimentally. So there left to determine the moment of gravity force.

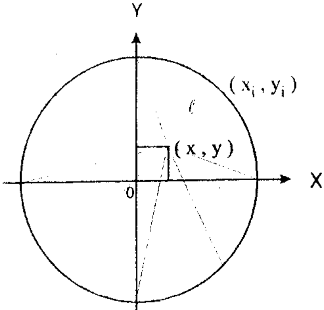


Fig5.Scheme used by calculating of displacement

$$\omega = \varepsilon t \qquad M = \varepsilon I \qquad \ell_i^2 = (x_i - x)^2 + (y_i - y)^2$$

$$\Pi = \sum_i \frac{k_i \ell_i^2}{2}$$

$$x = \frac{\sum_i k_i x_i}{\sum_i k_i}$$

ω - Angle speed
ε - Angle acceleration
t - Time
M - Force moment
I - Moment of inertia
ℓ - Length of rubber
k - Stiffness
Π - Potential energy

Lets find the laws of heating and cooling. The heating happens in lamp by the adsorbtion of the light energy. The cooling happens by the transmiting energy to the external medium. According to this we wrote formulas for rubber which is in the lamp(8), and outside(9).

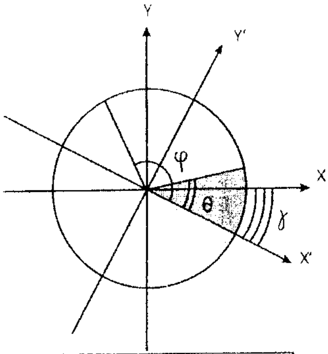


Fig5.Scheme used by calculating of temperatures

Parameters alpha and beta can be also measured experimentally. From this temperatures we can calculate stiffness of every rubber. We drawn graphs of the dependence of center's displacement on the angle speed by different lamp position. Rotation continues even when the lamp is already in the other side. Also is very interesting

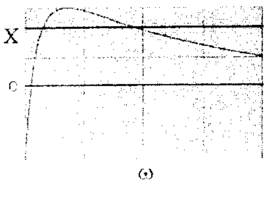
$$\frac{\delta Q}{dt} = \alpha(T - T_0)$$

$$P = \frac{\delta Q}{dt}$$

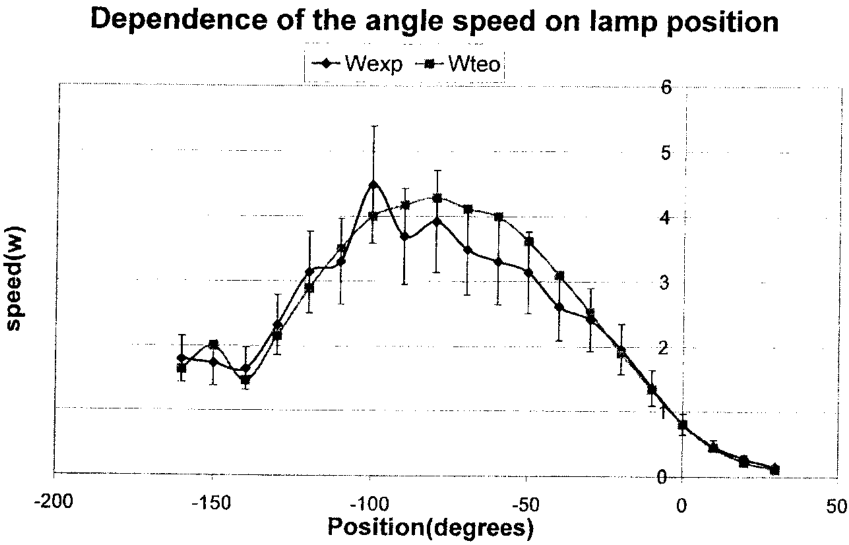
T_0 - External temperature
α - Coefficient of cooling
β - Coefficient of heating
φ - Rubber coordinate
θ - Lamp size
ω - Angle speed
P - Absorbted power
t - Time

$$T_2 = T_0 + \frac{\beta \Theta e^{-\frac{\alpha}{\omega}(2\pi - \Theta)}}{\omega\left(1 - e^{-\frac{\alpha}{\omega}(2\pi - \Theta)}\right)} + \frac{\beta \varphi}{\omega} \quad (8) \qquad T_1 = T_0 + \frac{\beta \Theta e^{-\frac{\alpha\varphi}{\omega}}}{\omega\left(1 - e^{-\frac{\alpha(2\pi - \Theta)}{\omega}}\right)} \quad (9)$$

graph of displacement on angle speed when the lamp is on the other side.



There are two angle speeds in which displacement is equal to necessary. The first angle speed shows critic value of speed which is necessary to make this rotation. If the angle speed is smaller machine will stop and will begin rear rotation. And second shows the stable speed of rotation. We detected from these graph dependence of the angle speed on the lamp position. You can see the graphs of the angle speed on the angle coordinate of the center of the lamp. The difference between theory and experiment is less than 20%.



This theory has list of admissions, such as : this theory cannot show the dynamic of rotation, was not took into account cooling of the rubber when it is in the section of the lamp, also was token contrast size of the lamp.

But not looking on that this theory gives rather good results, and with it can be found dependence of its work on parameters.

So as the result of my report I want to say, that as you already saw, trivial rubber heat machine, which can be found in any book about polymers, is very interesting for researching, and shows very interesting theory of it's uniform rotation. Of course this theory is not ideal, but I think no one is, but in future I think will be possible to delete some errors from it, maybe to make a theory which determinates also dynamic.