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solution to the problem no. 14
presented by the team of Poland

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Water rise

Immerse the end of a textile strip in water. How fast does the water rise in the strip and what height does it reach? In which way do these results depend on the properties of the textile?

Abstract

Aim of the studies was to find dependence between properties of the textile and velocity of the water rising when one end of the strip of textile is immersed in water.
Water absorbed inside the textile was composed of:
- Capillary ascent in fissures and canals made by fibres
- Wetting textile strips surface
- Diffusion

The results depended on properties of textile and water. The chemical structure of the fibres was the most important factor influenced water rising. The highest level of water in the cotton textile was connected with the greatest adhesion forces between cotton fibres and water.

Thanks

I want to thank very much M. A. Urszula Woźnikowska-Bezak, protector of Creative Group Quark, Prof. Władysław Borgieł and every people who helped me in this studies.

Overview

- Aim of the studies
- Theoretical background
- Experiment
- Results of the experiments
- Conclusions

1 Aim of the studies

Aim of the studies was to find the dependence between properties of the textile and the velocity of the water rising when one end of the strip of textile is immersed in water. I had to make an experiment with many measurements and try to find some dependencies supported by physical laws.

2 Theoretical background

When a textile strip is immersed in water, the last is absorbed inside the fibres and in fissures between them. Wetted fibres often swell because of felling up empty space in the fibres. Water is bonded to fibres by attractive forces. They work in short distances only in layer of water contacting with textile, rest of liquid is free. We can explain wetting textile surface or water drops adhesion by physical laws. The system air-water-textile is in a balance, depended on attractive forces between the bodies.
There are capillary fissures and canals in the textile strip. Their inside diameter is so small that we can see capillary effect. It is possible to use here theory of capillary ascent. The water is sometimes leaded in canals composed of many contacting each other canals. We should consider two events:

1. Forces between the pipe and liquid are smaller than VAN DER WAALS' cohesion forces in water; it brings about appearing of convex meniscus. In this case water does not ascent in the pipe, in fact it is pushed out from the pipe.

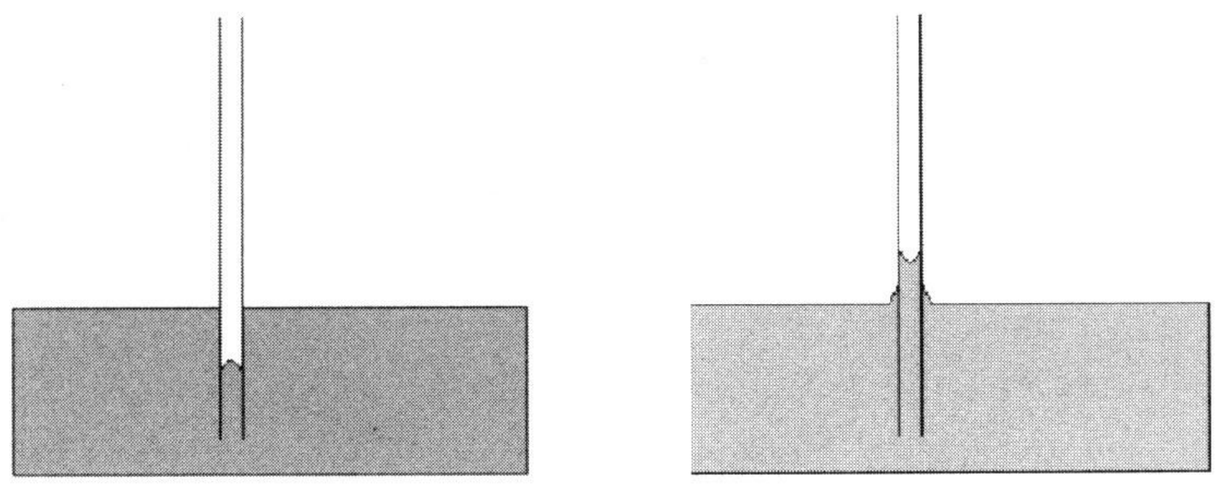

Figure 1: Left case 1, right case 2

2. Forces between the pipe and liquid are greater than VAN DER WAALS' cohesion forces in water; it brings about appearing of concave meniscus.

The second is more interesting for us because water ascends in the pipe. It is connected with additional pressure proceed from curving of water surface. There is a formula for the hight of water when capillary is a tube

$$h = \frac{2\alpha cos\beta}{r\rho g} \tag{1}$$

where:
α - coefficient of surface tension
r - radius of pipe
ρ - density of liquid
When there is a capillary fissure formula has similar form $h = \frac{2\alpha cos\beta}{d\rho g}$, where d is the inside diameter of fissure.

As conclusion to the formulas we can say that hight of water depends on kind of textile (width of capillaries, shape of meniscus) and water, its surface tension is connected with its temperature, surface-active compounds in it.
Of course it was impossible to measure fissures diameter in the textiles fibres. It was hard to estimate it, too, because of considerable differences in every textile.

3 Experiment

Now let's think about an experiment. I had prepared a watch and a ruler. I hanged up strips of various textile in the stand and immersed them in the vessel with water coloured by ink. I lighted up strong light source from the back – to see better the border (to use visual differences between wet and dry textile). I measured height of the level of water in the same periods of the time. I used different kinds of textile like: Cotton, flax, polyester, ortalion and canvas. The two last didn't absorbed any water, so I didn't use them any more.

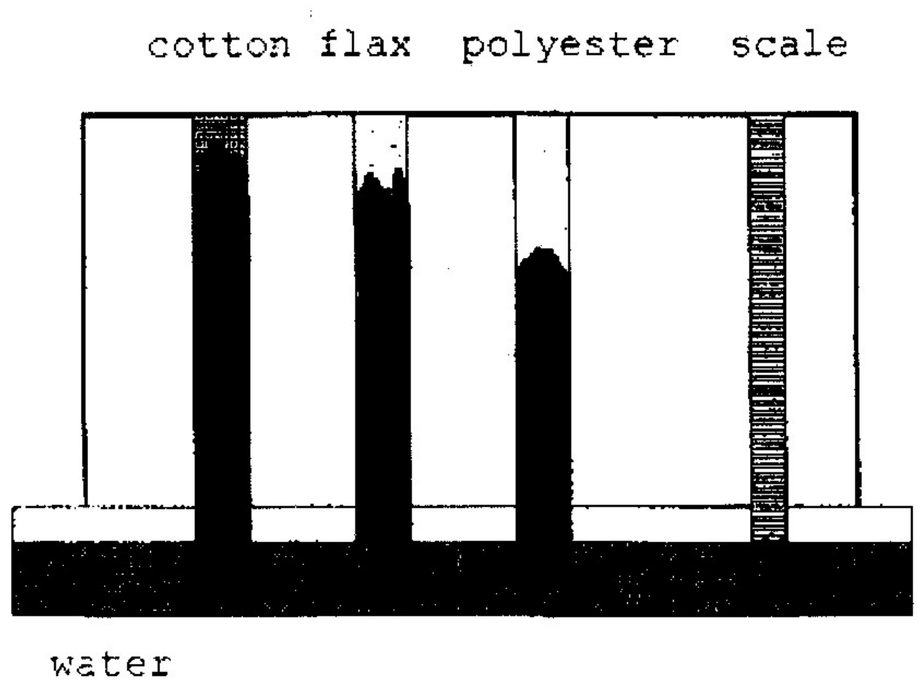

Figure 2: Experiment

4 Results of the experiments

I stored results of measurements in a computer and presented them at graphs. For clear view, there are two graphs. The first shows dependence between hight of water and time in the first 300 s, the second in 200 min.

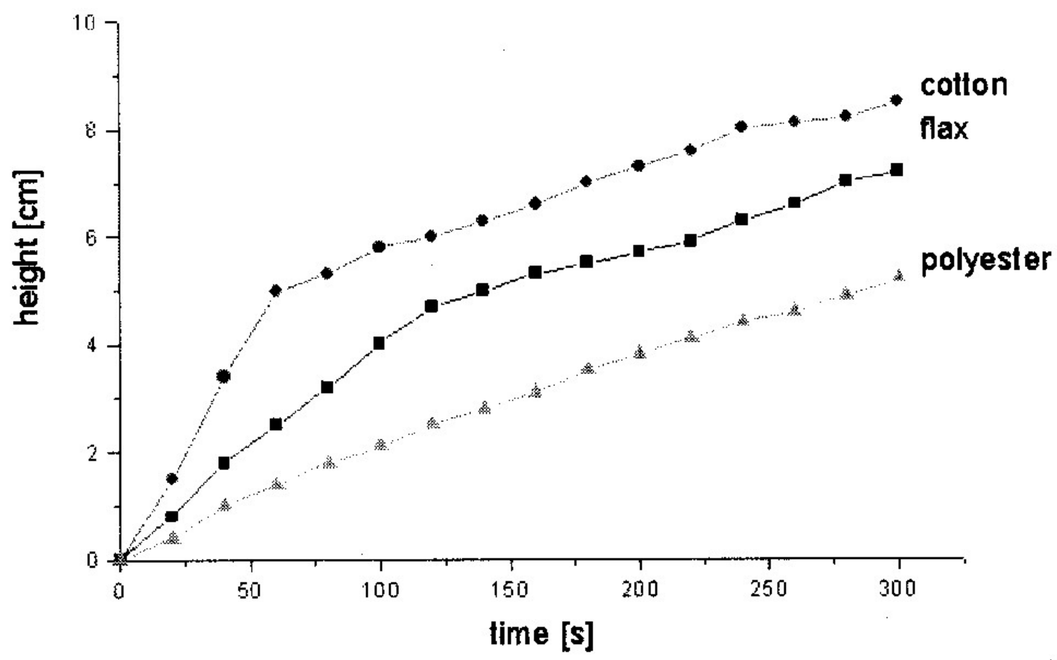

Figure 3: Height of water and time

The computer helps to calculate the velocity as time derive of the hight.
We can see that the all curves at the diagrams have the same shape. It is possible to find some phases in process of absorption: the first hight grows very fast, before about 120 min increase is negligible. It is connected with system's stabilising. Water absorbed inside the textile is composed of

- capillary ascent in fissures and canals made by fibres,
- wetting textile strips surface
- diffusion

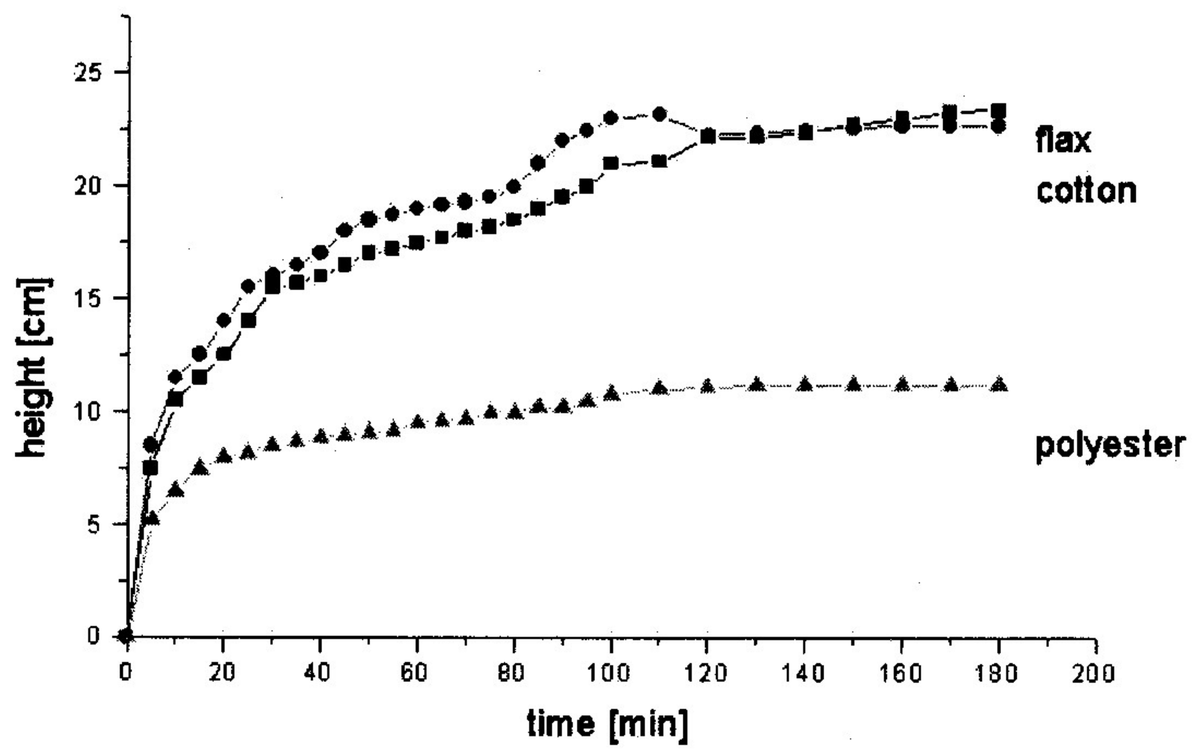

Figure 4: Height of water and time

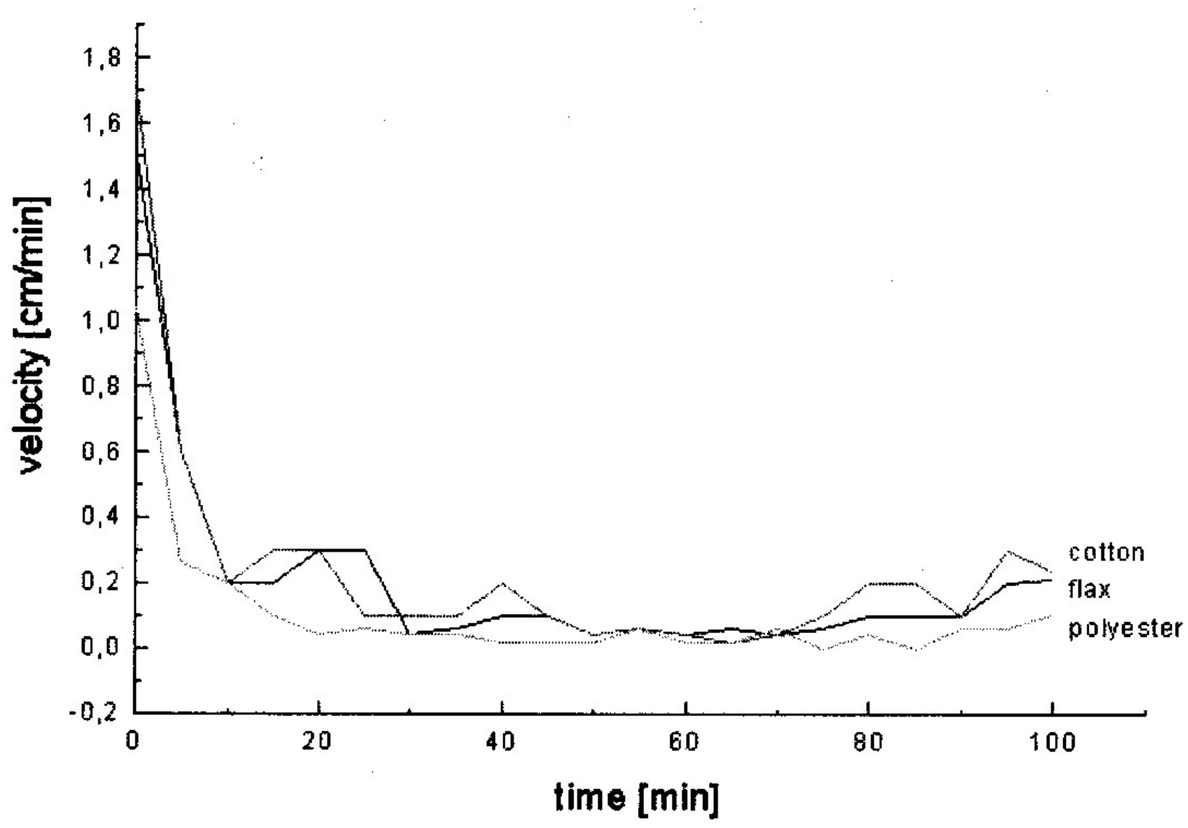

Figure 5: Velocity

Water is running out from the experimental system by vaporise. All processes persist until appear there the kind of hydrodynamic balance.

5 Conclusions

The results depends on the properties of the textile and the water. The chemical structure of the fibres is the most important factor influenced water rising. There was the highest level of water in the cotton textile, it's connected with the greatest adhesion forces between cotton fibres and water. Weave of textile influence the results, too, because of differences in width of capillaries and their shape.

Water properties are important, too. First I made an experiment in normal temperature (20°C), and pure water. When I add some surface-active compound into the water the increasement of its layer is lower; because surface tension coefficient is lower. It wasn't simple to examine how temperature of water influenced its increase; but it's possible to say that the small differences of temperature influence negligibly and when water temperature is about 100°C, vaporise is so high that water runs out from the textile faster than it rises.