SOIL MOISTURE THRESHOLD SENSOR WITH ELECTRICAL CONTACT

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Abstract: Herein we present a device whose sensitive element is made of a polyacrylamide hydrogel operating in cycles of water absorption-release. Changes in the volume of the sensing element are materialized by translating a rod acting on the blades of an electric contact so that when precalibrated soil moisture threshold value are reached, the lamellar contact state changes. The response time of the sensor depends on the balance of hydrophilic / hydrophobic polymer matrix specific to the type of polyacrylamide hydrogel used and its degree of reticulation.

Keywords: Soil moisture threshold sensor, electric contact, polyacrylamide hydrogel.

1. Introduction

The humidity sensor threshold with lamellar electrical contact (mechanical humidistat with electrical contact) shown in Fig. 1, is characterized in that its sensitive element made of a highly hygroscopic material (a polyacrylamide hydrogel type) which actuates a rod, when the soil moisture reaches a precalibrated value, determines the change of the contact state.

Figure 1: Soil moisture sensor threshold with electric contact

The items that give originality material of the device is the sensitive element (reticular acrylamide copolymer, C3H5NO with C3H3KO2 potassium acrylate) and adopted constructive solution for this. The copolymer, whose structure is schematically shown in Fig. 2, consists of an assembly of polymer chains which are parallel to each other and connected to one another by the usual cross-linking agents, thereby forming a network. When water comes into contact with one of these strands it is drawn inside the molecule by osmosis.

Figure 2: Polyacrylamide hydrogel assembly of polymer chains
Water rapidly migrates into the polymer network, where it is retained. As the soil dries, the polymer released into the soil up to 95% of the absorbed water.

The amount of the reticulation agent allows the modification of the polymer network. As there is more of the reticulation polymer, the network is more compact and its absorption capacity decreases but the polymer remains stable over time. On the contrary, as there is less of the reticulation polymer increases the amount absorbed, but polymer decreases the stability over time.

Similar mechanical hygrostats made up to date, based on changing the volume sensing element depending on the value of the relative humidity of the environment in which they are placed, used as strained hygroscopic materials wires of human or animal hair, cellulosic materials of treated timbers or synthetic polymers. Some of these materials have a low resistance to temperature fluctuations, chemical agents or mechanical stresses associated with repeated cycles of absorption-release of water and because of this, the reliability of these devices is small. Other negative influences sensitivity, response time and hysteresis of hygrostats.

Also, some of these materials involve the adoption of complicated construction solutions, which raise the cost price of such devices. To a greater or lesser extent, some of these disadvantages are removed using the polyacrylamide hydrogel referred to as a material for making the sensitive sensor element and adopted constructive solution for its protection against mechanical stress.

2. The experiment

2.1. The design and operation of the soil moisture sensor threshold

The soil moisture sensor threshold with lamellar electrical contact has two main areas, as shown in Fig.3.

![Figure 3: Detail of the soil moisture sensor threshold with lamellar electrical contact - sensing element sub-assembly and electric contact rod drive sub-assembly](image)

The tip of the sensor [1] allows the easy penetration of the soil. In the first area are placed sensitive element [4], and the second electrical contact [14].

Between the two devices is the membrane [10] that ensure environmental separation necessary to protect the environment against the ingress of moisture and fine soil particles in its immediate vicinity.

The tube [17] made of steel pipe has the required length of placing the hydrogel [4] to the desired depth at which the soil moisture monitoring needs to be carried out. The design allows adjusting the position adopted by the electrical contact [14] to facilitate sensor calibration in accordance with a pre-established threshold value. To this end, the contact body [15] is screwed / unscrewed, leading to a modification of 0.5 mm / revolution of the position of the blades in relation to the tip of the rod [9], within the contact body [11].
The seal [18], shown in Fig. 4 provides protection against pulling apart the two-wire cable [16] and sealing against the outside of the area of its connection with the electrical contact blades [14].

The soil moisture sensor threshold with electric contact lamellar works like this: when the soil moisture rises, the hydrogel [4] absorbs water and expands, causing a translation of the support rod [7] and thus near the top rod [9] from the electrical contact slides [11], deforming the membrane [10] and compressing additionally the spring [13]. The displacement of the rod is restricted by the pin [8] to the value corresponding to the maximum travel range of the work humidity sensor. The tip of the rod [9] is dimensioned in such a way as to make the elastic deformation and wear the small contact slide [14] to change its status. When atmospheric moisture decreases, the hydrogel [4] releases the absorbed water and reduces its volume causing a translation in the opposite direction of the support rod [7] and implicitly a withdrawal of the tip rod [9], decreased deformation of the membrane [10] and loosening the corresponding spring [13]. As a result, the precalibrated threshold value is reached for soil moisture and electrical contact status change occurs [14] from normally open or normally closed and backwards, according to the displacement direction. The contact body [11], which is fixed to the adjustable electrical contact [14] is assembled by screwing the tube [17] and presses the diaphragm [10] between its front surface and the front surface of the sheath [6] by means of the holender [12]. Thus it is ensured the environmental separation between the ground and the camera switch [14] inside the body contact [11].

2.2. Results and comments

Laboratory experiments out which aimed to determine the amount of water absorbed by the hydrogel used as sensitive element of the sensor in its specific conditions of the installation were carried for different value of soil moisture. For this purpose, in four containers were prepared soil samples with moisture content of 15%, 20%, 25%, and 30% (percentages by weight). It was then introduced in each of containers one threshold humidity sensor from which there were removed the first tube [17] and the seal [18] and the containers were then sealed from the external environment for preserving the humidity. Daily were weighed sensitive elements of the four sensors to highlight the moment when they reach hydric balance and therefore we will not highlight the weight gains of the hydrogel. Based on the results, we have drawn the chart shown in Fig. 5.

There were also determined the amount of water absorbed by the sensitive element of the sensor until the appropriate water balance of the four soil moisture defaults (quantification was made by mass sensing element, $m_e$). The data obtained are shown in the table below.

<table>
<thead>
<tr>
<th>Soil humidity, U [%]</th>
<th>Mass of absorbed water, $m_w$</th>
</tr>
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<tbody>
<tr>
<td>15</td>
<td>$3.5 \times m_e$</td>
</tr>
<tr>
<td>20</td>
<td>$5 \times m_e$</td>
</tr>
<tr>
<td>25</td>
<td>$8 \times m_e$</td>
</tr>
<tr>
<td>30</td>
<td>$12.5 \times m_e$</td>
</tr>
</tbody>
</table>

The obtained values of $m_w$ allowed the appropriate dimensioning of the volume bounded by the inner surface of the tube holder [2] and the end faces of the support [3] and the spacer [5], based on the weight of the hydrogel used as sensitive element of the sensor. However these values were the basis for sizing the spring [13] which, on the one hand must be tensioned to ensure recovery firm operating of the actioning rod of the electrical contact slide switch [14] to its original position and, secondly, they should allow maximum stroke of the rod without proper elastic force developed by it to cause damage or excessive tension of the hydrogel. The rate of absorption of the water-releasing response time of the sensor, depending on balance of hydrophilic / hydrophobic polymer matrix of the hydrogel and the degree of reticulation The amount of the reticulation agent allows a change in the degree of reticulation of the hydrogel. The more the hydrogel is reticulated, the more the polymer network is compact. As a result, the water absorption capacity decreases, but its properties remain stable over time. On the contrary, the less the hydrogel is reticulated, the lesser dense the polymer network is.
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As a result, there is an increased ability to absorb water, but decreases the stability of its properties over time. We must find an optimal degree of reticulation and further, it is indicated to provide in the maintenance procedures of the sensor that its sensitive element be changed every two years.

3. Conclusions

The threshold moisture soil sensor has presented a number of advantages that confer a high level of competitiveness on the market related to its field of application (automated irrigation systems for watering triggering, grain silos for signaling critical values). It is an autonomies device in terms of energy. Its electric contact, whose condition changes depending on a threshold value of the precalibrated soil moisture allows integration of the sensor element command with an active role in an automated irrigation system. Low maintenance costs under a specific mean up time of two years due to the ability of the polyacrylamide hydrogel keep unaltered its characteristic absorption-release water cycle even in heavy duty operation (corrosive environment, large temperature differences or high mechanical stress). This adopted design is simple and therefore it is inexpensive, given the high reliability of the sensor. The calibration and maintenance activities of the sensor are simple and do not require a high specialized operator.

4. References


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