Technology and equipment to improve reliability of pipeline transport

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Abstract. The article is dedicated to development of technology and hardware design of method pipeline transport reliability improving by improving the isolated coating properties modified by microwave radiation. The article describes the technology of the modification process of the coating and instrumentation production, which allows improving operational properties not only in stationary conditions in the manufacture of the insulation coating, but also during its replacement in the field.

1. Introduction
Improvement of the quality of the polymer isolated coating of the technology equipment, obstructive to the corrosion process, is an actual problem. So the main cause of pipeline transportation accidents, recorded in the acts of the technical investigation, are the processes of corrosion up to 30% of the total number of accidents. This can lead to significant damage of property, environmental pollution, since the area of distribution of the fracture may extend over distances from a few meters to kilometers. One of the main tasks to improve the reliability and corrosion resistance of the system is to increase the service life of the insulating polymer coating due to the improvement of their physicochemical properties. For these purposes, in particular, various kinds of improvement of the polymer materials properties are used: chemical, radiant, plasma chemical, vibroprocessing, and etc. These methods greatly complicate the technology of production and have a negative technogenic influence on the environment [1-4].

At present, methods of influencing technological environments, in particular polymers, are being increasingly used, with radiation of various types over a wide frequency range from ultrasonic 20 kHz to X-ray. One of the most effective solutions to the problem of increasing the service life of the insulating coating may be a transition to a new technology that uses physical phenomena, in particular, microwave radiation with a frequency of ~2.4 GHz. [5, 6]

2. Technologies of isolated coatings production
In the traditional scheme of production of polymeric insulating coatings, in particular PVC film, the polymer composition is fed inside extruders, where the final mixing, homogenizing, plasticizing, warming and thickening of the mass are occurring.
The mass, obtained in the extruder, is pressed through the head with aperture and is fed in the form a belt by band conveyors into the loading gap of the calender, which is a four-roll machine with the L-shaped arrangement of the rolls. [7]

From the low roll, the tape arrives to the cooling reel; then it arrives to the cooling device. The tape envelopes three reels consecutively, cooled by the circulation water, and then arrives to the reeling machine, where it is coiled into rolls.

From the literature [8], it is known that the improvement of the mechanical characteristics is observed in the formation of additional bonds between the macromolecules prolonged heating of polyvinyl chloride for 2-4 hours at a temperature of 175 °C.

It is offered to replace the long-term power-consuming thermotreatment, influencing the material, by the micro wave radiation with the dose of 15-30 kDj/kg during 1 minute and namely to install the electrodynamic high frequency device in the technological process of the isolated coating production between calendering and cooling stages. As a result, having the same technological parameters, the expended power may be reduce more than four times.

With changed technology, the polymer material will be loaded to the calendering knot and the calibration knot between gaps. After that, the tape arrives to the stage of handling by electromagnetic field, under influence of which modification of polymer structure occurs, and then to the cooling and coiling into rolls stage.

**Figure 1.** Traditional scheme of isolated coating production: I – calendering stage; II – cooling stage; III – winding stage; 1 – external roll; 2 – upper roll; 3 – medium roll; 4 – lower roll

**Figure 2.** Offered scheme of isolated coating production: I – calendering stage; II – cooling stage; III – winding stage; IV – electromagnetic high-frequency device 1 – external roll; 2 – upper roll; 3 – medium roll; 4 – lower roll

### 3. Equipment to improve operational performance

From the experimental studies [9], it is possible to draw a conclusion about sufficient efficiency of the use of electromagnetic radiation for the modification of polymeric materials, in particular polyvinylchloride film that is the basis for developing designs of microwave devices for modification of polymeric films in a continuous process with uniform application of the adhesive composition.

**Figure 3.** Combined microwave facility: 1 – loading device; 2 – working chamber; 3 – microwave generator; 4 – radiation system; 5 – membrane; 6 – guiding rolls; 7 – channeled reel for applying adhesive composition; 8 – conduit for adhesive composition fed; 9 – polymer tape; 10 – product unloading knot; 11 – slick channeled reel for distribution of adhesive composition
The operation of the facility is as follows. Polymer tape 9 exposed to the modification through
loading device 1 arrives to guide ceramic rolls 6. At the exit of the facility framework (of the
resonator), the adhesive composition is applied to the tape, which arrives to cylindrical grooved reel 7,
through channels 8 and is distributed on the tape surface by slick cylindrical reel 11. Then it moves to
the unloading knot of product 10.

Microwave radiation (with frequency 2450 MHz) is generated by microwave generator 3 and is
radiated to the facility framework through radiation system 4. Membrane 5, permeable for microwave
radiation, protects the generating device from moisture ingress.

The distance from the surface of the insulating coating to radiant systems is selected as the most
effective impacts of microwave radiation along the length of the processed material. To ensure full
absorption of microwave energy, the height of the product layer on the conveyor belt is set to be more
than the depth of penetration of the microwave radiation into the polymer substance. It is necessary
that the surface of the conveyor should not absorb electromagnetic energy, which will provide
multiple interactions with the polymer medium.

The radiating system energy can be determined from the experimental studies according to known
specific radiation power using the formula:

\[ W_d = P_d \cdot \tau_e, \quad (1) \]

where \( P_d \) - optimal power density, kVt/kg; \( \tau_e \) - exposition time, s.

The rate of tape broach and radiation power for the modification process is determined by facility
productivity:

\[ u = \frac{G}{d \cdot b \cdot \rho}, \quad \text{(2)} \]

\[ P = W_d \cdot G, \quad \text{(3)} \]

where \( G \) – productivity, kg/s; \( d \) – tape thickness, m; \( b \) – tape width, m; \( \rho \) – material density, kg/m³.

The number of reflections of electromagnetic radiation or the number of layers of the polymer film,
which must ensure the equality of the total thickness of the processed material and the maximum depth
of penetration of electromagnetic radiation in the material, i.e. all the energy of microwave radiation,
is absorbed by the treated substance, which allows one to increase the energy efficiency.

In case the radiation direction is oriented at an angle to the surface of the processed material, it is
necessary to satisfy the condition of shift of a signal reflected from the radiating system. It is possible
in case the reflected radiation in the longitudinal direction is greater than the diameter of the radiating
system.

The height of the chamber is determined as follows:

\[ H = \frac{D_o}{2 \sin \alpha_i}, \quad \text{(4)} \]

where \( D_o \) – diameter of the radiating system, m; \( \alpha_i \) - inclination angle of the radiation direction to
the modifiable material surface.

The length of the chamber is determined in the following way:

\[ L_\text{c} = N \cdot \frac{D}{2 \cos \alpha_i}, \quad \text{(5)} \]

The radiation power of the generating device will be determined by the capacity of the installation
and the specific energy of the polymer modification.

When replacing the external and internal insulation coatings in the field, the following facilities can be applied:
Figure 4. Facility for modification of polymer materials on the external surface of the pipeline: 1 – framework; 2 – rolls; 3 – magnetrons; 4 – engine; 5 – drive; 6 – cog-wheel [10]

The facility for modification of the tape insulation coating on the pipeline is the construction, which covers the pipeline, representing framework 1 with rolls 2, which tightly fit and move on the pipe surface. The metal ring is a steel sheet with additional bio-ceramic coating. The housing of the facility includes generators of microwave radiation 3 with the required output radiating power, the running mechanism, consisting of engine 4, drive 5 consisting of cogged and chain gear rolls 2, installed at a certain angle for the translational motion along the pipeline.

The motion is carried out through the transmission of rotary motion of cog-wheel 6, to which the rollers are attached. In the process of movement, the insulating coating of the pipeline is irradiated. By the influence of electromagnetic radiation, the adhesion parameter is increased.

Figure 5. The device for applying the tape polymer coating to the internal surface of the pipeline: 1 – pipeline; 2 – carriage; 3 – holder; 4 – clamping roll; 5 – power cylinder; 6 – bobbin; 7 – tape coating; 8 – microwave generator; 9 – radiating system; 10 – drive roll; 11 – regulating wheels; 12 – electric engine; 13 – chain gear; 14 – worm gearing.
The device for applying the tape polymer coating to the internal surface of pipeline 1 contains carriage 2 that is rigidly connected with drive 10 and with two pairs of regulating wheels 11. Clamping roll 4 with power cylinder 5 and bobbin 6 with tape coating material 7 are mounted on horizontal holder 3. The tape material is washed off by bobbin 6 and pressed to the pipeline surface by clamping roll 4. After application, the tape polymer coating is irradiated by means of microwave generators 8 with radiating systems 9, which ensure uniform irradiation and heating along the cylindrical surface of the band material of the coating by microwave radiation.

Microwave generators 8 creates electro magnetic radiation with frequency 2450 MHz and is protected by the membrane permeable for microwave radiation, which prevents it from hitting by the evaporated moisture.

The device movement is carried out by electric motor 12 through chain drives 13 and is synchronized with the winding rate of the tape material of coating through worm gear 14.

The optimal specific energy of the radiating system of facilities is determined by formula 1

\[ \tau = \rho \cdot \frac{l}{bd} \cdot G \]  

where \( l \) -pipeline length, m;

\[ P = W_a \cdot \frac{G}{2 \cdot \tau} \]  

where \( D \) – pipeline diameter, m.

4. Conclusion

The proposed technology and equipment allow improving the quality of insulating coatings (mechanical durability increases up to two times, water absorbing reduces up to three times, the electric resistance increases up to two times), which will, correspondingly, increase the reliability and longevity of pipeline transport.

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