Rationale for the development of the design of a microwave installation for cleaning wool yarn in the conditions of modern textile enterprises

Sergei Pryvala¹, Valeriy Pryvala²

¹ National Technical University of Ukraine "Igor Sikorsky Kiev Polytechnic Institute" 03056 Kyiv, Ukraine, Prospect Peremogy 37, phone: +380936319959
² Khmelnytsky National University 29016 Khmelnitsky city, st. Institutskaia-7, Ukraine, phone: +380975761194

e-mails: s.pryvala@gmail.com, pva2012hnu@gmail.com

Abstract: In the conditions of fierce competition in the world market of textile materials the important factor is optimization of process of fabrics production. Textiles must be of high quality, inexpensive and competitive. This concept is more or less adhered to by manufacturers of woven materials made of synthetic fibers, which are outwardly attractive and inexpensive. According to the last year's statistics, the dominant raw material in the production of fibrous materials is polyester. Its share in the world market is several times higher than the share of its closest competitor - wool. However, the cost of textiles based on wool fibers, taking into account its important performance properties, can not be cheap. Sewing products made of woolen materials are always in the trend of modern fashion. Coats, suits, dresses, sweaters, blankets, plaids - these are products for the manufacture of which woolen fabrics of various thicknesses, compositions and finishes are traditionally used. Thus, the issue of reducing the cost of textile production technology from wool yarn is relevant for domestic textile enterprises located in Chernihiv, Kryvyi Rih, Odessa, Sumy. However, modern wool cleaning technology remains multi-stage and energy consuming, which affects the quality and final cost of production [1]. Therefore, the purpose of research is to create energy-saving technology for wool cleaning through the use of ultra-high frequency electromagnetic field (UHF) at textile enterprises.

1. Introduction
As it was mentioned earlier [2, 3, 4, 5, 6], the use of high-frequency (HF) energy for drying various objects and substances is not new and has found wide application for drying wood, food, paper and others. Compared to the conventional HF drying method, heat is generated inside the material to be dried. This means that in the HF field, the drying process of the textile fiber begins not from its surface, but from the middle, and gradually develops towards the outer surface. This method of heating is faster than convection. However, high-frequency heating has its drawbacks, which are difficult to get rid of. For example, it is impossible to obtain a fixed heating temperature of materials, which can cause them to overheat and even destroy [7, 8, 9, 10].

In the early 1980s, a number of highly economically developed countries in Europe, Japan and the United States underwent a technical revolution in the development of technologies for drying and heating a variety of materials and substances using ultra-high frequency electromagnetic fields (UHF). That is, technologies for heat treatment of food, vulcanization of rubber chambers, paper drying, gluing
wood panels and so on, have appeared in the field of ultra-high frequencies (1450 MHz). However, the complexity of design and manufacture of microwave generators made these technical innovations economically unprofitable. And only in the early 90's of the last century, due to cheaper technology for the production of microwave equipment, the use of microwave technology has received a new impetus [11, 12, 13].

The Ukrainian scientists also made their contribution to the theoretical developments and practical application of the ultrahigh frequency field, which is reflected in the scientific works of Vodotovka L.I. (National Technical University of Ukraine, Kyiv Polytechnic Institute named after Igor Sikorsky), Bereznenko M.P. and Bereznenko S.M. (Kyiv National University of Technology and Design), Skrypnyk V.M. (Khmelnitsky National University) and others. Due to the research of these scientists this area has become closer to the national light industry [14, 15, 16].

In the previous publication [17, 18] the theoretical substantiation of the possibility of using the electric field of ultrahigh frequencies in combination with centrifugal forces to optimize the process of cleaning wool yarn is presented in detail. Namely, at the appropriate technological stage of wool processing it is offered to perform its extraction by centrifugation of the drum of the working chamber with the imposition of the microwave field on it. Due to this, it is expected to reduce the time for drying wool. To implement this concept, it is necessary to develop an appropriate installation, the schematic diagram of which is shown below.

2. Methods

Figure 1 shows a layout diagram of an industrial microwave unit. The construction of the existing industrial installation, which is used for wool cleaning at Ukrainian textile enterprises, is taken as a basis.

![Figure 1. Schematic layout of the installation for industrial cleaning of wool yarn using a microwave field: 1-microwave generator (magnetron); 2- waveguide with resonator chamber; 3- perforated drum; 4-impeller for circulation of washing agent; 5- electric motor; 7- reducer; 8- resonator cover; 9 - shock-absorbers of a working chamber; 10-pipe; 11- pump; 12-branch pipe for draining of washing agent; 13 - water compressor; 14- container with distilled water; 15- pump; 16 - installation for cooling of a magnetron; 17- power supply of the magnetron; 18 - installation control panel.](image-url)
The difference is that in the new installation, the bath for washing wool has been replaced by a chamber in the form of a perforated drum 3 of conical shape, which has the ability to rotate similarly to industrial washing machines. In addition, the new apparatus is completed with a magnetron 1 and a water cooling system, which consists of tanks 16 and a water pump 15, which causes the circulation of water in a closed system. Therefore, in this installation, the thermal energy for drying wool is not transmitted by heated air, i.e. convection, but by means of an electric alternating field with a frequency of 1450 MHz, which creates a magnetron 1 with a power of 25 kW.

The technological process of wool purification at existing national enterprises is multi-stage, energy-intensive and time-consuming. The technological sequence of wool processing consists of a number of main and auxiliary production stages, which are listed below:

1. Quantitative and qualitative acceptance of wool.
2. Sorting wool by type.
3. Sorting wool in unwashed form by varieties.
4. Supply of wool to washing machines.
5. Adding feeder-scarifier to the wool.
6. Sink in five baths: the first bath (soda solution for soaking wool); second and third baths (soap and soda solution); fourth bath (soap solution); fifth bath (rinsing).
7. Squeezing wool.
8. Drying wool in the dryer.
9. Transportation through ventilation pipes for packaging.
10. Determination of qualitative indicators of residual moisture.
11. Quality control.
12. Transportation of finished products to the warehouse.

3. Results
It is for the optimization of stages № 7 and 8 (combination of the process of extraction and drying) the modernization of this installation has been performed. As for all other technological stages, they remain unchanged and therefore are not described in detail in this publication. Another feature of the new installation is that the perforated drum 3 must be made not of metal but of polymer, which is able to freely transmit electromagnetic oscillations, creating a microwave generator (magnetron) 1 and a waveguide 2. Therefore, after the completion of technological stages (6, the perforated drum of the unit should switch to centrifugation mode to remove moisture from the washed wool forcibly. After that, the microwave generator is turned on to create a high-frequency electromagnetic field, which will generate heat, that is necessary for complete drying of the yarn. Another feature of the new installation is the need to create a protective screen against the possible harmful effects of microwave energy on others.

4. Conclusion
Modern innovative technologies are increasingly penetrating into various areas of production. At the same time, their practical application can sometimes be found in completely unexpected industries: chemical industry, agriculture, food industry, and so on. A clear example of this is the installation project, which is discussed in this article. This installation should allow processing wool yarn in the range of 1250-1500 kg / hour, which exceeds the productivity of existing industrial installations. At the same time, the total time for the entire technological cycle should be reduced, while creating the prerequisites for increasing labor productivity and reducing the cost of wool processing.

References
[1] Vovnyana promislovist Ukraina http://ukrkniga.org.ua/ukrkniga-text/842/17
[2] Orlov V V and Alferov A S 2006 Prospects for the use of microwave processing of liquid food products MIUITMO Series "Processes and Apparatus for Food Production" no 2 pp 53-57
[3] Vlasov V V 2011 Physics and technology of ultra-high frequency range of electromagnetic oscillations (Kharkiv: KhNU named after V.N. Karazin) p 169
[4] Sobenin N P and Milovanov O S 2007 Microwave Technique (M: Energoatomizdat) p 543
[5] Danilin A A 2008 *Measurements in microwave technology: a textbook for universities* (M: Radiotechnika) p 184

[6] Neganov V A, Klyuev D S and Tabakov D P 2020 *Microwave devices and antennas: Design, constructive implementation, examples of the use of microwave devices* (Moscow: Izd. Stereotype) p 608

[7] Sukhodolets L G 2014 *Powerful vacuum microwave devices. Textbook for the study of EEC microwave* (Moscow: Ikar) p 72

[8] Molodtsova M A and Sevastyanova Y V 2017 Opportunities and prospects for the use of microwave radiation in industry Lesn zhurn no 2 pp 82–83

[9] Baranov A V and Kozikov A L 2018 Complementary techniques for designing three-point microwave autogenerators *Electronic engineering. Series 1: Microwave equipment* no 3 pp 75–82

[10] Imenokhoyev I, Matthes A and Walter G 2011 Numerical 3D-FEM-Simulation made by COMSOL Multiphysics of a Microwave Assisted Cleaning System for a Diesel Sooty Particle Filter and its Experimental Validation In *Proceeding Book: International COMSOL Multiphysics Conference Ludwigsburg* 2011 October 26–28

[11] Yan S J, Zhen L, Xu C Y, Jiang J T and Shao W Z 2010 Microwave absorption properties of FeNi3 submicrometre spheres and SiO2 FeNi3 core-shell structures *Journal of Physics D: Applied Physics* vol 43 no 24 p 245

[12] Acher O and Dubourg S 2008 Generalization of Sneck's law to ferromagnetic film sand composites *Physical review B* 77, 104440

[13] Liu L, Duan Y, Ma L, Liu S and Yu Z 2010 Microwave absorption properties of a wave-absorbing coating employing carbonyl-iron powder and carbon black *Applied Surface Science* vol 257 no 3 pp. 842-846

[14] Vodotovka V I, Dudikevich V B and Zhelkobaev Zh E 2016 Vimiryuvalna and numerical technology in technological processes (VOTTP-16-2016) *Materials of the XVth international: science and technology conference Odessa 2016* ed Vodotovka V I, Dudikevich V B and Zhelkobaev Zh E 2016 (Odessa: KhNU) p 221

[15] Privala V O and Michko A A 2009 Development of a methodology for providing the necessary porosity to various plastics materials *Bulletin of KhNU* no 3 pp 109-111

[16] Skripnik V M, Yakovlev V V, Komarov V V and Privala V O 1998 Razrakhunok structure of the field in the area of interaction with textile material in the middle of the needle-water element *Vimiryuvalna and numerical technology in technological processes* no 1 pp 147-151

[17] Privala V O and Zazornov O S 2015 Theoretical obruntuvannya rozrobka microchilles technology of cleaning out yarn in the drainage of textile enterprises *Visnyk KhNU* no 6 pp 115-119

[18] Ushakova N F, Kopylova T S, Kasatkina V V, Kudryashova A G 2013 Experience of using microwave energy in food production *Food industry* no 10 pp 30-32