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Preface

We would like to present, with great pleasure, the inaugural volume-5, Issue-11, November 2019, of a scholarly journal, *International Journal of Engineering Research & Science*. This journal is part of the AD Publications series *in the field of Engineering, Mathematics, Physics, Chemistry and science Research Development*, and is devoted to the gamut of Engineering and Science issues, from theoretical aspects to application-dependent studies and the validation of emerging technologies.

This journal was envisioned and founded to represent the growing needs of Engineering and Science as an emerging and increasingly vital field, now widely recognized as an integral part of scientific and technical investigations. Its mission is to become a voice of the Engineering and Science community, addressing researchers and practitioners in below areas

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Each article in this issue provides an example of a concrete industrial application or a case study of the presented methodology to amplify the impact of the contribution. We are very thankful to everybody within that community who supported the idea of creating a new Research with IJOER. We are certain that this issue will be followed by many others, reporting new developments in the Engineering and Science field. This issue would not have been possible without the great support of the Reviewer, Editorial Board members and also with our Advisory Board Members, and we would like to express our sincere thanks to all of them. We would also like to express our gratitude to the editorial staff of AD Publications, who supported us at every stage of the project. It is our hope that this fine collection of articles will be a valuable resource for *IJOER* readers and will stimulate further research into the vibrant area of Engineering and Science Research.

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Material Recovery of the Glassy Slag Produced from Asbestos Containing Waste

Marián Lázár[1], Tomáš Brestovič[2], Natália Jasminská[3], RomanaDobáková[4], Ľubica Bednárová[5]

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Abstract*—The present article deals with the option of high-temperature processing of asbestos-cement roof tiles in a plasma reactor. It describes the process of melting this type of waste in a plasma reactor which is aimed at obtaining the resulting product in the form of vitreous slag of the inert nature. The article also briefly comments on the potential recovery of the formed slag which may be used as the secondary material for further manufacture processes.*

Keywords*—*asbestos, glassy slag, ceramic foam.

I. INTRODUCTION

Converting materials into material values and increasing their life standard are associated with many problems which affect, to various extents, the natural environment and consequently also humans. One of the apparent human interventions in the natural environment is the production of waste and the persisting existence thereof in the environment. It may be assumed that the amount of waste will grow and this will also increase the number of problems regarding the waste disposal. This means that most waste types, categorised depending on their characteristics and environmental hazard, will have to be recycled in future, not only because of the potential to recover certain desired components (e.g., metals), or because of their energy potential, but mainly because of the environmental protection [3].

A special waste category is the hazardous waste which includes the asbestos-containing waste. The disposal of this kind of waste must be paid special attention as this waste possesses hazardous properties.

At present, the disposal of asbestos-containing waste is divided into seven waste disposal categories. In terms of the environmental protection, important disposal methods are the methods categorised under numbers 01 to 03, i.e., material recovery, energy recovery, and other. The percentage of the recovered hazardous waste is still insignificant due to its hazardous properties.

The removal of asbestos materials from buildings is subjected to the permit issued by the Public Health Authority of the Slovak Republic pursuant to Act No 355/2007 Coll. on the Protection, Support and Development of Public Health. The yearly production of asbestos-containing waste in the period from 2010 to 2015 is shown in Fig. 1 [1].

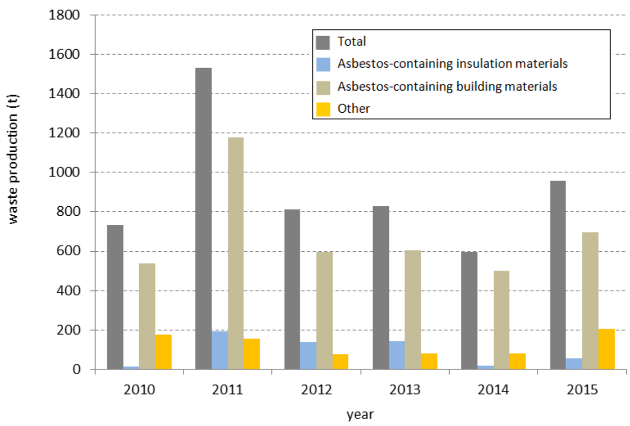


FIGURE 1: Production of asbestos-containing waste in years 2010 – 2015

The 17 06 05 waste category represents an important item in the total amount of the produced asbestos-containing waste. The highest amount of this type of waste, 1,179.65 tons, was produced in 2011 and the lowest amount in 2014 in the quantity of 498.79 tons. These quantities represented 77 % of the total amount of produced asbestos-containing waste in 2011 and approximately 84 % in 2014. The proportion thereof in years 2010 to 2015 ranged from 73 % to 84 %. The proportion of asbestos-containing waste in the total production of hazardous waste in the SR is depicted in Fig. 2 [1].

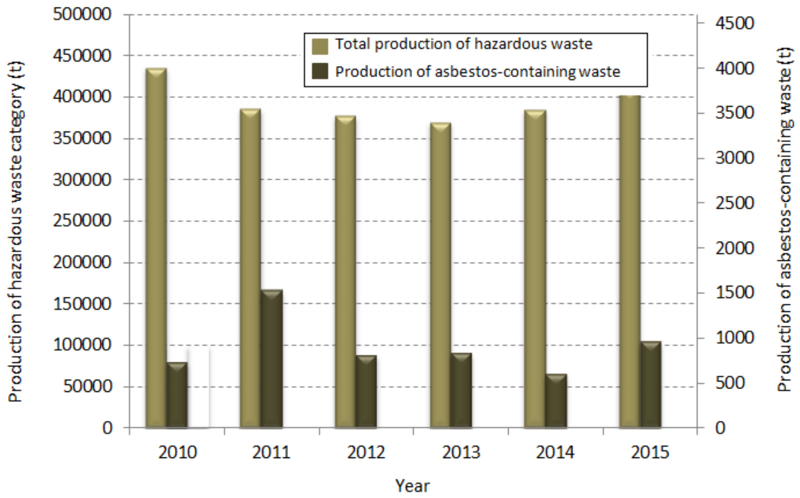


FIGURE 2: Proportion of asbestos-containing waste in the total production of hazardous waste in the SR

Asbestos-containing materials belong to the category of waste typically stored at landfills with controlled regimes. This disposal method represents only a temporary solution, even regarding the potential further use of the material potential inherent in such waste.

In respect of the above mentioned facts, new methods of disposal of asbestos-containing products are being searched. Newly proposed processing methods are expected to meet the requirement for the recovery of even those products that are the results of the waste reprocessing.

II. HIGH-TEMPERATURE PROCESSING OF ASBESTOS-CEMENT ROOF TILES

Probably an efficient method how to dispose of asbestos fibres contained in the waste of various categories is to reprocess it through a thermal process [2, 3]. The effects of high temperatures and chemical reactions running during the process cause that asbestos fibres contained in the waste are subjected to various stages of transformation and phase transitions.

Asbestos waste originating from a disassembled roof of a family house was processed in a plasma reactor at the temperature of 1,470 °C. Free chrysotile fibres on the surface of the roof tiles are depicted in the images made by the Scanning Electron Microscope – SEM (Fig. 3). The images show poorly bound fibres of chrysotile on the surface of the tiles and at the place where the tile was broken.

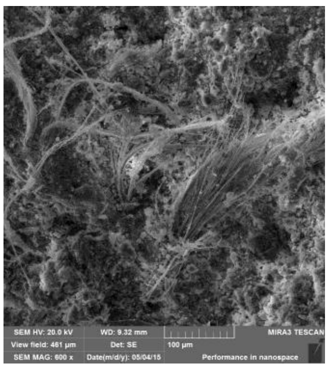


FIGURE 3: Detail of the surface of the used ACRT prior to the experiment waste in the SR

As the melting point of asbestos-cement roof tiles as such is high, it may be reduced by adding an acidic flux. In this particular case, such flux was the fly ash from fluidised-bed combustion chambers. The process of melting the asbestos-cement roof tiles together with the fly ash may also be applied to recover the energy potential of the fly ash. The unburned material contained in the fly ash, weighing > 10 wt.%, will be used in the plasma melting as the reducing agent.

Melting the mixture of ACRTs and fly ash from fluidised-bed boilers, mixed in the 1 : 1 ratio, was carried out in a plasma reactor in reducing conditions. More detailed information on the boundary conditions and on the course of the melting process are provided in [2, 4].

III. DISCUSSION

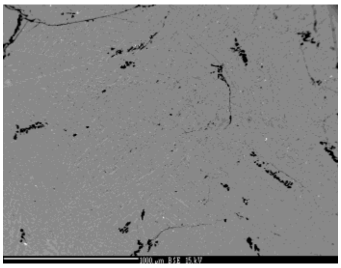
The two main resulting products of the high-temperature melting of the mixture of ACRTs and fly ash from fluidised-bed boilers with a high content of unburned material were the synthesis gas and the vitrified slag [2, 5]. The proportions of the light ash and of the reduced metals were both low and they were untraceable during the laboratory experiment because the slag became mixed with microscopic inclusions of the reduced metals which could not sediment as a separate metal phase during the melting process because their amount and volume were low.

The energy of the produced synthesis gas, when cleaned, may be recovered for example in the charge drying process or for the production of electric energy in a cogeneration unit in form of auxiliary fuel [6]. The utilisation of the synthesis gas energy is conditioned primarily by the gas being cleaned of undesired components, such as sulphur dioxide.

Slag, as the main product of the high-temperature melting of fly ash and asbestos-cement products, represents the polycomponent system comprising metal oxides and non-metallic components which combine and form chemical compounds and solutions. In addition to the above mentioned components, slag may contain, depending on the course of waste melting and tapping process, also sulphides of metals, gaseous components, droplets of the reduced metal component, etc.

In the first stage of the experiment evaluation, the attention was paid mainly to the produced slag. Its density was approximately 2,850 $kg \cdot m^{-3}$. The waste weight reduction represented 21.5 wt.% and the volume reduction was as much as 79 vol.%. The analyses of the water extract and ecotoxicity confirmed that the product was environmentally acceptable [2, 4].

For melting the mixture of asbestos-cement roof tiles and fly ash from fluidised-bed boilers at the average temperature of 1,470 °C it is also assumed that despite the high melting point of pure chrysotile fibres (1,521 °C) [2] they would decompose as a result of chemical reactions running in the melt. The decomposition process is also significantly affected by the temperature at the site where the arch discharge is maintained; this temperature is significantly higher than the temperature of the melt on the bottom of the reactor. The absence of chrysotile fibres in the slag was confirmed by the finding of ground particles of the slag on the electron micro analyser which did not confirm the presence of chrysotile fibres in vitrified slag (Fig. 4).



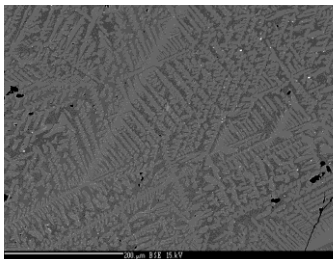
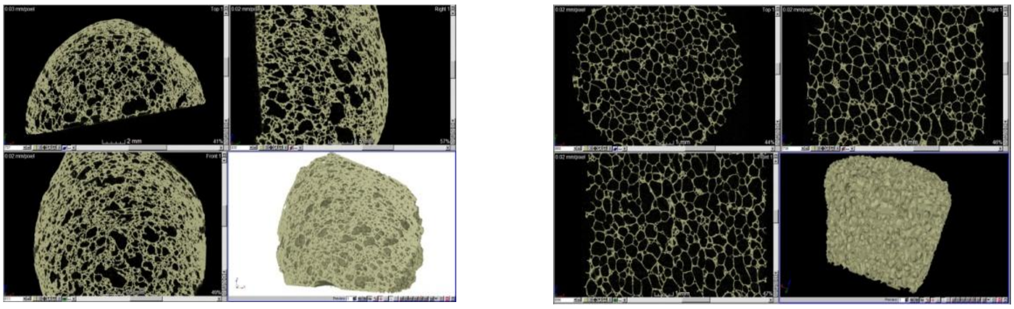


FIGURE 4: Images of the vitrified slag made by the electron micro analyser

The analysis of mechanical properties of the slag confirmed that they are similar to those of silica glass. The dominant phase in the collected slag specimens was gehlenite (DSC analysis).

Considering the technological procedure of waste processing (high-temperature melting), it is possible to discuss the potential of using the liquid slag in the production of mineral wool. The chemical composition of the slag that would be appropriate for the production of foam glass may be achieved by minor modification of its composition. Another method how to recover the vitrified slag produced in the process of thermal processing of fly ash and asbestos-cement roof tiles is the production of porous building materials with low thermal conductivity coefficient, such as foam glass (glass-ceramic foam). The specimen of the glass-ceramic foam was obtained by shock-heating the mixture of the ground melted slag and 1 wt.% of $CaSO_4$ at the temperature of 1,030 °C. The sizes and morphology of pores in the structure of the obtained material (Fig. 5a) are considerably different from the porosity of the commercial foam glass (Fig. 5b). Unlike the commercial product manufactured from the recycled glass applying the well-established technology, the walls of pores in the prepared specimen of the vitrified slag were unevenly thick and the size-based distribution of pores and their shapes changed significantly towards the edge of the specimen. These structural differences may be caused by insufficient homogenisation of the input mixture and by thermal processing. More detailed information on the research on the production of glass-ceramic foam is provided in [2, 4].



a) glass-ceramic foam **b) commercial foam glass**

FIGURE 5: Structure of pores

IV. CONCLUSION

The comprehensive evaluation of the waste management level in the Slovak Republic indicates that the waste disposal is the segment that has been neglected for a long period of time, as to the technology level and the development the market relationships, and nowadays this segment experiences dynamic development. Novel legislation and the incorporation of the European regulations into the laws of the Slovak Republic created the fundamental regulatory and control conditions for further development of this segment.

In terms of the environmental protection, the purpose of the manufacturing segment is to produce products which may be used as the sources of secondary materials or energy after being decommissioned. Achieving this goal, especially in the segment of manufacture and processing of the products possessing hazardous properties, is often difficult. A potential solution for the recovery of waste containing asbestos fibres is to remelt it applying the high-temperature melting process. In addition to obtaining the inert slag, the resulting slag may be used as the secondary material after slightly modifying its composition. The production of ceramic material will result in the product which may be regarded as 100% recyclable after its service life elapses. In addition to this factor, another advantage is that even the hazardous waste, i.e., asbestos-cement roof tiles, will be recovered and disposed of.

ACKNOWLEDGEMENTS

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The Analysis of Selected Characteristics of Secondary Heat Networks

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Abstract— *A heat network is a pipeline system through which the heat-transferring medium is conveyed, in the required amount and condition, from a source to a heating appliance. The heat loss depends on a number of parameters, such as the temperature of the medium, temperature of the environment where the analysed heat network is located, and the thickness and quality of the installed insulation. The present article deals with the efficiency of the heat distribution system relative to the temperature in the supply pipeline and in the return pipeline in overhead and direct-buried distribution systems, as well as the effect of the heat loss on such efficiency.*

Keywords—heat network, efficiency, heat loss, ambient temperature.

I. INTRODUCTION

When conveying heat trough heat networks, it is not possible to exclude heat losses that significantly affect the operation of a particular heat network and the overall cost-efficiency of the heat supply. Therefore, they must be paid more attention and it is necessary to understand the physics behind the heat loss formation in order to subsequently minimise it to the optimal level. It is also important to express the heat loss as the percentage of the distributed heat. The efficiency of the distribution system, with regard to the intact installed pipeline insulation, may acquire various values.

II. THE EFFECT OF THE TEMPERATURE ON THE HEAT NETWORK EFFICIENCY

The efficiency of a distribution system is determined by the ratio of the output (heat flux received from the system) to the input (heat flux supplied to the system).

The heat network efficiency may be mathematically expressed as follows:

- efficiency of the supply pipeline:

$$\eta_{\mathrm{SP}} = \frac{Q_{\mathrm{n}} - Q_{\mathrm{l}}}{Q_{\mathrm{n}}} \cdot 100 \ (\%) \tag{1}$$

Where Q_{n} is the heat network input (W) and Q_{l} is the heat network loss (W);

- efficiency of the return pipeline:

$$\eta_{\mathrm{RP}} = \frac{Q_{\mathrm{n}} - Q_{\mathrm{l}}}{Q_{\mathrm{n}}} \cdot 100 \ (\%) \tag{2}$$

Where Q_{n} is heat network input (W) and Q_{l} is the heat network loss (W).

Therefore, the total efficiency of the heat network may be expressed as follows:

$$\eta_{\mathrm{tot}} = \eta_{\mathrm{SP}} \cdot \eta_{\mathrm{RP}} \ (\%) \tag{3}$$

The distribution system efficiency only serves as an indicator for a particular heat network of certain length and may acquire different values, depending on the quantity of the supplied thermal capacity (MW) or the heat supplied (GJ).

The correlation between the heat distribution system efficiency and the temperatures in the supply and return pipelines is shown in Fig. 1 for the overhead system and in Fig. 2 for the direct-buried system. These curves apply to a theoretical heat network with the PIPO ALS insulation, at the design external temperature of -13 °C.

The diagrams indicate that in order to increase the efficiency of the heat network, the temperature in the supply pipeline must be reduced and the medium in the heating appliance must be cooled to the lowest possible temperature. Cooling the medium is limited by the used type of the heat exchanger. In practice, however, the required degree of cooling is never reached.

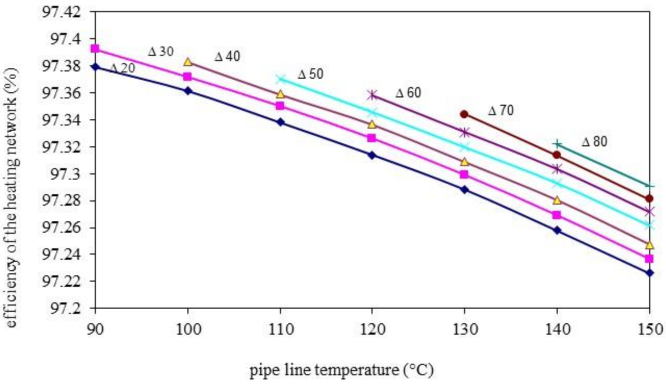

FIGURE 1 Relationship between the heat network efficiency and the temperature in the overhead supply pipeline

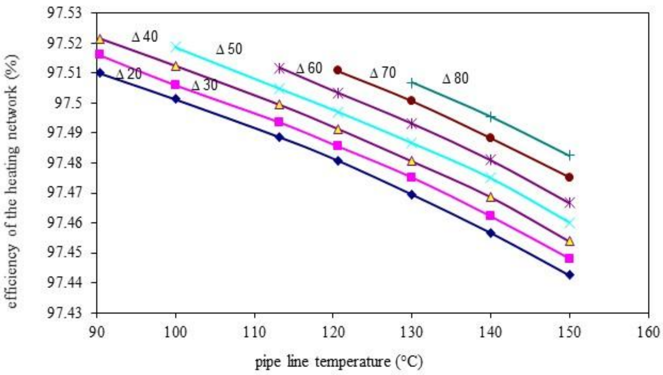

FIGURE 2 Relationship between the heat network efficiency and the temperature in the direct-buried supply pipeline

III. THE EFFECT OF THE TEMPERATURE ON THE SPECIFIC HEAT LOSS OF THE HEAT NETWORK

The heat loss depends primarily on the temperature of the conveyed medium, heat network type and length, and the thickness and quality of the used thermal insulation.

The specific heat loss per1 m of the overhead pipeline (OP) was calculated using the formula:

$$q_{l,\mathrm{OP}} = q_{l,\mathrm{OP},1} + q_{l,\mathrm{OP},2} = \frac{t_{\mathrm{i},1} - t_{\mathrm{a}}}{R_{l,1}} + \frac{t_{\mathrm{i},2} - t_{\mathrm{a}}}{R_{l,2}} \quad (\mathrm{W \cdot m^{-1}}) \tag{4}$$

Where $q_{l,\mathrm{OP},1}$ is the specific heat loss for the supply pipeline ($\mathrm{W \cdot m^{-1}}$); $q_{l,\mathrm{OP},2}$ is the specific heat loss for the return pipeline ($\mathrm{W \cdot m^{-1}}$); $t_{i,1}$ is the temperature of water in the supply pipeline(K); $t_{i,2}$ is the temperature of water in the return pipeline (K), t_{a} is the ambient temperature (K); $R_{l,1}$ is the linear specific thermal resistance of the return pipeline ($\mathrm{m \cdot K \cdot W^{-1}}$); and $R_{l,2}$ is the linear specific thermal resistance of the return pipeline ($\mathrm{m \cdot K \cdot W^{-1}}$).

The linear specific thermal resistance during the heat transfer from the heat-transferring medium to the pipeline wall and the linear specific thermal resistance during the heat transfer through the wall of the steel pipe did not exceed 0.02 % of the total linear specific thermal resistance; hence, it may be ignored in the calculation and the formula to be used is as follows:

$$R_{l,1(2)} = \frac{1}{2\pi \cdot \lambda_{\mathrm{in}}} \cdot \ln \frac{d_3}{d_2} + \frac{1}{\pi \cdot d_3 \cdot a_{\mathrm{c},2}} \quad (\mathrm{m \cdot K \cdot W^{-1}}) \tag{5}$$

Where d_2 is the external diameter of the heat-transfer pipe (m); λ_{in} is the thermal conductivity of the insulation ($\mathrm{W \cdot m^{-1} \cdot K^{-1}}$); $d_3$is the external diameter of the thermally insulated pipeline (m); and $\alpha_{\mathrm{c},2}$ is the coefficient of heat transfer from the surface of the insulated pipeline to the external environment ($\mathrm{W \cdot m^{-2} \cdot K^{-1}}$).

The specific heat loss per 1 m of the pipeline in the direct-buried pipeline (DBP) was calculated using the following formula:

$$q_{l,\mathrm{DBP}} = q_{l,\mathrm{DBP},1} + q_{l,\mathrm{DBP},2} \quad (\mathrm{W \cdot m^{-1}}) \tag{6}$$

or

$$q_{l,\mathrm{DBP}} = \frac{R_{l,2} \cdot (t_{\mathrm{i},1} - t_{\mathrm{a}}) - R_{\mathrm{z}} \cdot (t_{\mathrm{i},2} - t_{\mathrm{a}})}{R_l} + \frac{R_{l,1} \cdot (t_{\mathrm{i},2} - t_{\mathrm{a}}) - R_{\mathrm{z}} \cdot (t_{\mathrm{i},1} - t_{\mathrm{a}})}{R_l} \quad (\mathrm{W \cdot m^{-1}}) \tag{7}$$

where $q_{l,\mathrm{DBP},1}$ is the specific heat loss for the supply pipeline($\mathrm{W \cdot m^{-1}}$) and $q_{l,\mathrm{DBP},2}$ is the specific heat loss for the return pipeline ($\mathrm{W \cdot m^{-1}}$).

Again, for this type of the pipeline, the calculation of the total linear specific thermal resistance R_l was made using only the formula for the linear specific thermal resistance of the insulation $R_{l,\mathrm{in}}$ and of the soil R_s.

The linear thermal resistance $R_{l,1}$ of the supply pipeline was calculated as the sum of the resistance of the insulation and the resistance of the soil, using the following formula:

$$R_{l,1} = \frac{1}{2\cdot\pi\cdot\lambda_{\mathrm{in},1}}\cdot\ln\frac{d_3}{d_2} + \frac{1}{2\cdot\pi\cdot\lambda_\mathrm{s}}\cdot\ln\frac{4\cdot D_\mathrm{r}}{d_3} \;\; (\mathrm{m\cdot K\cdot W^{-1}}) \tag{8}$$

The linear thermal resistance $R_{l,2}$of the return pipeline was calculated as the sum of the resistance of the insulation and the resistance of the soil, using the following formula:

$$R_{l,2} = \frac{1}{2\cdot\pi\cdot\lambda_{\mathrm{in},2}}\cdot\ln\frac{d_3}{d_2} + \frac{1}{2\cdot\pi\cdot\lambda_\mathrm{s}}\cdot\ln\frac{4\cdot D_\mathrm{r}}{d_3} \;\; (\mathrm{m\cdot K\cdot W^{-1}}) \tag{9}$$

The resistance of the soil located between the two pipelines (degree of mutual effects) was calculated using the following formula:

$$R_\mathrm{s} \frac{1}{2\cdot\pi\cdot\lambda_\mathrm{s}}\cdot\ln\sqrt{\left(\frac{2.D_\mathrm{r}}{C}\right)^2+1} \; (\mathrm{m\cdot K\cdot W^{-1}}) \tag{10}$$

And the calculation of the reduced depth of the pipeline D_r was made using the following formula:

$$D_\mathrm{r} = D_1 + \frac{\lambda_\mathrm{s}}{\alpha_0} \;\; (\mathrm{m}) \tag{11}$$

whereD_1 (D_2) is the depth of the pipeline under the ground (supply, return) (m);$\lambda_\mathrm{s}$is the coefficient of thermal conductivity of the soil ($\mathrm{W\cdot m^{-1}\cdot K^{-1}}$);$\alpha_0$ is the coefficient of heat transfer from the surface of the ground to the external environment ($\mathrm{W\cdot m^{-2}\cdot K^{-1}}$); and C is the distance between the axes of the pipelines (m).

The total thermal resistance was calculated using the following formula:

$$R_l = R_{l,1}\cdot R_{l,2} - R_z^{\,2} \quad (\mathrm{m\cdot K\cdot W^{-1}}) \tag{12}$$

Figures 3 and 4 show the relationships between the specific heat loss and the temperatures in the overhead and direct-buried supply pipelines. The graphs apply to the theoretical heat network with the PIPO ALS insulation, for the external design temperature of -13 °C.

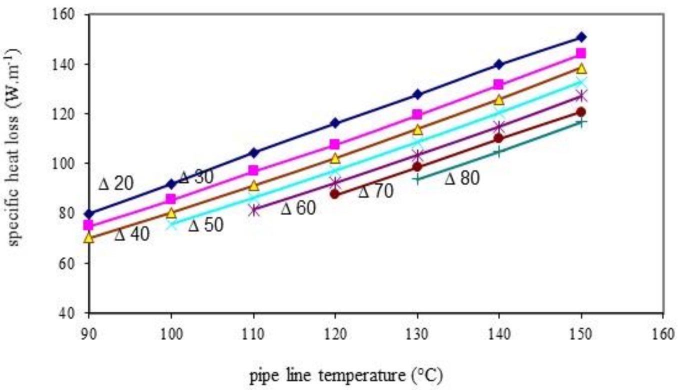

FIGURE 3 Relationship between the specific heat loss and the temperature in the overhead supply pipeline

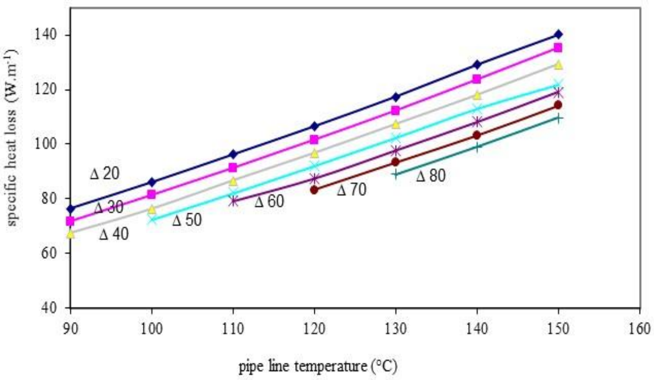

FIGURE 4: Relationship between the specific heat loss and the temperature in the direct-buried supply pipeline

In order to reduce the heat loss, it is necessary, similarly to the case of increasing the efficiency of the heat network, to reduce the temperature in the supply pipeline and ensure that the heat-transferring medium in the appliance is cooled to the lowest possible temperature.

Another important parameter affecting the quantity of the heat loss is the thermal insulation; it is therefore necessary to pay adequate attention to the selection thereof.

Fig. 5 shows the relationship between the specific heat loss and the pipeline DN for the overhead as well as direct-buried pipelines. The calculation of the specific heat loss were carried out assuming that the ambient temperature was -13 °C, the temperature gradient for the supply and return pipelines was Δ 20, and the used insulation was PIPO ALS. This insulation is made of mineral wool and organic resin. It has a shape of a hollow cylinder divided along its length, made of one or more segments, with the lock preventing from the heat loss through the longitudinal joint.

The PIPO ALS product comprises the aluminium foil as the surface finishing, reinforced with the fibre glass grating. Such thermal insulation may be used at temperatures ranging from -15 to +250 °C.

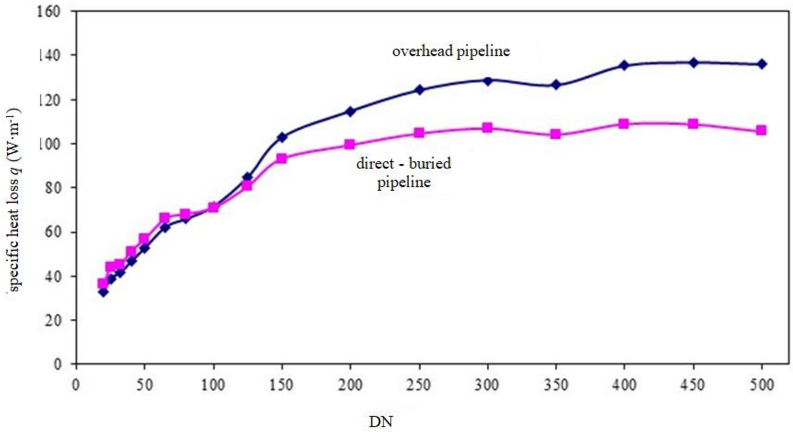

FIGURE 5: Relationship between the specific heat loss and the pipeline DN for overhead and direct-buried pipelines

Fig. 6 depicts the relationship between the efficiency of the supply and return pipelines and the specific thermal conductivity. Thermal conductivity belongs to the key parameters of insulation materials in terms of thermal protection. It represents the level of the heat transfer through the insulation.

The graph applies to the design external temperature of -13 °C and the temperature gradient Δ 40 for the supply and return overhead pipelines.

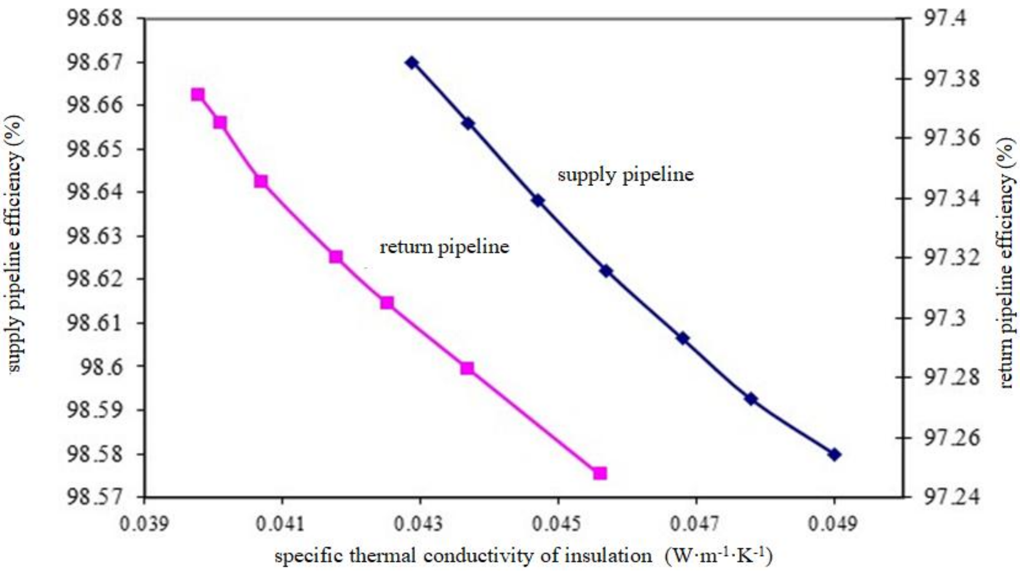

FIGURE 6: indicates that when identical insulation types are used, the heat loss is lower in the direct-buried pipeline

The graph clearly indicates that the higher the specific thermal conductivity of the insulation, the lower the efficiency of the heat network and the higher the heat loss.

IV. CONCLUSION

The heat loss of networks cannot be determined in general, only specifically for a particular network, because it largely depends on the network size and capacity. If the capacity of a particular heat network is not sufficiently used, the specific heat loss is high and such operation is not cost-efficient.

The graphs presented above indicate that the process of designing the heat distribution pipelines should be performed while considering the optimal parameters in order to achieve the minimum heat loss.

ACKNOWLEDGEMENTS

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The Prototype of Metal Hydride Hydrogen Compressor with Heat Pump

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Abstract— *The metal hydride materials are characterized by a high pressure gradient as a function of temperature, which has been used in the construction of a compressor that compresses hydrogen by a chemical-thermal cycle. The present paper describes a prototype of a metal hydride compressor working using a heat pump that provides thermal management between metal hydride containers. The principle of the compressor is to use a suitable metal alloy that can absorb and desorbed hydrogen into its intermetallic structure. By heating the alloy, there is a significant increase in pressure, which makes it possible to compress hydrogen without directly contacting the moving parts, thereby increasing process safety.*

Keywords— hydrogen, metal hydride alloy, metal hydride compressor, heat pump.

I. INTRODUCTION

The equipment is the prototype of compressor which it uses for hydrogen compression the chemical-thermal cycles of absorption and desorption of hydrogen into the intermetallic structure of metal. The used conception of hydrogen compressor rests in use, suitable alloy of metal which allows the hydrogen absorption into its structure at low temperature and pressure. Significant pressure increase occurs after heating of alloy what it allows compression of hydrogen without its direct contact with moving parts what it increase the safety of the process. Hydrogen compressor consists of a pair of tandem-connected metal hydride (MH) tanks with heat exchanger. The tanks are heating and cooling alternately while at hydrogen absorption in one of the tank occurs for hydrogen desorption in the second tank. The transport of heat for heating and cooling is secure by heat pump thanks which it occurs to considerable saving of electric energy. Control programme is launched in operating system Raspbian on Raspberry Pi.

II. DETAIL DESCRIBE OF EQUIPMENT

The basic principle of hydrogen compression is its absorption into a suitable metal alloy. Absorption takes place progress at reduced temperature wherein heat is taken from the storage tank by a heat pump. After absorption, it necessary to the alloy heat up to higher temperature resulting in a significant increase in pressure. Subsequently, hydrogen desorption occurs at elevated temperature and greatly increased pressure. After hydrogen desorption at higher pressure is necessary the alloy to cool again and lower the temperature to start value. In order to maintain the continuous operation of the compressor, it has been proposed to tandem the connection of two MH storage tanks between which heats is transported using a heat pump. At the time of absorption in the MH1 tank, hydrogen is desorbed from the MH2 tank. However, when the operating temperature change, neither of the tanks absorbs hydrogen and therefore the compressor is equipped with an intermediate MH tank. This tank has own temperature management which is based on a pair of Peltier cells. Using them it can be used to change the temperature within the required range. The compressor achieves a compression ratio in one degree. A middle value COP of heat pump is 3 which means that for compression is used 1/3 of electrical energy compared to with produced heat energy. This results in a reduction in the electricity consumption of hydrogen compression. The compressor works in one MH tank during one cycle with 0.3 m3 of hydrogen. In Fig. 1 is a view of the finalization of the equipment in the premises of the Faculty of Mechanical Engineering, TU in Košice [1-5].

FIGURE 1: View of the final construction of the metal hydride compressor

Electrically operated hydrogen valves, safety valves and pressure sensors with analog output signal are part of connection of hydrogen circuit. In Fig. 2 is a view of an embodiment of a hydrogen circuit.

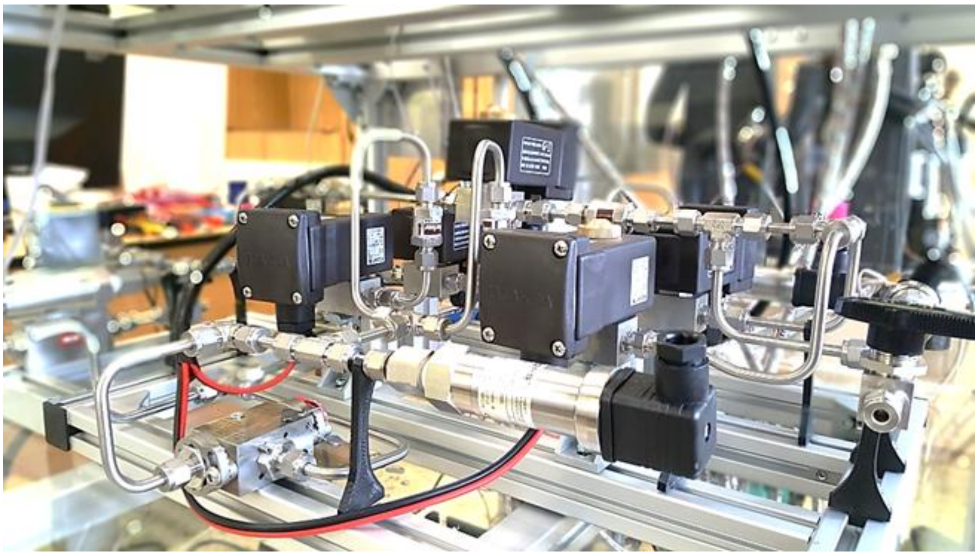

FIGURE 2: Photo of the hydrogen circuit

The role of the hydrogen circuit is to distribute hydrogen and measure its parameters during compressor operation. In Fig. 3 is a view of a tandem pair of MH tanks and intermediate tank with a temperature management.

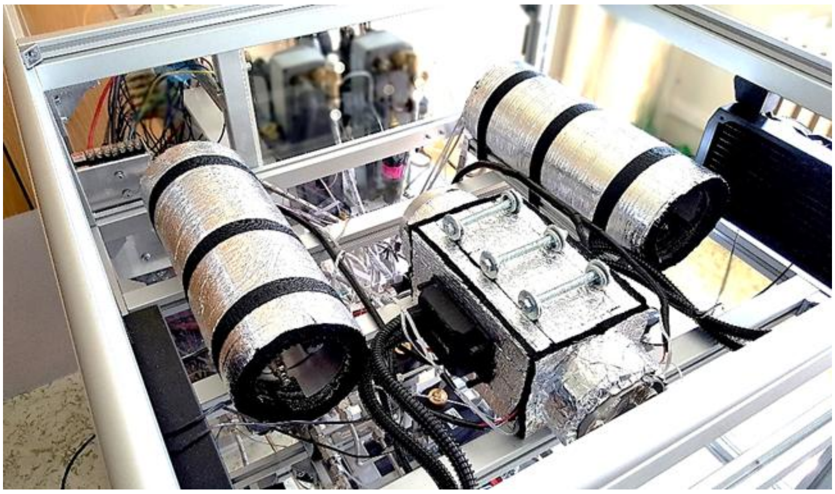

FIGURE 3: View of a tandem pair of MH tanks and an intermediate tank with temperature management

Using the electronically controlled three-way zone valves of the water circuit, it is possible to change the flow direction of the heat transfer medium from the heat pump condenser to the MH1 or MH2. This allows the temperature of both tanks to be cyclically changed. An external air cooler is situated on the condenser side to provide excess heat dissipation that results from greater heat output compared to with cooling.

The heat pump was made-to-measure in cooperation with Tatramat - water heaters, s.r.o. The view of its construction is shown in Fig. 4. In Fig. 5 is a view of a water circuit with valves, pumps and flow meters.

FIGURE 4: Modified heat pumps for MH compressor needs

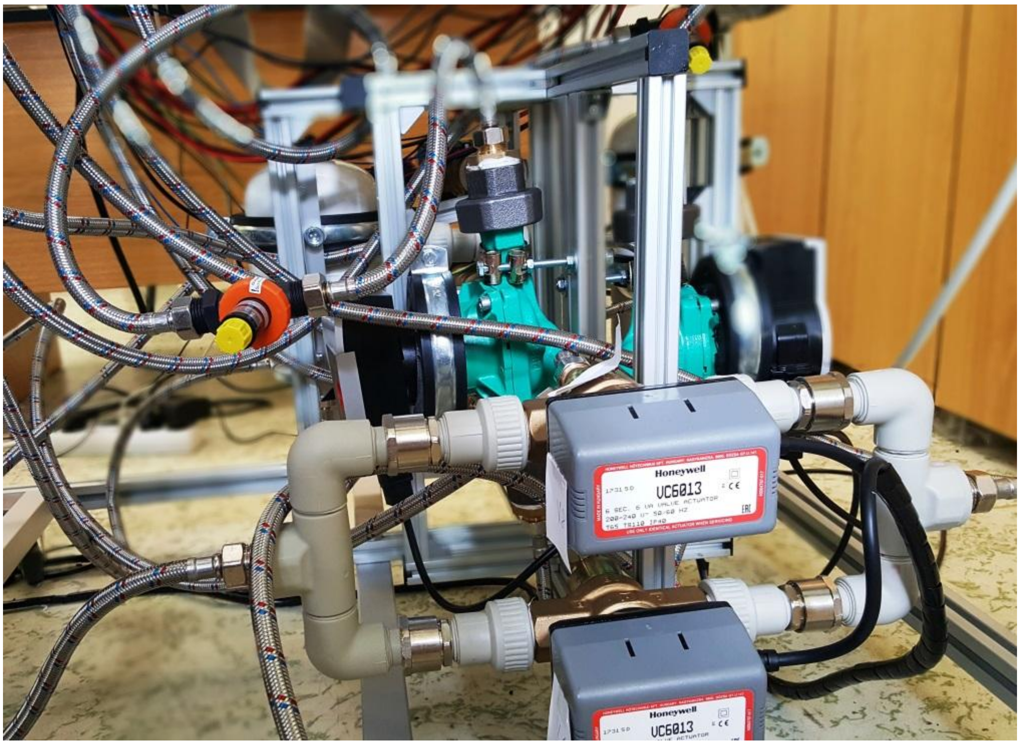

FIGURE 5: View of the water circuit of the MH compressor

The prototype MH compressor with heat pump is created in an autonomous version of the control. For this purpose, a mini-computer Raspberry Pi with additional cards is implemented (1-wire; A/D converter -16 inputs; I/O ports – 32x). The operating system is distributed by the Linux Raspbian. The control software is written in C ++ in the Qt Creator environment. A view of the basic window of the control program is shown in FIG. 9. In FIG. 10 is one of the side windows with a view of the measured parameters of the MH2 tank. The compressor is equipped with touch display for control and visual of measured data. One of the benefits to using minicomputers is that the source code of the controlled program is possible change and compile directly in the compressor and in a real short time. Therefore, measurement and control activities are possible to optimize.

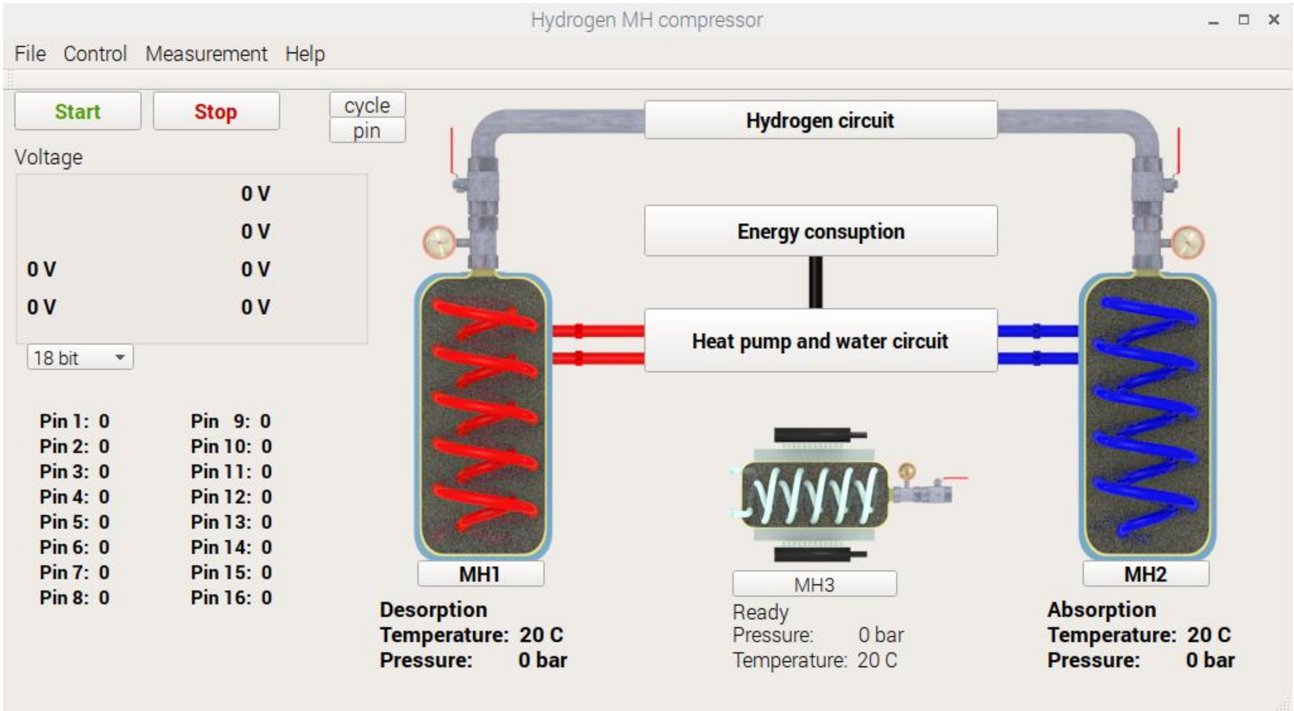

FIGURE 6: View of basic window of control program

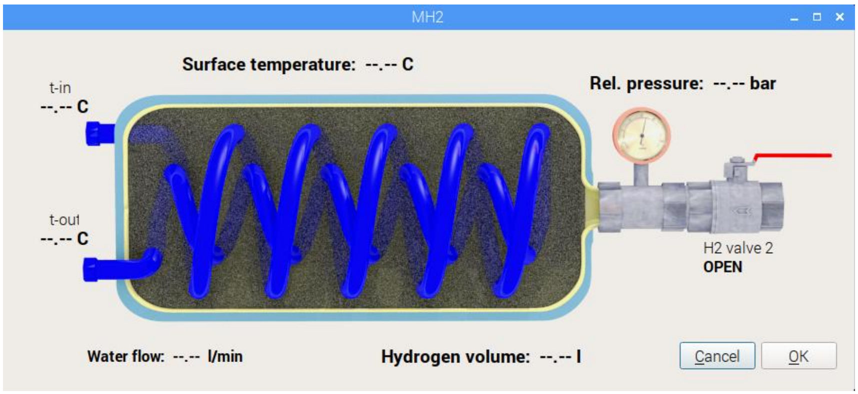

FIGURE 7: Program window monitoring the operation of the MH2 tank

Prototype of compressor was created for next research in area of MH compressors. Therefore, the design solutions as measurement stand. By design is compiled from independent modules for possible fast exchange during optimization of equipment. This allows the effective exchanges and design optimization. In total, 36 temperature sensors are connected to the control PC to monitor the temperature fields of the individual components. The measuring system also includes 7 pressure sensors (5 for H2, 2 for heat pump coolant) and 4 flow meters (1 mass flow meter hydrogen and 3 cooling water flow meter). At the output of the I / O ports are connected 27 relays, which can control all compressor devices (electronic valves, devices, coolers, etc.).

The prototype MH compressor is the first facility of its kind in Central Europe and allows research and development in the field of hydrogen technology. Employees of the Faculty of Mechanical Engineering, domestic and foreign students participate in the development of the facility.

III. CONCLUSION

A conclusion section must be included and should indicate clearly the advantages, limitations, and possible applications of the paper. Although a conclusion may review the main points of the paper, do not replicate the abstract as the conclusion. A conclusion might elaborate on the importance of the work or suggest applications and extensions.

ACKNOWLEDGEMENTS

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A Survey of Nitrogen Level Estimation in Plants using Image Processing

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***Abstract*—** *Nutrients in plants are commonly associated with the Nitrogen Content present in the given plant at the given time. The evaluation of Nitrogen content is thus a pretty accurate measure of the health of the Plant in question. Traditional methods of Nitrogen Content estimation relied on either destructive and time-consuming methods which were extremely inefficient or on methods that required human eyesight to compare using a Colour Chart which had a really high probability of being incorrect as the colour on the chart itself may or may not be accurately printed. Thus, the use of Computer based Nitrogen Level estimation Techniques is sought.*

This paper tells us about a few techniques used for Nitrogen Estimation and details some of the differences in the techniques whilst giving us a brief idea of the biggest drawbacks of each of the mentioned techniques.

***Keywords*— survey, agriculture, colour detection, comparison, dselm, image processing, image recognition, MATLAB.**

I. INTRODUCTION

With the turn to digital technologies for almost every aspect of Electronics-based Surveying it was time to make Agricultural Analysis be digitally enabled. The theories for such a change were planted long before the actual technology itself could catch up. Thus, it is only in the last decade that we can see easier ways of creating programs that utilize those theoretical topics. All of the techniques are implemented using the software 'MATLAB' by MathWorks. With a host of useful Add-Ons, built in applications and an exhaustive library of Functions, MATLAB is near perfect Software for a variety of Engineering and Research tasks.

Almost all of the mentioned techniques use a single reference plant which is documented over a long period of time or has a database prepared around various plants of the same species. Furthermore, all of these papers use slight variation of Artificial Intelligence and/or Machine Learning for better accuracy and efficiency over time. The Colour Recognition in all the papers surveyed below deals with the RGB and HSV (HIS) Colour Scale. We need both the Colour Scales for higher accuracy because just a single scale does not accurately describe the colour we are observing. The other important similarity between all of the papers is the need to sample down the image to a required size. This is performed for achieving a better balance between accuracy and efficiency. A down sampled image uses lesser temporary data whilst still providing us with relatively detailed matrix of the colours present in the actual/original Image.

II. LITERATURE SURVEY

2.1 Computational Deep Intelligence Vision Sensing for Nutrient Content Estimation in Agricultural Automation

(Image Resolution used: 1632 x 1224 => 448 x 336**)**

The paper presents a computational intelligence vision sensing approach to estimate nutrient content in wheat leaves by analyzing color features of the leaf images captured on field under various lighting conditions. It also proposes the development of Deep Sparse Extreme Learning Machines (DSELM) fusion along with a Genetic Algorithm (GA) to normalize plant images as well as to reduce color variability due to a variation of sunlight intensities. We also apply the DSELM in image segmentation to differentiate wheat leaves from a complex background.

2.2 Estimation of Nitrogen Content in leaves using Image Processing

(Image Resolution used: 4920 x 3264 => 512 x 512**)**

This paper presents us a simpler approach towards Image Processing based Nitrogen Content Estimation wherein, we use N-values calculated using Traditional methods. This technique uses image preprocessing for consistent and accurate results after the first run. This program also integrates texture detection which helps the HSV colour scale to accurately read even the slightest colour errors.

2.3 Preliminary research on Total Nitrogen content prediction of Sandalwood using the Error-in-variable models based on Digital Image Processing

(Image Resolution used: 1024 x 768**)**

This paper presents before us a method for predicting the total nitrogen content in Sandalwood using Digital Image Processing. The goal of this study is to provide a real-time, efficient, and highly automated nutritional diagnosis system for producers by analyzing images obtained in forests. Using images acquired from field servers, which were installed in various forest farms at different locations.

2.4 Miscellaneous

Image processing techniques were developed by Gautam R.K. and Panigrahi [4] to extract statistical and textural features from multi-spectral bands of aerial images. Along with the conventional image bands of red, green, and near-infrared, two additional image bands, normalized difference vegetation index (NDVI) and green vegetation index (GVI) were derived. Two neural network architectures, multilayer perception and radial basis function were applied to develop twenty neural network (NN) models for predicting leaf nitrogen content of corn plants in field conditions. The extracted image features were used as input to the neural network models. Performance of the neural network models were evaluated based on simultaneous comparison of root mean square error of prediction (RMSEP), minimum prediction accuracy (MPA), and correlation coefficient. The optimum NN model was based on the radial basis function architecture and used textural image features as its inputs. The radial basis function based on green vegetation index texture (RBGvT) provided an RMSEP of 6.6%, MPA of 88.8%, and correlation coefficient of 78% for predicting leaf nitrogen content infield conditions.

2.5 Miscellaneous

This paper [5] proposes a for method using color image analysis to estimate the nitrogen content in grapes. The function used to estimate gives us a significant correlation and gives a coefficient of determination of 0.89 with mean square error 0.08935. The proposed method is faster, noticeably accurate and efficient compared to conventional methods.

III. COMPARISON BETWEEN MAIN METHODS

TABLE 1
COMPARISON BETWEEN MAIN METHOD

Sr. No.	Paper Name	Advantages	Disadvantages
01.	Computational Deep Intelligence Vision Sensing for Nutrient Content Estimation in Agricultural Automation	Use of DSELM and GA provides unmatched accuracy alongside easier functioning	Takes a lot of time to construct the database of the entire program. Can be used only on a single object of interest, adding another Object result in Large amount of recoding.
02.	Estimation of Nitrogen content in leaves using Image processing	Smaller database required for functioning. Image Pre-Processing results in a more consistent system overall.	Requires Manual entry for every action. Requires strictly clinical environments with clean backgrounds.
03.	Preliminary research on total nitrogen content prediction of sandalwood using the error-in-variable models based on digital image processing	Covers large areas and a huge number of sample sizes. Variety of Environment sensors gives highly accurate results.	Feasibility restricted to only a sample size of >100 samples. Definitely not cheap to justify use unless Automation or One-Time Investment is involved.

IV. CONCLUSIONS

Thus, we can conclude that the idea of Nitrogen Level Computation using only Image Processing, a Non-Traditional and Non-Destructive method is uniquely suitable for further research. A Common disadvantage in all of the Papers proposed here is the fact that all of them only work for a single type of plant which makes it difficult to use them as a general-purpose system. If a system combining the numerous positives of these systems are coupled to a relatively larger types of data, we can get a Swiss Army Knife tool which could also integrate Water Level Sensors, Soil Analyzer, etc.

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