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# INFLUENCE OF THE HUMAN-MACHINE SYSTEMS (HMS) OPERATION MODE ON THE INCREASE OF GRAIN-HARVESTING AGGREGATES PRODUCTIVITY

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**ABSTRACT**

The article is devoted to the development of optimal operation modes of grain-harvesting aggregates, and the mechanizer is presented as an operator of the human-machine system (HMS). The block schematic diagram describes the HMS and the cybernetic human-machine model, as well as the scheme of external and internal human-machine-external interactions; in this scheme the connections are described. With the help of two graphs, the dynamics of human performance during the day and the change in working capacity during the work shift are presented, indicating the stages of increasing working capacity, stable working capacity and decrease in working capacity. Based on this, variants of operation modes of technological aggregates have been developed. Graphs of energy expenditures by a human-operator are given for various operation modes of organizational HMS, and the tables offer operators' schedules at 6 hour, 9 hour and 12 hour shifts with a main cycle of 56 shifts. In summary, conclusions on the temporary impact of the operation mode on the productivity of grain-harvesting aggregates are presented.

**KEYWORDS**

Human-machine, working capacity, labor process, per hour output, grain-harvesting aggregate.

## 1. INTRODUCTION

HMS in the agro-engineering field attracts more and more attention of specialists. Rational conditions for their usage, even at the stage of formation, are already one of the most significant factors for increasing the efficiency of the agro-industrial complex of any state [1]. Expanding the concept of "human-machine" or interpreting it broadly as the "human-labor process", we present the structural and cybernetic model of the system (Figures 1,2).

Its task is to perform any work, and at this time the value and relative magnitude of both parts of the system – human and machine – can vary within wide limits. The concept of "machine" can mean both the simplest instrument and complex technical objects. The concept of "human" covers both the employee performing the most primitive work and the operator watching the flow of the automated technological process according to the indicators of the devices without directly influencing the flow of the process stipulated in the program of the machine [2].

It can be stated that the basis of many technological problems is not a separate machine-tractor aggregate as a technical (mechanical) system and not a group of these aggregates in the form of mechanized units, brigades, compressors as objects of study and improvement, but a new formation – "human-machine system", in which the human operator possesses certain features of the subject of labor activity and plays no less a role than the machine [3]. The interaction of a human being with the external environment during the labor process is presented in Figure 3.

Connection 1 determines the impact of a human-being on a machine during the labor process. It is carried out through the mechanical movements of a human-being. Connection 2 characterizes the effect of a machine on a human-being, which is partially perceived by a human-being through the senses and carries with it both useful information and information that is not of interest from the point of view of the goals of the work activity. Connection 3 describes the impact of the environment on a human-being. It includes economic, social, physical, psychological and hygienic factors. Connection 4 describes the impact of a human-being on the external environment, which is diverse. Connection 5 characterizes and describes the impact of the external environment on a machine and includes supplying the machine with the energy necessary for its operation, maintenance, which cannot be performed by the person working in this system. Connection 6 determines the impact of the machine on the external environment, which appears, for example, in the form of noise, vibration, etc. [4].

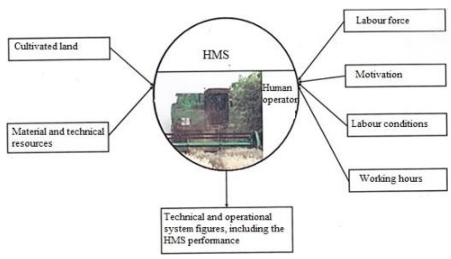


**Figure 1**: Block schematic diagram of the HMS

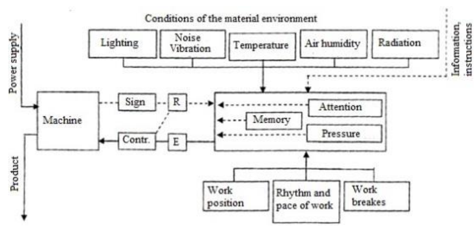


**Figure 2**: Cybernatic "human-machine" model:

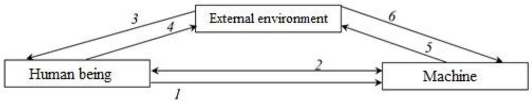


**Figure 3**: Diagram of the external and internal “human-machine-external environment” interactions

Based on this, it is appropriate to develop new fundamentals of designing next-generation technical devices — already as HMS, new methods for designing human-machine mobile aggregates, determining their reliability, mode of operation, and performance. The researches of GOSNITI (State scientific and research technological institute of tractor and agricultural machine repair and maintenance), VNIPTIMESH (Russian scientific and research project and research institute of agriculture mechanization and energy connectivity), VNII (All-Union research and development institute) of labor protection and a number of works of Russian scientific institutions and universities are devoted to the influence of the mode of operation on the increase in productivity of grain-harvesting aggregates. The mode of operation determines the level and intensity of adaptation of a human operator, their fatigue, performance, their technological reliability, therefore, the reliability of the entire HMS, both within an element of a separate aggregate and the organizational system as a whole. First of all, it is necessary to consider the issues of the organisational HMS functioning, and then to conduct the selection and study of their modes of operation.

The main purpose of studying the operation modes is to obtain some basic information that can be used to guide changes in work schedules and at the same time to show the possible complications that can be caused by using at random schedules on the efficiency of harvesting.

## 2. MATERIALS AND METHODS

Studies show that the circadian system is highly resistant to large sudden changes in the established mode and is usually quite stable. The change in the dynamics of working capacity during the day is presented in Figure 4 [5].

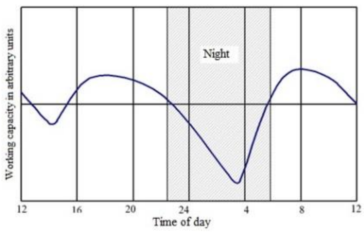


**Figure 4**: Dynamics of human being working capacity during the day

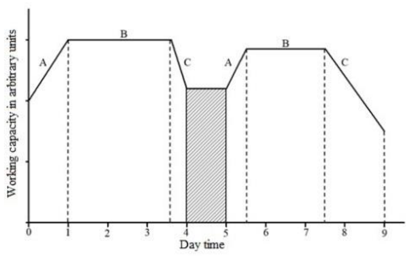


**Figure 5**: Changes in working capacity during the shift: A – stage of increasing working capacity, B – stage of stable working capacity, C – stage of decreasing working capacity

To maintain good health, it is necessary to maintain normal synchronization of the leisure / activity behavioral cycle with the cycle of the circadian biological system. Thus, preference should be given to such work schedules, which either maintain this synchronism, or contribute to such a change in the circadian system, in which it is synchronized with the working activity [6].

During the shift, combiners must have rest breaks. The need for rest arises from a decrease in performance due to fatigue, causing a drop in daily output, an increase in losses and, as a consequence, an increase in the duration of harvesting. Working capacity means “the ability of a human being to perform a certain work for a long time or more” [7,8]. It points out that "performance is related to labor productivity." Performance is not constant; it changes during the day or week. The schedule of changes in working capacity is presented in Figure 5 [9].

## 3. RESULTS AND DISCUSSION

The main reason for the decrease in working capacity during the labor process is the work itself; in the process of more or less long-term performance its capacity decreases [10]. Reduced working capacity under the influence of work is considered to be fatigue [11-19]. As a result of fatigue, a disorder of previously formed skills occurs. This is manifested, for example, in a change in the working position: the combiner strongly tilts the body forward or throws it back, which makes it difficult to use the steering wheel, pedals, and levers; as a result, there is a decrease in performance. To prevent fatigue, it is necessary to rationally organize work with obligatory and timely rest. Based on the current practice in the agricultural production, it can be stated that shift work is a fairly common phenomenon [20]. In many cases, the operation mode can be improved, i.e., changes can be made to it that will increase the productivity of the grain harvesting aggregates. Rational operation mode should ensure high production efficiency, preserve the health of workers, and also fully contribute to the development of their physical and spiritual strength. For workers in agriculture in this regard, the implementation of the dual-shift organization of labor is of great importance [21].

The usage of two-shift work reduces fatigue of machine operators and, in so doing, improves the use of technology and increases labor productivity. Time observations of the author showed that the use of working time and hourly output with two shifts of work mode is 27% higher, downtime is halved, the quality of work has improved; time for field work has reduced. The three variants of operation modes of technological aggregates proposed in significantly increase the efficiency of the operation of the HMS [22]. Figure 6 shows the graphs of the operation modes in three versions with reference to functional specialized complexes.

*The first variant* provides for work of the aggregates in the field conditions during 18 hours (these are, first of all, harvest-transport complexes in those cases when, under the conditions of changes in the humidity of the threshed culture, they cannot work around the clock). On the aggregate, two machine operators work consecutively without interruptions, changing each other every six hours. The graphs are compiled in the coordinates of "working time", "energy costs of the operator." Energy costs are given in arbitrary units, when the unit takes energy costs for an eight-hour working day (this is 1200-1800 kcal or 5024-103 – 7536-103 J). After six hours of work, there is a change of operators: the first takes food and then has a rest for six hours. The second operator, by the beginning of his work, who has already taken food, starts work at 14 o’clock and works continuously until 20 o’clock. Then he is replaced by the first operator, who works continuously until the period of increasing the moisture of the harvest because of the dew. The changed operator takes food and has a rest (the energy recovery curves of the operators are represented by dotted lines: the first operator is presented with one dotted line, the second one – with two).

*The second variant* of the operating mode provides for the operator to work for nine hours with a break for eating and a short rest for one hour after 4 hours of work – from 8 to 12 o’clock. The first operator finishes work at 17 o’clock; then he takes food and has a rest. The second operator starts to work at 17 o’clock and works until the period of increasing the moisture of the harvest because of the dew; then he rests. At 8 o'clock the first operator starts work.

Finally, *the third variant* of the operation mode describes the round-the-clock work of the specialized HMS. This may be one of the modes of operation of the cultivable complex or a complex for the harvesting of silage crops, both on-farm and as part of the HMS. It provides a twelve-hour work of the operator with a invariable one and a half increase in daily load, therefore, with two short breaks every four hours for taking meals. The work of the first operator lasts from 8 to 20 hours; then the operator changes, and the first rests until 8 am the next morning. The second operator works from 8 pm to 8 am on the next calendar day, then has a 12-hour rest. The first operator starts work at 8 am on the next calendar day. This is actually a two-shift non-stop operation.

The line graphs of Figure 6 show the energy consumption curves of operators associated with variable intensity during a shift. Work for 1.0-

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1.5 hours after the beginning of the shift is characterized by lower specific productivity due to the period of adaptation of the worker [23]. Then HMS reaches maximum performance, and this period lasts 4-6 hours. After that, fatigue occurs; during the last 1.5-2.0 hours, the operator is working in the mode of fatigue, the performance of the HMS decreases. It should be noted that, working in the mode of fatigue, he spends more energy, trying to keep at a level of relatively high performance [24].

Such a nature of operator's energy costs is possible on long shifts: nine-hour and especially twelve-hour; in both cases, the energy cost curves are S – shaped. With a short scheme, this nature of the intensity of operator's energy costs is not observed. The given nature of the energy costs will certainly affect the shift production of the HMS, which with the increase in the duration increases, but does not have the character of direct proportionality with the duration of the shift [25].

The following are the basic sequences and main cycles as applied to the considered schedules of operation. Table 1 shows the operation mode with an operating time of 18 hours per day with two operators with shift duration of 6 hours and a main cycle of 8 days. This is a schedule of limited usage: only in functional HMS for on-farm purposes, when operators are free from work and have a rest directly in the field, and the duration of HMS operation itself does not exceed 10-12 days [26].

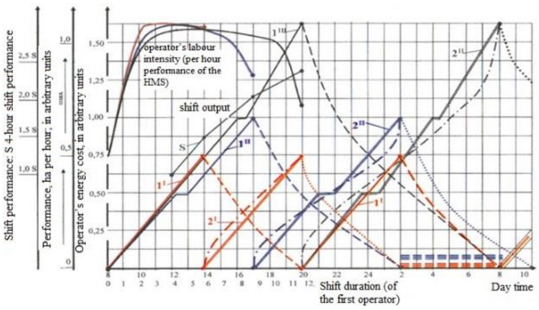


**Figure 6:** Graphs of energy cost by a human-operator with different operating modes of organizational HMS: 1I and 2I – the first option, 1 and 2 operators, the operation time is 18 h (change after 6 h); 1II and 2II – the second option, the duration of 18 hours (change after 9 hours with one break); 1III and 2III – the third option – around the clock, the mode of operation of 1 and 2 operators (12 hour shift with two breaks)

The second work schedule (Table 2) provides for the duration of the operation of the HMS during the day – 18 hours with two operators and shift duration of 9 hours with one hour break in 4 hours after the start of the shift [27]. It provides for the transfer of operators to another shift after 16 shifts, the main cycle is 32 shifts. This schedule is suitable for on-farm HMS. The reduced mode is somewhat more difficult (more costly in the sense of operator energy) than the first one.

The third schedule of the operation mode is given in Table 3. It implies round-the-clock operation of the HMS with two shift operators working 12 hours a day every two shifts, shift duration of 12 hours with two breaks after 4 hours to have meals. The schedule provides for an overload mode for the operator's energy costs [28]. Therefore, after 14 days there is a three-day break; through the same period, the operators change shifts. The non-working part of the day – operators spend 12 hours either at home or in other stationary conditions. The duration of the main cycle is 56 shifts. This, in general, hard mode is used for the operation of the HMS as part of the MTS.

At present moment, very expensive equipment is used in agricultural enterprises, even well-organized and cost-effective, in one shift due to the clearly insufficient number of highly skilled machine operators with significantly higher wages (not in absolute terms but compared to other categories).

**Table 1:** Schedule of work of two operators at a 6-hour shift with a main cycle of eight shifts (on-farm UTK) with an 18-hour operation of HMS per day

| | | Operator's Number | |
|---|---|---|---|
| | | 1 | 2 |
| 1st day | 8-14 | 1 | 0 |
| | 14-20 | 0 | 2 |
| | 20-2 | 1 | 0 |
| | 2-8 | 0 | 0 |
| 2nd day | 8-14 | 0 | 2 |
| | 14-20 | 1 | 0 |
| | 20-2 | 0 | 2 |
| | 2-8 | 0 | 0 |
| 3rd day | 8-14 | 1 | 0 |
| | 14-20 | 0 | 2 |
| | 20-2 | 1 | 0 |
| | 2-8 | 0 | 0 |
| 4th day | 8-14 | 0 | 2 |
| | 14-20 | 1 | 0 |
| | 20-2 | 0 | 2 |
| | 2-8 | 0 | 0 |
| 5th day | 8-14 | 1 | 0 |
| | 14-20 | 0 | 2 |
| | 20-2 | 1 | 0 |
| | 2-8 | 0 | 0 |
| 6th day | 8-14 | 0 | 2 |
| | 14-20 | 1 | 0 |
| | 20-2 | 0 | 2 |
| | 2-8 | 0 | 0 |
| 7th day | 8-14 | 1 | 0 |
| | 14-20 | 0 | 2 |
| | 20-2 | 1 | 0 |
| | 2-8 | 0 | 0 |
| 8th day | 8-14 | 0 | 2 |
| | 14-20 | 1 | 0 |
| | 20-2 | 1 | 2 |
| | 2-8 | 0 | 0 |
| 9th day | 8-14 | 1 | 0 |
| | 14-20 | 0 | 2 |
| | 20-2 | 1 | 0 |
| | 2-8 | 0 | 0 |
| 10th day | 8-14 | 0 | 2 |
| | 14-20 | 1 | 0 |
| | 20-2 | 0 | 2 |
| | 2-8 | 0 | 0 |
| 11th day | 8-14 | 1 | 0 |
| | 14-20 | 0 | 2 |
| | 20-2 | 1 | 0 |
| | 2-8 | 0 | 0 |
| 12th day | 8-14 | 0 | 2 |
| | 14-20 | 1 | 0 |
| | 20-2 | 0 | 2 |
| | 2-8 | 0 | 0 |

**Table 2:** Schedule of work of two operators at a 9-hour shift with a main cycle of 32 shifts at 18-hour operation of the HMS per day

| | | Operator's Number | |
|---|---|---|---|
| | | 1 | 2 |
| 1st day | 8-17 | 1 | 0 |
| | 17-02 | 0 | 2 |
| | 02-08 | 0 | 0 |
| 2nd day | 8-17 | 1 | 0 |
| | 17-02 | 0 | 2 |

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| | | | |
|---|---|---|---|
| | 02-08 | 0 | 0 |
| 3rd day | 8-17 | 1 | 0 |
| | 17-02 | 0 | 2 |
| | 02-08 | 0 | 0 |
| 4th day | 8-17 | 1 | 0 |
| | 17-02 | 0 | 2 |
| | 02-08 | 0 | 0 |
| 5th day | 8-17 | 1 | 0 |
| | 17-02 | 0 | 2 |
| | 02-08 | 0 | 0 |
| 6th day | 8-17 | 1 | 0 |
| | 17-02 | 0 | 2 |
| | 02-08 | 0 | 0 |
| 7th day | 8-17 | 0 | 2 |
| | 17-02 | 1 | 0 |
| | 02-08 | 0 | 0 |
| 8th day | 8-17 | 0 | 2 |
| | 17-02 | 1 | 0 |
| | 02-08 | 0 | 0 |
| 9th day | 8-17 | 0 | 2 |
| | 17-02 | 1 | 0 |
| | 02-08 | 0 | 0 |
| 10th day | 8-17 | 0 | 2 |
| | 17-02 | 1 | 0 |
| | 02-08 | 0 | 0 |
| 11th day | 8-17 | 0 | 2 |
| | 17-02 | 1 | 0 |
| | 02-08 | 0 | 0 |
| 12th day | 8-17 | 0 | 2 |
| | 17-02 | 1 | 0 |
| | 02-08 | 0 | 0 |

**Table 3**: Schedule of work of two operators at a 12-hour shift with a main cycle of 56 shifts with round-the-clock operation of the HMS (operation as part of the MTS)

| | | Operator's Number | |
|---|---|---|---|
| | | 1 | 2 |
| 1st day | 8-20 | 1 | 0 |
| | 20-08 | 0 | 2 |
| 2nd day | 8-20 | 1 | 0 |
| | 20-08 | 0 | 2 |
| 3rd day | 8-20 | 1 | 0 |
| | 20-08 | 0 | 2 |
| 4th day | 8-20 | 1 | 0 |
| | 20-08 | 0 | 2 |
| 5th day | 8-20 | 1 | 0 |
| | 20-08 | 0 | 2 |
| 6th day | 8-20 | 1 | 0 |
| | 20-08 | 0 | 2 |
| 7th day | 8-17 | 1 | 0 |
| | 17-02 | 0 | 2 |
| 8th day | 8-17 | 1 | 0 |
| | 17-02 | 0 | 2 |
| 9th day | 8-17 | 1 | 0 |
| | 17-02 | 0 | 2 |
| 10th day | 8-17 | 1 | 0 |
| | 17-02 | 0 | 2 |
| 11th day | 02-08 | 1 | 0 |
| | 08-17 | 0 | 2 |
| 12th day | 17-02 | 1 | 0 |
| | 02-08 | 0 | 2 |
| 13th day | 8-17 | 1 | 0 |
| | 17-03 | 0 | 2 |
| 14th day | 02-08 | 1 | 0 |
| | 08-17 | 0 | 2 |
| 15th day | 17-02 | 0 | 0 |
| | 02-08 | 0 | 0 |
| 16th day | 8-17 | 0 | 0 |
| | 17-02 | 0 | 0 |
| 17th day | 02-08 | 0 | 0 |
| | 08-17 | 0 | 0 |
| 18th day | 17-02 | 0 | 2 |
| | 02-08 | 1 | 0 |

## 4. CONCLUSION

Modern agricultural equipment does not have sufficiently high parameters for working conditions to ensure intensive work of HMS. The problem lies in the development of methodological bases to evaluate the effectiveness of additional technical solutions and equipment on complex agricultural machinery (primarily self-propelled combines), which ensure an increase in the level of working conditions.

Studies have shown that the operation mode determines the level and intensity of adaptation of a human operator, their fatigue, performance, their technical reliability, consequently, the reliability of the entire HMS, both within the element – a separate agreggate and organizational system. We considered, in our opinion, the main modes and schedules of work of operators of technological aggregates. However, other operation modes of operation are possible.

Thus, it is safe to conclude that the productivity of the grain-harvesting agreggate directly depends on the condition of the operator of the HMS, in turn, which is influenced by the operation schedules of the agreggate. According to our research, the graphics developed and tested by us are optimal, and the agreggates controlled by operators who adhere to these schedules ensured maximum performance.

## REFERENCES

[1] Adamovich, N.V. 1977. Machine controllability: ergonomic framework for optimizing the workplace of a human operator. Moscow: Kolos.

[2] Anokhin, P.K. 1968. Biology and neurophysiology of the conditioned

reflex. Moscow: Mysl'.

[3] Vaynshteyn, L.A. 1992. Engineering and psychological aspects of creating electronic automation equipment for MTA. Tractors and Agricultural Machinery, 7, 25-28.

[4] Petrenko, N.V. 2008. Improving the performance of grain harvesting units as man-machine systems by justifying the modes of operation of operators: Dis. Candidate of Technical Sciences. Zernograd, Azov-Black Sea State Agroengineering Academy.

[5] Demidov, V.P., Chepurin, G.E. 1980. Justification of the need for a hammer mill for a combine harvester. The design of technological processes of cultivation and harvesting of grain in Siberia. Novosibirsk: Siberian Branch of the All-Union Academy of Agricultural Sciences named after Lenin, 55-57.

[6] Wever, R.A. 1979. The circadian system of man. Berlin. Springer-Verlag.

[7] Kosilov, S.A. 1965. Essays on the physiology of labor. Moscow. Meditsina.

[8] Kosilov, S.A. 1969. Physiological basis of NOT. Moscow: Economy.

[9] Kuperman, A.I. 1999. Road safety: a reference book. 2nd ed. Moscow. Vysshaya shkola. Izd. Tsentr Akademiya, 320.

[10] Vernon, H.M. 1925. Industrial fatigue and productivity. Moscow-Leningrad: Voprosy truda.

[11] Konopasevich, P.A. 1892. Further materials on the physiology of muscular fatigue in humans. Dis. Doctors of medicine. St. Petersburg.

[12] Krestovnikov, A.N. 1951. Human physiology. Moscow. Fizkul'tura i sport.

[13] Ostapenko, Yu.M. 2003. Economics and Management in Agriculture. Moscow: Academy, 352.

[14] Rosenblat, V.V. 1961. Fatigue problem. Moscow: Medgiz.

[15] Rosenblat, V.V. 1975. Fatigue problem. Moscow: Meditsina.

[16] Rozenblat, V.V. 1969. Fatigue. Manual on the physiology of labor. Moscow: Meditsina.

[17] Chumakov, B.N. 2006. Human physiology for engineers. Moscow. Russian Pedagogical Society, 256.

[18] Adams, J.A. 1982. Issues in human reliability. Hyman Factors, 24(1), 1-10.

[19] Scheufler, B. 1998. Application of mineral fertilizers. Yearbook Agricultural Engineering, 10, 109-114.

[20] Presser, H.B., Cain, V.S. 1983. Shift work among dual-earner couples with children. Science, 219(4586), 876-879.

[21] Kurbatov, I.D. 1975. Labor organization in a highly mechanized agricultural production. Moscow: Economy, 122.

[22] Lipkovich, I.E. 2004. Man-machine systems in the agro-engineering field of crop production: mechanical and ergonomic foundations of creation and operation. Rostov-on-Don: LLC Terra, 612.

[23] Sazonov, S.N. 1998. Methodology of effective formation and use of production resources in peasant (farmer) farms: Author. Dis. Doctors of Technical Sciences. Saratov, Saratov State Agricultural Engineering University.

[24] Elmnifi, M., Amhamed, M., Abdelwanis, N., Imrayed, O. 2018. Solar Supported Steam Production For Power Generation In Libya. Acta Mechanica Malaysia, 2(2), 05-09.

[25] Sathishkumar, S., Kannan, M. 2018. Design And Fatigue Analysis Of Multi Cylinder Engine And Its Structural Components. Acta Mechanica Malaysia, 2(2), 10-14.

[26] Xu, D.Y. 2019. Research On Supply Chain Management Strategy Of Longtang Electric Engineering Co. Ltd. Acta Electronica Malaysia, 3(1), 10-13.

[27] Jain, T., Kumar, R. 2019. A Study Of Vein Recognition System. Acta Informatica Malaysia, 3(1), 13-15.

[28] Khan, J., Ilyas, S., Akram, B., Siddiq, M., Ashraf, M.A. 2018. Zno/NiO coated multi-walled carbon nanotubes for textile dyes degradation. Arabian Journal of Chemistry, 11(6), 880-896