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Analysis of methods for predicting life of metallurgical machines under cyclic loading

Suleiman Ibrahim Mohammad[1,2,*], *Khaleel Al-Daoud*[3], *Badrea Al Qraini*[4], *Iyad A.A Khanfar*[1] *and Asokan Vasudevan*[5]

[1]Electronic Marketing and Social Media, Economic and Administrative Sciences Zarqa University, 13110 Zarqa, Jordan
[2]INTI International University, 71800 Negeri Sembilan, Malaysia
[3]Department of Accounting, Business school faculty, Al-Ahliyya Amman University, Amman, Jordan
[4]Department of Business Administration, College of Business and Economics, Qassim University, Qassim, Saudi Arabia
[5]Faculty of Business and Communications, INTI International University, Persiaran Perdana BBN Putra Nilai, 71800 Nilai, Negeri Sembilan, Malaysia

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Abstract: In modern production conditions, the life prediction issues become key, as they can optimize the maintenance and repair modes, assess the reliability, risk and safety of the equipment. The features of metallurgical equipment affecting the methodology for assessing durability are considered, among which the organizational and technological factor is identified as one of the significant ones. An algorithm for implementing the operability of mechanical systems of metallurgical production is developed. A new algorithm for searching the durability distribution function is presented. The application in it of interblock and intrablock accumulated damages concept and internal and external factors concept makes it possible to assess the life more accurately and reliably.

Keywords: Cyclic loading, fatigue, life, operability, durability distribution, reliability

1 Introduction

Before analyzing the algorithms for predicting the life of metallurgical machines, it is necessary to understand what are the common features of metallurgical equipment as a whole, whether it is legitimate such an association in terms of methodology. Indeed, in metallurgy, the substances in three aggregate states (liquid, solid, gaseous) are treated; operating elements of metallurgical machines and aggregates interact with such specific systems as bulk materials, metal in liquid and plastic states. Therefore, the main feature of metallurgical equipment can be considered its **diversity**, both in terms of structural designs, and in terms of operating conditions. This premise brings into question any generalizations related to the metallurgical equipment.

Nevertheless, mechanical systems in metallurgy are united territorially by a single engineering-production process. They are created and maintained by holistic teams. Therefore, the range of issues related to the metallurgical equipment, was formed naturally. Accordingly, a School of Metallurgical Machine Science appeared in science and education. It was intensively developed in the USSR by the second half of the 20th century. This was promoted by the socialist mode of production, characterized by the aggregate production structure, which require a large number of specialists in the same field. The achievements of the Soviet Metallurgical Engineering fell within the field of view of the American CIA, which investigated this phenomenon and worried about the growing exports of heavy trucks from the USSR [1,2,3,4].

The global approach is that universities train multiskilled mechanical engineers. Metallurgical equipment tests are directly financed and carried out by firms based on their interests. These firms are not inclined to widely publicize the equipment manufacturing methods, although they are willing to share its advantages. Therefore, there is relatively little open information for analyzing the fatigue strength and durability of metallurgical equipment.

In modern metallurgical production with surplus capacity, the construction of new large facilities is invested with utmost restraint. Deep modernization of

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[*] Corresponding author e-mail: dr_sliman@yahoo.com

acting facilities is becoming more popular and profitable, making it more flexible and economical, and products - more qualitative [5,6,7,8].

There is a problem of the assessment of technical condition and residual life of basic structural elements that have almost reached their end of life and have accumulated the fatigue damages.

Trends regarding the building of mini-mills and combined units are observed. It causes problems of designing material and energy-intensive metallurgical machines, operated under high cyclic stress conditions. In this aspect, the life prediction issues become key, as they can optimize the maintenance and repair modes, assess the reliability, risk and safety of the equipment. The latter is essential to manufacturing equipment under the concept of "Industry 4.0" [9,10,11,12].

Similar problems emerged during the period of widespread intensification of production, when the speeds and individual capacities of metallurgical machines increased significantly. Then, to ensure the reliability of metallurgical equipment, the fatigue life calculation methods were developed [13,14,15,16]. Later, on their basis, more advanced automated design systems of mechanisms and fatigue calculation software packages were developed. As practice has shown, the results obtained with their help do not always adequately predict the expected life. Therefore, modern engineering tools often need to be adapted to the features of metallurgical equipment and production.

The objective of this study is to analyze known algorithms for predicting the life of metallurgical machines and their improvement, based on modern operating conditions.

2 Features of metallurgical machines

It is difficult to find common features in equipment differing by the set of actuating mechanisms, drives and operating elements. But they are in the aspect of developing a unified life prediction methodology.

First of all, metallurgical machines differ in their scale, both in weight and in dimensions. This will not only raise the scale factor among the most influential in developing model of fatigue resistance. The enlarged dimensions of structural elements increase the probability of defects. In this situation, models based on fracture mechanics become promising to assess the reliability.

The operating elements of production machines in metallurgy are exposed to mechanical and thermal stress produced in an aggressive environment. Its impact is due to flow of gas, liquid, loose batch, leading to different types of wear. It is not always clear which type of failure will prevail in the facility. In this situation, the models of multidimensional reliability, complex loading and multi-degradation processes are becoming more relevant.

The continuous nature of metallurgical processes imposes special requirements on the reliability of equipment. First of all, the technological lines of units should be designed with redundant configuration.

This allows the preventive maintenance to be used to support equipment in operating condition, when large manufacturing areas are repaired at the same time. However, since the 2000s, there has been a more advantageous strategy of the technical condition maintenance. Recovery operations make a substantial contribution to the business of metallurgical enterprises. Such contribution to the procedure for monitoring the technical condition and residual life of equipment is carried out by the organizational and technological factor. It implies the provided processing sequence of standard sizes of the product and technological operations. As a result, performance criteria have a deterministic and random nature. Processes of loss of reliability and operability become not monotonous, but get a stick-slip nature. The loading processes are not purely random. Having a steady-state frequency, they can be classified as pseudorandom or periodically-random [17,18,19,20]. Due to a certain organization of production, the loading process becomes multimode.

Despite the availability of standard structural diagrams of the main metallurgical machines, in fact the equipment is unique. Each shop and site is projected for each enterprise separately, although serially manufactured machines and mechanisms can be used. Modernization of equipment (characteristic feature of repairs in metallurgy) makes them single. In such conditions, mathematical and statistical reliability methods do not work, giving way to probabilistic-physical methods.

3 Stages of machine operability prediction

Any calculation relating to processing equipment, performed at the design stage (Design, Fig. 1), is a prediction of its operability. There are calculations to ensure the functioning of mechanical systems and the ability to perform the technological operations assigned to them (Group 1 - Functioning, Fig. 1), as well as strength and reliability calculations intended to confirm the operating life and quality produced by the equipment (Group 2 - Strength, reliability, safety, Fig. 1). The manufacturing of the metallurgical complex equipment should begin with the resolving the issues of the Group 1. This is understandable, since, as a rule, such equipment is designed as unique and, first of all, it is important to ensure the implementation of the technology. After the object is tested according to functional and technological criteria, the stage of its improvement begins (testing of reliability and safety).

The sequence of providing the functionality includes calculations of the machine operating characteristics, the most important of which is the performance (Stage 1.1.-*perf*, Fig. 1) . In stages 1.2 and 1.3, useful technological resistances Q_u, M_u, as well as parasitic loads of friction Q_f, M_f and inertial Q_D, M_D origin are calculated. The latter include a dynamic analysis of machines, in which the maximum loads and dynamic factors are set. The results of dynamic analysis were used to identify the causes and sources of unfavorable vibrations, in order to minimize the emergence of dangerous transition processes by means of structural and operational measures. These include the optimization of mass-rigid parameters, within which it is actual to use shock absorbers [21,22,23,24].

The dynamic analysis has long been associated with durability of equipment. This was due to the fact that the allowable stresses had a narrow range of variation. And this, in turn, is explained by a limited number of materials used to manufacture machines and by ignoring the criteria of fatigue strength. In that regard, the concepts of allowable stresses are transformed. It turns out that their intensity even for one material is a function of many factors. Therefore, they began to change over from allowable stress criteria to durability prediction. The results of modern dynamic analysis in the form of a predictive oscillatory process are used to generate loading histories [25]. For the same purpose, the results of stage 1.4 (*Cyclogramme*, Fig. 1) are used, which reveals the shape of cyclogrammes and determines the severity of drive operating mode. Group 1 of calculations is completed in stages 1.5 and 1.6, when the power of the process executed by the machine (*Pow*, Fig. 1) is determined using load diagrams $Q_\Sigma(t)$, $M_\Sigma(t)$.

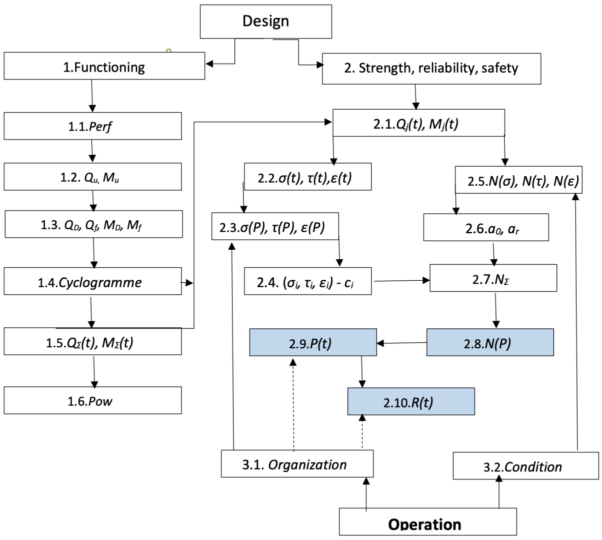

Fig. 1: Diagram of algorithm for implementing the operability of mechanical systems of metallurgical production.

The tasks of Group 1 include stages 2.1 and 2.2, when calculations are changed over from total loads to loading of individual elements Q_j, M_j and their stress-strain state with exponents σ, τ, ε. This makes it possible to verify the strength of the object, but these calculations have no yet relevance to the assessment of reliability, although they contribute to its assurance.

To assess the reliability indices to which this development is dedicated, it is necessary to have a temporary implementation of the process of changing the stresses $\sigma(t)$, $\tau(t)$ or strains $\varepsilon(t)$. The subsequent stages 2.3 and 2.4, associated with obtaining the frequency distributions $\sigma(P)$, $\tau(P)$, $\varepsilon(P)$ and their approximations in the form of discrete loading blocks $(\sigma_i, \tau_i, \varepsilon_i)$ - c_i, shall be implemented taking into account the production organization and operation (*Operation*, 3.1- *Organization*, Fig.1).

Stages 2.5 and 2.6 dedicated to the development of models of fatigue resistance in the force formulation $N(\sigma)$, $N(\tau)$ or strain formulation $N(\varepsilon)$ for particular operating conditions (3.2 - *Condition*, Fig.1) are performed parallel. In fact, the algorithm for searching the total durability N_Σ (a number of cycles of different level of damaging to the element limiting state), is in stage 2.6, where the law of summation of damages a_0, a_r is established. The inverse reliability function $P(t)$ (stages 2.7 and 2.8) is obtained by the durability distribution function $N(P)$. Moving from a probability of survival P to a probability of failure and taking into account its damage can determine the risk and safety function $R(t)$. Stages 2.9 and 2.10 are carried out using probabilistic-physical methods based on individual indicators of reliability and risk. If the number of objects is sufficient from a statistical point of view, the reliability and safety functions can be obtained through research of the entire mechanical system using mathematical and statistical methods (dashed line, Fig. 1).

4 Predicting the distribution of durability

In metallurgy it is customary to set the loading of structural elements in the form of blocks. With regard to power-type fatigue resistance model, the number of blocks to the limiting state will be the following [13,26]:

$$\lambda = \frac{a_0 \sigma_{Rd}^m N_G}{\Sigma \sigma_{ai}^m n_i} \tag{1}$$

where σ_{ai} is a stress amplitude at the i-th stage with cycle asymmetry R,

n_i is a number of cycles of repetition of amplitude σ_{ai} at the i-th stage of block,

σ_{Rd} is a limit of fatigue of the structural element for cycle asymmetry R,

N_G is an infinite life corresponding to the value σ_{Rd},

m is a ratio of slope of the fatigue curve,

a_0 is a damage accumulated to the moment of the limiting state.

The total durability for a block with a capacity of cycles n_b is the following: $N_\Sigma = \lambda n_b = \lambda \sum n_i$.

The accumulated damage value, adjusting the linear summation hypothesis, is determined a posteriori through durability at the level of the i-th stage N_i as $a_0 = \sum(n_i/N_i)$. This value can be set a priori by the block parameters σ_{amax} (maximum level σ_{ai}) and $c_i = n_i/n_b$ (stage relative duration) as follows [26]:

$$a_0 = \frac{\sigma_{a\max}\xi - 0,5\sigma_{Rd}}{\sigma_{a\max} - 0,5\sigma_{Rd}} = \frac{\Sigma\sigma_{ai}c_i - 0,5\sigma_{Rd}}{\sigma_{a\max} - 0,5\sigma_{Rd}} \tag{2}$$

$$\xi = \Sigma\frac{\sigma_{ai}}{\sigma_{a\max}}c_i \tag{3}$$

The distribution of durability of elements of metallurgical machines is approximated logarithmically by normal law or Weibull law. In most situations, preference is given to the first, for which the standard deviation is determined either by the linearization method:

$$S_{\lg N_\Sigma} = 0,43m\left(V_{\sigma Rd}^2 + V_y^2\right)^{1/2} \tag{4}$$

or by the delta method [13,26]:

$$S_{\lg N_\Sigma} = \left[0.43 \cdot V_y \Big/ \sum\left(\frac{\sigma_{a_{\max}}}{\sigma_{a_i}}\right)^m \cdot c_i\right] \cdot \sqrt{\sum\left[\left(\frac{\sigma_{a_{\max}}}{\sigma_{a_i}}\right)^{2m} \cdot c_i\right]^2} \tag{5}$$

where $V_{\sigma Rd}$ is a coefficient of variation of the part fatigue limit, V_y is a variation of external factor, measured as a coefficient of variation of the block stage maximum in amplitude.

With the development of the mechanical monitoring systems of metallurgical machines, algorithms with loading history for determining the residual life were developed.

This circumstance becomes relevant during service life extension, when the object has reached its mean life. The distribution function of residual durability obeys Weibull law and is as follows [27]:

$$N_\gamma = \alpha\left[\left(\frac{\bar{N}_\Sigma}{\alpha}\right)^\beta - \ln\gamma\right]^{1/\beta} - \bar{N}_\Sigma \tag{6}$$

where $\gamma > 0.5$ is a probability of residual durability, α and β are parameters of distribution.

This formula is suitable when the observed time λ_{nb} reaches the median predictive life $\bar{N}_\Sigma$.

The impact of the organizational and technological factor can be taken into account by developing a formalized block of loading. It is obtained using a specially developed for this purpose method of loading synthesis [28]. The formalized block reflects the typical sequence of the technological operations performed by the machine. Owing to it, a transition from a purely random process to a loading process with random variable parameters is carried out. With respect to the schematization of loading with formalized blocks, an algorithm for searching the durability distribution functions by means of the Monte Carlo method was developed [29]. In this paper, the authors propose a similar algorithm implemented by a less laborious method of linearization.

Using the life parameters to describe the median formalized block, the total durability is determined as follows:

$$\bar{N}_\Sigma = \frac{a_r a_0}{\sum c_i d_i} \tag{7}$$

where α_r is an interblock damage, accumulated by the moment of the limiting state, which takes into account the random nature of loading;

α_{0_i} is an intrablock damage, accumulated by the moment of the limiting state, for the i-th stage of block, which takes into account the nonlinearity of the summation of damages;

$d_i = 1/N_i$ is an elementary damage in the form of relative durability from the stage of the i-th level.

The random value of the accumulated damage in (7) is defined as deterministic and is usually adjusted depending on the block shape. Having obtained the value $\bar{N}_\Sigma$, and taking into account the relation between the parameters of the normal distribution and logarithmically normal distribution, we determine the median value for the lognormal distribution:

$$\overline{\lg N_\Sigma} = \lg\bar{N}_\Sigma - 1,15 \cdot S_{\lg N\Sigma}^2 \tag{8}$$

Then the DDF will be as follows:

$$\lg N_{\Sigma P} = \overline{\lg N_\Sigma} \pm u_p \cdot S_{\lg N\Sigma} \tag{9}$$

where S_{lgN_Σ} is a standard deviation of the durability logarithm for the adopted loading conditions, u_p–is a normal distribution quantile.

The relationship between the root-mean-square deviations of the durability $S_{N\Sigma}$ and the durability logarithm $S_{lgN\Sigma}$ can be calculated using the following formula:

$$S_{\lg N_\Sigma} = S_{N\Sigma}/2,3 \cdot \bar{N}_\Sigma \tag{10}$$

Spread in a number of cycles to fracture during unsteady loading condition depends on the internal and external factors. The internal factor is understood as the durability scattering caused by the material nonhomogenity, part shape inaccuracy and static fatigue effect. The external factor is understood as the scattering caused by the deviation of the real loading condition from the design condition. In this regard, it can be assumed that by recording the loading process during operation, it is possible to get rid of the impact of the external factor and to assess the service life more accurately. In the formula

(4), the value V_y serves as an assessment of the external factor, and the value $V_{\sigma Rd}$ serves as an internal factor.

According to formula (7), the impact of the external factor can be assessed through the spread of the value $y = \Sigma c_i d_i$ that is the block parameter. In [29] there is a derivation of formula of the variation coefficient of the internal factor through the damage accumulated from the loading stages. The same result can be obtained immediately as follows:

$$V_a = 2,3 \cdot S_{\lg N} \tag{11}$$

if S_{lgN} is a standard deviation of the durability $N = N_\Sigma$ at the level of steady load corresponding to the number of cycles N_Σ in the unsteady condition. Such a procedure is possible if the dependence $S_{lgN} = f(lgN)$ is available as a component of the fatigue resistance model.

Assuming in this situation the value c_i as non-random and knowing the standard deviation of the characteristics of the loading stages S_{d_i}, we have the standard deviation of the external factor S_y:

$$S_y = \sqrt{\sum c_i^2 \cdot S_{d_i}^2} \tag{12}$$

Dividing this value by the value $\bar{y}$ for the block with median parameters d_i, we obtain the external factor variation coefficient V_y. Then, according to the addition law of errors, we finally obtain the following formula:

$$S_{N\Sigma} = \bar{N}_\Sigma \cdot \sqrt{V_a^2 + V_y^2} \tag{13}$$

As a result, the DDF parameters (9) are determined by formula (10).

5 Conclusions

Despite the wide variety of the structural diagrams of metallurgical machines, the common features of their use have been revealed. As a result, the organizational and technological factor becomes one of the significant factors affecting the operating characteristics. Taking into account only the regularities of the functioning of mechanical systems it is difficult to establish their reliable value. It is necessary to examined and take into account the nature of production and operation.

The key role of the stages for searching the life in the probabilistic aspect to ensure the operability and efficient operation of metallurgical machines is substantiated. The proposed algorithm for searching the durability distribution function distinguishes the application of the concept of interblock and intrablock accumulated damages, making it possible to more reliably predict the mean life. The use of the concept of internal and external impact on the distribution of durability contributes to a more accurate prediction of the reliability.

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References

[1] Trends in soviet production of metallurgical equipment for the steel industry 1959 – 65//Economic intelligence report.CIA/RR ER 63 – 1.- 1963.- 46p.

[2] A.M. Alrabei, Green electronic auditing and accounting information reliability in the Jordanian social security corporation: the mediating role of cloud computing, *International Journal of Financial Studies*,**11**, 114 (2024).

[3] A.M. Alrabei, The mediating effect of COVID 19—pandemic on the Nexus between accounting information systems reliability and e-commerce: from the perception of documentary credit employees, *Inf. Sci. Lett.*,**12**, 2867-2876 (2023).

[4] A.M. Alrabei, O. Jawabreh, A.M.M. Saleh, Accounting Information and Role It on Financial Reports Quality in Jordanian Hotels, and Social Performance as a Mediating Effect, *International Journal of Sustainable Development & Planning*,**18**, 2271-2279 (2023).

[5] Sveikovsky U. Performance modules increase efficiency of long product mills //MPT.- 2016. – V.5.- p. 38-41.

[6] A.M.A. Alrabei, Perception of Jordanian Banks Employees on the Relationship between Accounting Information Quality (AIQ) and Documentary Credits, *International Journal of Applied Business and Economic Research*,**15**, 409-419 (2017).

[7] A.M. Alrabei, The influence of accounting information systems in enhancing the efficiency of internal control at Jordanian commercial banks, *Journal of Management Information and Decision Sciences*,**24**, 1-9 (2021).

[8] A.M. Alrabei, D.S. Ababnehi, The Moderating Effect of Information Technology on the Relationship between Audit Quality and the Quality of Accounting Information: Jordanian Auditors' Perception, *Journal of Theoretical and Applied Information Technology*,**99**, 3365-3378 (2021).

[9] Winsand B., Warmbier D. Risk assessment safe installations can make the mill a safer and more productive workplace // MPT.- 2017.-V.1. – p.46-47.

[10] A.M. Alrabei, L.N. Al-Othman, T.A. Abutaber, M.S. Alathamneh, T.M. Almomani, M.H. Qeshta, S.A.M. Amareen, Nexus between Intellectual Capital and Financial Performance Sustainability: Evidence from Listed Jordanian Firms. *Appl. Math.*,**17**, 881-888 (2023).

[11] A.M. Alrabei, L.N. Al-Othman, F.A. Al-Dalabih, T. Taber, B.J. Ali, S.A.M. Amareen, The impact of mobile payment on the financial inclusion rates, *Information Sciences Letters*,**11**, 1033-1044 (2022).

[12] A. Jahmani, O. Jawabreh, R. Abokhoza, A.M. Alrabei, The impact of marketing mix elements on tourist's satisfaction towards Five Stars Hotel Services in Dubai during COVID-19, *Journal of Environmental Management & Tourism*,**14**, 335-346 (2023).

[13] Grebenik V.M., Tsapko V.K. Reliability of metallurgical equipment: reference book.-Moscow: Metallurgy.- 1989.- 592p. (in Russian).

[14] A.M. Alrabei, A.A.A. Haija, L.A. Aryan, The mediating effect of information technology on the relationship between organizational culture and accounting information system, *International Journal of Advanced Science and Technology*,**29**, 1085-1095 (2020).

[15] T. Almomani, M. Almomani, M. Obeidat, M. Alathamneh, A. Alrabei, M. Al-Tahrawi, D. Almajali, Audit committee characteristics and firm performance in Jordan: The moderating effect of board of directors' ownership, *Uncertain Supply Chain Management*,**11**, 1897-1904 (2023).

[16] H.A. Owida, N.M. Turab, J. Al-Nabulsi, Carbon nanomaterials advancements for biomedical applications, *Bulletin of Electrical Engineering and Informatics*,**12**, 891-901 (2023).

[17] Collacott R.A. Mechanical fault diagnosis and condition monitoring.- New York: Wiley. – 1977. - 496p.

[18] H.A. Owida, J.I. Al-Nabulsi, N.M. Turab, F. Alnaimat, H. Rababah, M.Y. Shakour, Autocharging techniques for implantable medical applications, *International Journal of Biomaterials*,**2021**, 6074657 (2021).

[19] B. Al-Naami, H. Abu Owida, M. Abu Mallouh, A new prototype of smart wearable monitoring system solution for Alzheimer's patients, *Medical Devices: Evidence and Research*,**14**, 423-433 (2021).

[20] H.A. Owida, H.S. Migdadi, O.S.M. Hemied, N.F.F. Alshdaifat, S.F.A. Abuowaida, R.S. Alkhawaldeh, Deep learning algorithms to improve COVID-19 classification based on CT images, *Bulletin of Electrical Engineering and Informatics*,**11**, 2876-2885 (2022). https://doi.org/10.11591/eei.v11i5.3802

[21] Gharaibeh N. S., Matarneh M. I. and Artyukh V.G. Loading Decrease in Metallurgical Machines // Res. J. Appl. Sci. Eng. Technol. - V. 8(12). - 2014. - p. 1461-1464.

[22] H. Abu Owida, Recent biomimetic approaches for articular cartilage tissue engineering and their clinical applications: narrative review of the literature, *Advances in Orthopedics*,**2022**, 8670174 (2022).

[23] H.A. Owida,O.S.M. Hemied, R.S. Alkhawaldeh, N.F.F. Alshdaifat, S.F.A. Abuowaida, Improved deep learning approaches for covid-19 recognition in ct images, *Journal of Theoretical and Applied Information Technology*,**100**, 4925-4931 (2022).

[24] H.A. Owida, H.S. Migdadi, O.S.M. Hemied, N.F.F. Alshdaifat, S.F.A. Abuowaida, R.S. Alkhawaldeh, Deep learning algorithms to improve COVID-19 classification based on CT images, *Bulletin of Electrical Engineering and Informatics*,**11**, 2876-2885 (2022).

[25] Bol'shakov V. I. Loads and strength of metallurgical equipment //Materials Science, Vol. 37, No. 2, 2001 p.311-318.

[26] Kogaev V. P. Calculation of strength under stresses variable in time. –Moscow: Mashinostroenie. - 1977. - (in Russian).

[27] Maltcev A.A., Rusakov A.D. Predicting the lifetime of parts of the main line work stand "PNA-320" // Rolled products. - 2012. - No. 6. - P. 33-37. (in Russian).

[28] Konovalov L.V. Statistical analysis and synthesis of technological loading of working stands of rolling mills // Steel. - 1993. - No.12. - p.30-36.(in Russian) .

[29] Belodedenko S.V. Evaluation of safe longevity of structural elements in the design and operation of process equipment / Factory laboratory. Diagnosis of materials.-2005.-No.6.-p.40-46. (in Russian).

Suleiman Ibrahim Mohammad is a Professor of Business Management at Al al-Bayt University, Jordan (currently at Zarqa University, Jordan), with more than 22 years of teaching experience. He has published over 400 research papers in prestigious journals. He holds a PhD in Financial Management and an MCom from Rajasthan University, India, and a Bachelor's in Commerce from Yarmouk University, Jordan. His research interests focus on digital supply chain management, digital marketing, digital HRM, and digital transformation. His ORCID ID is orcid.org/0000-0001-6156-9063.

Khaleel Al-Daoud is an Associate Professor of Accounting at Al-Ahliyya Amman University with a Ph.D. in Accounting from Universiti Utara Malaysia. He has taught a wide range of accounting courses, including Managerial Accounting and Islamic Accounting. His research interests focus on corporate governance and forensic accounting, with numerous publications in prestigious journals. Dr. Al-Daoud has also participated in international conferences and supervised several university theses on key accounting topics. He has practical experience as an accountant and has received recognition, including an award for his research from Universiti Utara Malaysia. His work contributes significantly to both the academic and professional fields of accounting.

Badrea Saleh Al Oraini is an accomplished Assistant Professor of Marketing at Qassim University, with a robust academic background, including a Ph.D. in E-Marketing from Strathclyde University. With over two decades of teaching experience, Dr. Al Oraini has significantly contributed to the academic community through research-led teaching, participation in university committees, and a commitment to community service. Her research interests include digital marketing, AI in supply chains, and adopting new technologies, reflecting her dedication to advancing the marketing field in both academic and practical contexts.

Iyad Abdulilah Khanfar is an Associate Professor in the Faculty of Economics and Administrative Sciences – E-Marketing & social media department at Zarqa University in Jordan. He earned his PhD in Marketing from the University of Rajasthan in India in 2002, a master’s degree in commerce from the University of Mysore in India in 1998, and a Bachelor’s degree in Commerce from Marathwada University in India in 1995. He has extensive teaching experience, having worked at several universities in Jordan and Saudi Arabia. Since 2012, E-Marketing & social media department at Zarqa University in Jordan. Previously, he served at King Abdul-Aziz University in Saudi Arabia and the Hashemite University and Al-Isra University in Jordan. Dr. Khanfar has published several research papers in peer-reviewed scientific journals, additionally, he has authored several books in the field of marketing. He is also a member of various scientific and professional committees.

Asokan Vasudevan is a distinguished academic at INTI International University, Malaysia. He holds multiple degrees, including a PhD in Management from UNITEN, Malaysia, and has held key roles such as Lecturer, Department Chair, and Program Director. His research, published in esteemed journals, focuses on business management, ethics, and leadership. Dr. Vasudevan has received several awards, including the Best Lecturer Award from Infrastructure University Kuala Lumpur and the Teaching Excellence Award from INTI International University. His ORCID ID is orcid.org/0000-0002-9866-4045.