JSTER | JOURNAL OF SCIENTIFIC, TECHNOLOGY AND ENGINEERING RESEARCH

Bilim, Teknoloji ve Mühendislik Araştırmaları Dergisi
***ISSN*: 2717-8404**
Cilt/*Volume*: 3 Sayı/Issue: 1 Yıl/*Year*: 2022

JOURNAL

SCIENTIFIC | TECHNOLOGY | ENGINEERING

Bilim ⊕ Teknoloji ⊕ Mühendislik

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ISSN : 2717-8404 *https://dergipark.org.tr/tr/pub/jster*

RESEARCH ARTICLE

Validity of Exponential Distribution for Modelling Inter-failure Arrival Times of Windows based Industrial Process Control Data Exchange

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HIGHLIGHTS

- *Investigates failure arrivals in a Windows Industrial Workshop Communication environment*
- *Among the rare observations for failure arrival times.*
- *Exponential can be used with reasonable error that paves way for Markovian Analysis.*

Keywords:

- Inter-Failure Arrival Times and distribution
- Markov Arrival Processes
- Exponential Arrival Process
- Test for sample Independence
- Goodness of Fit Tests

GRAPHICAL ABSTRACT

Using a reliability function with a known classical distribution, at an instance in time, the chances of an activity success can be predicted. Based on this curve, a proper reset period can be appointed. This would help to keep the risk under control. For this purpose, a test bed mimicking the machine to machine (M2M) communication of a Digital Oil Rig is employed. It contains an Embedded Computer Server and an ordinary computer acting as a client querying data from the server. On this testbed, as the communication protocol Open Platform Communications - Unified Architecture (OPC UA) is run. In “most occasions, the arrival processes are assumed as a Poisson Arrival Process. The Question of a concern: "Is this assumption valid in case of an Embedded Computer responding to queries?". Our results indicate that the failure arrivals are independent identically distributed (IID) and can be modeled with an Exponential Distribution by accepting a reasonable error.

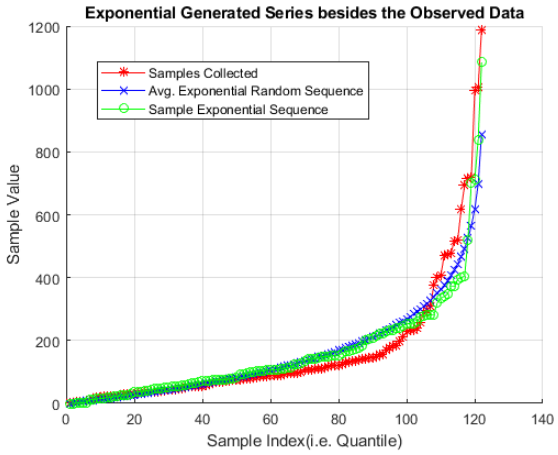

Figure A. or Table A The name figure or table about given info and results

Article Info:

Received: 31 October 2021
Accepted: 23 November 2021

DOI: 10.53525/jster.1017004

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Aim of Article: *To illustrate that the failure arrival times can be according to a known distribution.*

Theory and Methodology: *Observations on physical peer to peer system is performed for Industrial Workshop communication protocol running on Windows. The number of repeated actions is observed and recorded as failure arrival times. These arrival series are investigated with Goodness of Fit tests for their stochastic character.*

Findings and Results: *It is quite possible with reasonable error to model inter-failure arrival times as Exponentially distributed, whereas, for average ranges Gaussian is useful as well.*

Conclusion: *The failures of an windows industrial workshop software communications can be modelled with Markovian Arrival Processes.*

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Citation:
Yücesan, O., Ozkil, A., Özbek, M.E., (2022). *The Problems Encountered in the Process of Publishing Articles in the Journal and Investigation of the Solutions*, Journal of Science, Technology and Engineering Research, 3(1):1-8. DOI:10.53525/jster.1017004

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Using a reliability function with a known classical distribution, at an instance in time, the chances of an activity success can be predicted. Based on this curve, a proper reset period can be appointed. This would help to keep the risk under control. For this purpose, a test bed mimicking the machine to machine (M2M) communication of a Digital Oil Rig is employed. It contains an Embedded Computer Server and an ordinary computer acting as a client querying data from the server. On this testbed, as the communication protocol Open Platform Communications - Unified Architecture (OPC-UA) is run. In “most occasions, the arrival processes are assumed as a Poisson Arrival Process. The Question of a concern: "Is this assumption valid in case of an Embedded Computer responding to queries?". Our results indicate that the failure arrivals are independent identically distributed (IID) and can be modelled with an Exponential Distribution by accepting a reasonable error.

Keywords: Inter-Failure Arrival Times, Markov Arrival Processes, Exponential Arrival Process, Test for sample Independence, Goodness of Fit Tests

I. INTRODUCTION

Industrial Internet of Things (IIoT), and Machine to Machine (M2M) communications concepts include research for devices to be able to collaborate with other entities. When there are humans in the cycle, the reliable operations are related to their safety. The verification and validation activities in form of functional tests can be a method for tackling the issue.

The reliability, when there is a single core CPU, can be dependent on the utilizations. When maximum utilization is reached, resources to address any other functionality is not there. Besides, the reliability can be dependent on "how often and how many repetitions of the same function takes place?". The executions of the same command may not result with success always. By observing inter-failure durations, a reliability function can be identified. Under realistic scenarios, a company would be able to establish

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guarantee periods and maintenance schedules based on this data. For this instance, a series of experiments targeting to collect the inter-failure durations are conducted.

The tools employed in the study are Commercial of the Shelf (COTS) Window based OPC UA server and a Prosys Client Modified to support an HMI. These are running on a 1.4 GHz Celeron Server and an i7 Desktop computer in respective ordering. The performance aspects of OPC UA Server-Client architectures are widely investigated. As well as, the latencies are considered in many studies.

Among the previous studies about performance bottleneck identifications, Burger et al. [1]. Cavalieri et al. [2] studies the end-to-end delay performance of OPC UA suites. Morato et al. [8] indicates there may be further time delays in cases of Real Time operating systems just to regulate the process period.

Eckhardt et al. [3] studies the round-trip time of OPC UA Server and client architecture. Their Xilinx systems use a dedicated ARM Real Time Processor for performing Ethernet communication tasks. Cenedese et al. [4] compares the RTT performances of open source OPC UA servers and clients, where C based open62541 is identified as more efficient. Kim et al. [5] indicates that there is an optimum point for the highest transferable data rate with respect to the query interval. Unix, Linux and Windows seem to be equivalently open to the Denial-of-Service attacks (DoS) which have been studied by Neu et al. [6] for OPC UA.

If a Markovian Arrival Process is considered, the number of arrivals within a time duration are accepted as Poisson distributed. In this circumstance, the time duration that is needed after an arrival for a new arrival to take place is Exponentially distributed. That is a subcase of Erlangian distribution for k=1. Event is conditioned on a previous arrival had taken place or experiment had started, following a Markovian Character. Garcia-Mora et al. [11] reviews a situation when there are additional significant conditions affecting the duration other than just simple arrival of the previous sample, as an answer to question whether inter-failure times are stationary. Yucesan et al. [9] presents an asymptotic expectation on test duration for a given test suite. This could give an idea about how long a test with given count of test cases could take place. This analysis can be broadened to include variety of failure arrivals. Also, Yucesan et al. [10] present a preceding study investigating effects of increasing load and query periods on reliability.

The rest of the paper is organized as follows: in Section II. Experimental results taken from the OPC-UA testbed are provided, as well as, discussions over them in Section III. Finally, the paper is concluded in Section IV.

II. EXPERIMENTAL RESULTS

A continuous block of data transfer, which is called Historic Data Access (HDA), is employed for this effort. For instance, we monitor failure arrivals on Commercial of the Shelf (COTS) Windows OPC UA platform. Two observation series will be investigated for how all samples statistically could have come from the same distribution. First comes from Mean time Between Failure (MTBF) observations. The second is obtained by gathering all observations.

A. MTBF Observations and Candidate Random Distributions

MTBF data placed into a sorted series. To compare the MTBF series, same size pseudo-random exponential sequences are presented in an averaged and an example format. These sequences are sorted and rounded to the nearest integer. We can see them in Figure 1. The purpose is to find out if the underlying distribution of observed series are suiting to an Exponential or another random variable, see Trivedi et al. [7].

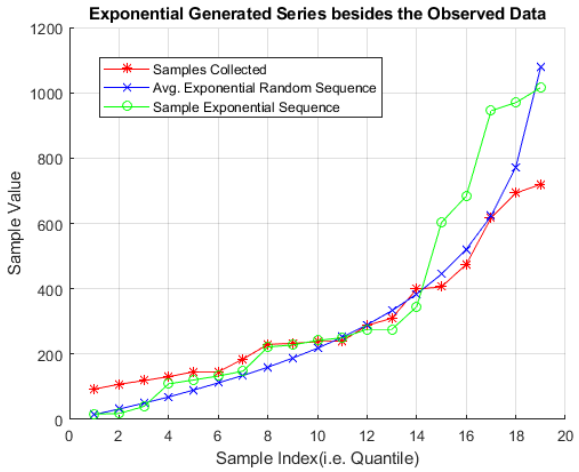

Figure 1 Collected samples sorted manner along with Sorted Series of generated Random Numbers according to an Exponential Random Variable. An example and averaged series.

From the figure, it is seen that the samples collected do not start from zero (0) level. They have a threshold above this value. Since the data are collected by

continuing the experiment till to a point, where the transmitted window remains empty, a threshold form. If we look at them side by side, the lower quantiles or indices of exponential random specimens have lower sample values with regard to the collected data. The higher quantiles or indices for exponential have higher values. Mid ranges have better fit among the series. For better understanding the underlying character, further examinations will be performed in the following sections.

B. Distribution Comparison with QQ plots

In this section, the results of comparisons which have been made using available QQplot functionality of MATLAB is presented. The consistently collected MTBF results are compared to the various series obtained by using the random number generator of MATLAB through variety of candidate stochastic distributions. Once again sorted series are compared.

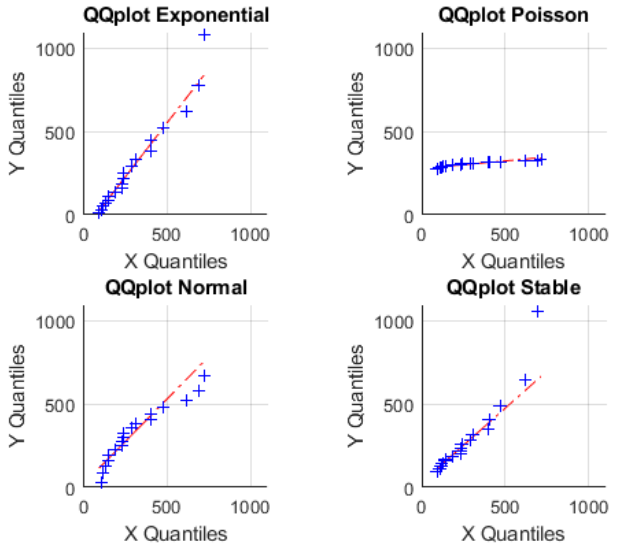

Figure 2 Plots for comparisons with Exponential, Poisson, Normal and Stable Distributions.

For this instance, the sample mean μ= 304.0526 and the standard deviation σ = 197.4078 from the consistent MTBF series was calculated. The series used for comparison are the samples from the Exponential, Poisson and Normal pseudorandom generated series regarding to the obtained mean and standard deviation. The Quantile to Quantile (QQ) plots are presented in Figure 2. X-axis corresponds to the samples of the observed experimental results. The y-axis corresponds to the quantiles of distributions generated with pseudo random number generator. Figure is drawn as (x,y) ordered pairs. The stable distribution characteristic equation is as defined in Equation (1). Others are classical known distributions. The parameters for the Stable distribution are α= 1.02024, β= 1.0, δ= 72.4507 and γ= 190.45.

$$E(e\hat{}(itX)) = \begin{cases} exp\left(-\gamma^{\alpha}|t|^{\alpha}\left[1+i\beta sign(t)tan\frac{\pi}{2}((\gamma|t|)^{1-\alpha})\right]+i\delta t\right), \alpha \neq 1, \\ exp\left(-\gamma|t|\left[1+i\beta sign(t)tan\frac{\pi}{2}(\gamma|t|)\right]+i\delta t\right), \alpha = 1 \end{cases} \quad (1)$$

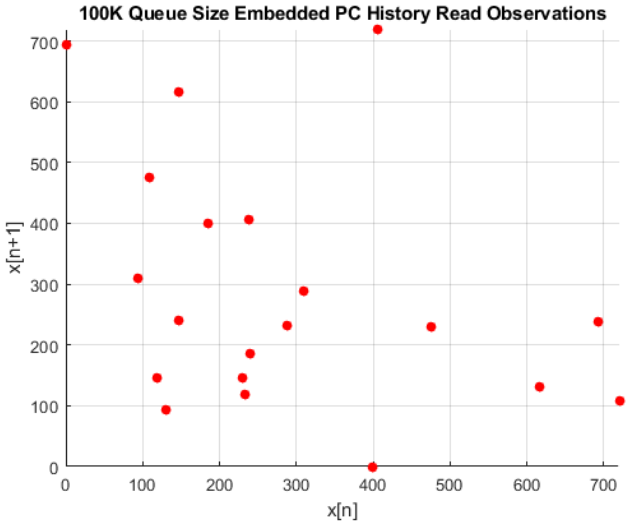

Figure 3 XY Scatterplots drawn with x[n] versus x[n+1]

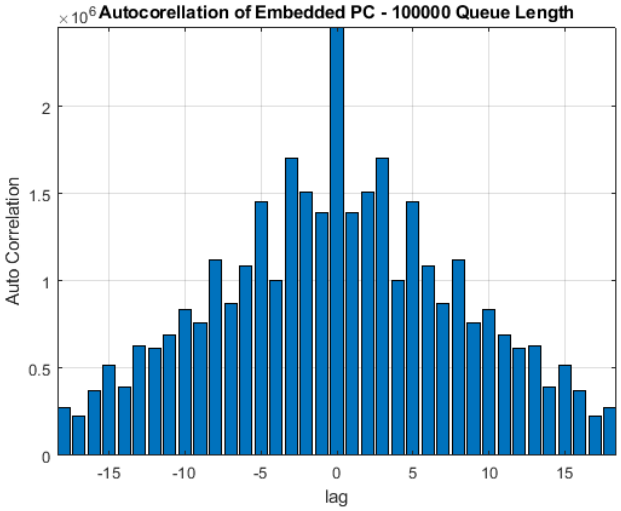

Figure 4 The auto-correlation plot of the Independent Identical Distribution (IID) property

In the QQ plots, the Exponential distribution presents a linear manner fit with an acceptable error. There is a shift towards right, representing the threshold of the consistent MTBF series. The Poisson is generally used for modelling the probabilities of the

accumulated chances of arrivals, which is not the case in the examination perspective. The Gaussian distribution presents a good match around the mid-range values. Early quantiles from the Gaussian series have negative sample values. The tail also presents fluctuations. The Stable distribution is coming from the MATLAB Distribution Fitter. It is more suitably crafted for the specifics of the MTBF series observations, rather than general characteristics of the experiment.

C. Is the sequence Independent Identically Distributed?

In the scatter graph, obtained in respective order of the observation from the MTBF series, as observed from Figure 3 there are no evident patterns, other than an insignificant alignment between 200 to 300 values. When the autocorrelation results in Figure 4 are considered for consistent MTBF series, with the first shift there is a significant fall. This emphasizes the independence among samples. For a shorter series, the values obviously have limited difference. The level keeps on falling slowly. This would be due to reasonable amounts of errors. The oscillations and slow behavior represent an identical structure.

D. All Embedded PC Observations

The data considered for this section is an all-inclusive observation set from the experiments. It even includes early phases' results and outcomes, when the test scenario was not mature, included all sorts of different working conditions.

In Figure 5, we can observe the red asterisk pointed line as all samples obtained during experimentation. The highest duration observed is 1200 sample valued experiment result with index 122. There is also a 1005 sample valued time with 120th indexed outcome. This value was observed during a later experiment with 12 variables. The observation is way above the average in the consistent MTBF series that could have appeared within this series as well.

The green line with circle points is an example exponential series, where blue crossed pointed lines are averaged exponential series. The Figure 5 also indicates that an exponential generated random number sequence tail resembling to the observations could have had happened in reality, as green line is very close to red observations series.

The QQ plots available in Figure 6 tells that the early samples of exponential present very good match with the observation series. When middle ranges reached, a second line is observed for exponential. Omitting Poisson, the Normal has similar character.

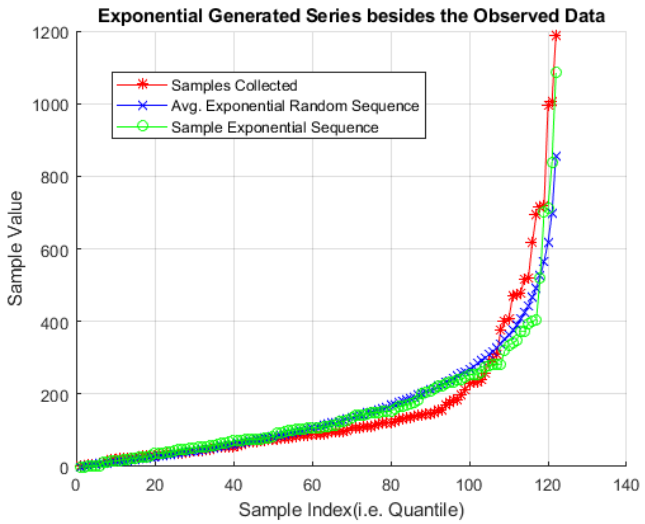

Figure 5 Sorted Series of observed Mean Time Between Failure (MTBF) Results for all samples

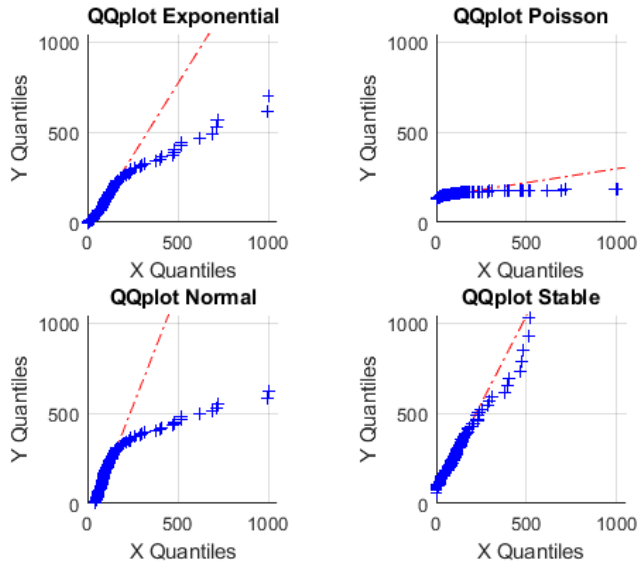

Figure 6 Plots for comparisons with Exponential, Poisson, Normal and Stable Distributions over all sample

However, the shift towards right is due to the early negative sample valued quantiles of the Gaussian pseudo random series. Even though *Stable* sequence looks like matching almost perfectly to the all-inclusive set, as can be observed from the Figure 7, it has excessively high values for the tail part as represented with red lines. This figure includes averaged sequence over repeated generation of the series of random numbers for more than 120 experimentations with pseudorandom generator. The blue line in this figure is for the Gaussian, the green

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is the Exponential, where almost flat black dotted line for the Poisson random number generators. It reflects specifically crafted character of the Stable again regarding just the available set of samples for MTBF series. In the Scatter graph presented in the Figure 8, the scatter graph has no evident patterns. The Autocorrelations available in Figure 9 shows that there is a great fall with the first shift. There are also oscillations and eventually correlation slightly fade. This reflects the identical behavior and also some imperfections. Since level is below a threshold, it is reasonable to indicate that the series has IID property acceptable within error tolerances.

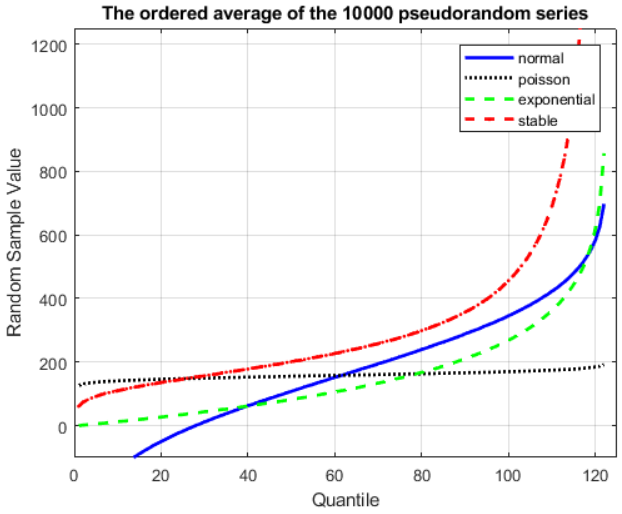

Figure 7 Ordered Samples from pseudo random series generated according to Normal, Poisson, Exponential and Stable distributions over all samples from Embedded PC

E. Distribution Comparisons with Goodness of Fit Tests

There are two set of tables available for this section. First of them is on the results obtained from the consistently obtained set. Second is the set of all included set of observations. Since all embedded PC samples have IID property and include the consistent set, the results are comparable to each other by accepting certain errors and statistical differences.

These are referred to as Manual K-S and MATLAB K-S respectively to the ordering in Table I-A. The Manual K-S in the table indicates 10% significance for not being able to reject the Exponential distribution and 20% significance for the Gaussian random variable. However, it rejects the Stable distribution, because the manual implementation does not exclude the tail samples that are off. Omitting some samples is common in statistical techniques. This is reflected in the results for the MATLAB K-S tests, they mention Stable distribution generated one have the best fit with 35% significance. The Gaussian and the Exponential are at 10% and 30% significance. The MATLAB A-D indicates similar results, 15%, 35% and 40% significance for the Exponential, Gaussian and the Stable respectively. Where it is 20%, 25% and 40% for χ^2 test with same respective ordering.

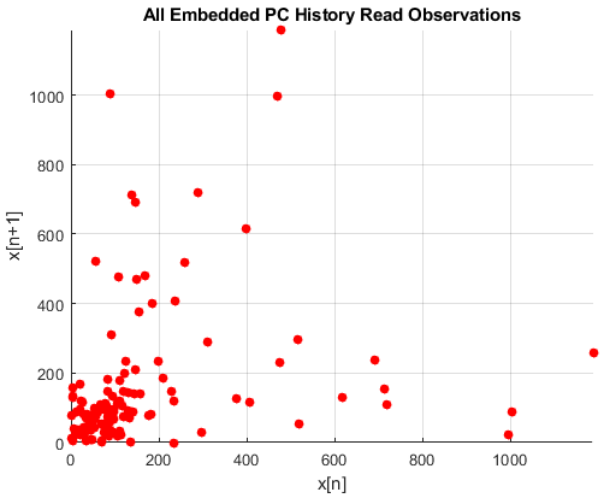

Figure 8 XY Scatterplots drawn with x[n] versus x[n+1]

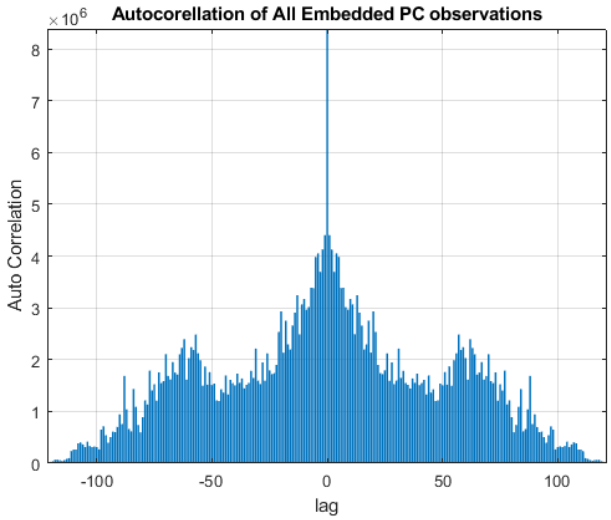

Figure 9 The auto-correlation plot of the Independent Identical Distribution (IID) property for all observed samples

When considering the Table I-B, we observe that for samples collected from all experiments, even the significance levels are low, one cannot deny the existence of exponential character. The significances for these results are with 2%, 1%, 1% and 0.5% for Manual K-S, Matlab K-S, A-D and χ^2 tests with respective order.

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Goodness of Fit Test Results				
Distrib.	Manual K-S	Matlab K-S	MatlabA-D	$\chi 2$
Expon. Gauss Stable	10% Sign. 20% Sign. Null H. Rej	10% Sign. 30% Sign. 35% Sign.	15% Sign. 35% Sign. 40% Sign.	20% Sign. 25% Sign. 40% Sign.

A

Goodness of Fit Test Results				
Distrib.	Manual K-S	Matlab K-S	MatlabA-D	$\chi 2$
Expon. Gauss Stable	2% Sign. Null Rej Null Rej	1% Sign. Null Rej Null Rej	1% Sign. Null Rej Null Rej	0.5% Sign. Null Rej Null Rej

B

Table 1 *The results of the Goodness of Fit Tests with respect to Exponential, Normal, Stable distributions tested with Kolmogorov-Smirnov Manually and on MATLAB, Anderson Darling on MATLAB, and $\chi 2$ on MATLAB*

III. DISCUSSIONS

The consistent MTBF series, since its samples were collected in disciplined manner involved a threshold. This series did not have any immature test starts. As additional data were collected in the later stages of the research effort, some sample values unexpectedly arrived alike 1005. This reaffirms that as number of observations increases, the confidence to the results increases. Furthermore, that with series distributed according to an exponential random variable, any value for the outcome is possible. By results of the goodness of fit tests, QQ-plots, scatter and autocorrelation graphs, the IID property and exponential underlying distribution was found to be undeniable to certain significances. The generality of the samples is accumulated in the smaller values, emphasizing also that the exponential has its most power in the smaller sample values. Therefore, character of the existing samples is determined to a degree. The Stable Distribution sequence rather than capturing possible subsequent outcomes, it offers predictions for the data present at hand. Early quantiles of this distribution have a better fit while the tail has evident deviations.

The goodness of fit tests indicates Gaussian can be of a choice. It can be observed in the Figure 7 as well, that for the middle ranges, Gaussian and Exponential variables approaches each other. Therefore, even though goodness of fit tests would not give a direct result, for middle ranged conditions like MTBF, the Gaussian random variable can bring ease to reliability predictions.

Since the resets are almost perfect, if not leaving a heat trace from a previous run, the IID property and theoretical matches of Exponential distribution are reasonable for an Embedded computer condition. However, heat such as room temperature, heat of the CPU, how much aimed to be alleviated with uses of the fans, may be a reason of imperfections on IID results. Since it's granted that a stationary series is to have autocorrelation with only central lag is significant, it is not necessarily true that the auto correlation following this rule grants stationary property. In our observations, in some series slightly Near-Term Dependence, which is the case for Wide Sense Stationary signals are the case. We accept this situation within scope of reasonable error.

Through the study, the concentration has been on the exponential inter-arrival times and their IID character. It may be a good future work to investigate independent identical or homogenous character of the Poisson Arrival Process or an Erlangian Arrival Process based on accumulated result of times. Our study presented early results of reliability in this field, which could be useful in almost any Industrial Workshop communication where clients are most of the time lacking means of many resources. These communication mechanisms are, as well, used for some aeronautical vehicles and space baring student probe rockets [12] requiring some rigorous availabilities.

IV. CONCLUSION

The observations of 304 read counts corresponding to roughly 76 minutes of MTBF is tiny for 7/24 intense operations. Same value is 159.19 reads with all samples included. The Celeron 1.4 Ghz Embedded PC computer is for lot simpler tasks than bulky continuous transfers of historic data with lacking cache structure not being able to utilize CPU to its maximum extend.

Per the observations on Failure Arrivals in an M2M environment, with the data at hand, it is possible to tell classical assumption of modeling any arrival process with Exponential inter-arrival times is valid also for Failure Arrivals with OPC UA Client/Server Architecture History Reads as well. It is therefore possible to predict the outcomes of the future experiments over the given scenario.

CONFLICTS OF INTEREST

They reported that there was no conflict of interest between the authors and their respective institutions.

RESEARCH AND PUBLICATION ETHICS

In the studies carried out within the scope of this article, the rules of research and publication ethics were followed.

ACKNOWLEDGMENT

This research is supported by TUBITAK (KAMAG) under the grant no: 115G007. Research is conducted for the needs of Turkish Petroleum Anonymous Partnership (TPAO) and Turkish Petroleum International Company (TPIC).

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JOURNAL OF SCIENCE, TECHNOLOGY AND ENGINEERING RESEARCH
Bilim, Teknoloji ve Mühendislik Araştırmaları Dergisi, (2022) - 3(1): 9-23
ISSN : 2717-8404 *https://dergipark.org.tr/en/pub/jster*

RESEARCH ARTICLE

Job Stress Assessment and Analyzing the Factors Influencing Health Care Workers during COVID-19 Pandemic in Saudi Arabia

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HIGHLIGHTS

- *Stress affected health care workers negatively during COVID-19*
- *Reliable sources of information can improve workers' efficiency*
- *A financial plan can help reduce work-related stress during COVID-19*
- *Statistical approaches were employed to balance the psychological, economic, and work-related stress.*

Keywords:

- Job Stress Assessment
- COVID-19 Pandemic
- Financial Factor
- Work-related Stress
- Structural Equation Model

Article Info:

Received : 14 February 2022
Accepted : 4 March 2022

DOI:

10.53525/jster.1073058

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GRAPHICAL ABSTRACT

This study was undertaken to explore the influences of socio-demographics, psychological and financial factors on work-related stress; amongst health employees in Saudi Arabia in due course of the pandemic. The study was conducted in some hospitals on 204 health workers. The techniques mainly include the statistical methods and a self-administered questionnaire held in the hospitals. Figure A shows the factors influencing work-related stress.

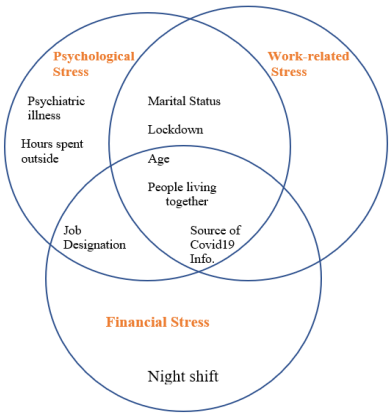

Figure A. The factors influencing work-related stress

Aim of Article: *The prevalence and identification of potential factors contributing to mental health problems, financial impact, and work-related stress of healthcare workers.*

Theory and Methodology: *Descriptive analysis explores the levels of factors. Also, Cluster analysis and chi-square examine the effects factors on stress. Finally, the regression model and a multivariate structural equation model peer the influence of financial and psychological factors on work-related stress.*

Findings and Results: *Financial factors have the most significant relationship with work-related stress (Correlation= 0.401, p-value = 0.001). financial and phycological burden increases by 1 unit, the work-related stress increase by (0.289) unit on average. Not all sociodemographic factors are linked to work-related stress among health workers.*

Conclusion: *Health workers should avoid living alone and get COVID-19 information from reliable sources such as the Ministry of Health and trusted Journals to improve their work efficiency.*

RESEARCH ARTICLE

Job Stress Assessment and Analyzing the Factors Influencing Health Care Workers during COVID-19 Pandemic in Saudi Arabia

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Citation:

Alharbi, R., Taylan, O. (2022). *Job Stress Assessment and Analysing the Factors Influencing Health Care Workers during COVID-19 Pandemic in Saudi Arabia*, Journal of Science, Technology and Engineering Research, 3(1):9-23. Doi:10.53525/jster.1073058

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ABSTRACT

This study was undertaken to explore the influences of sociodemographic, psychological, and financial factors on work-related stress amongst health employees in Saudi Arabia during the COVID-19 pandemic. The study was conducted in two hospitals on 204 health workers. The techniques mainly include the statistical methods and self-administered questionnaires held in the hospitals. The analysis was carried out using Regression Model, a multivariate Structural Equation Model. Descriptive statistics, chi-square distribution, and correlation of the factors were employed to assess the factors. The preliminary analysis depicted that the financial factors have the most significant effects. It was found that the work-related stress increases by 0.280 units on average when the overall psychological stress level increases 1 unit negatively when all other constraints (financial, people living with workers, and hour's spending outside) are kept fixed. Linguistic terms such as "Moderate, high, low, etc." were used to analyse the data for qualitative factors.Moreover, a cluster analysis was carried out to determine the level of financial stress and the factors causing psychological stress. In contrast, the structural equation model depicted that not all sociodemographic factors are linked to work stress among health workers. This study will indorse all related bodies to establish a new approach to relieving health workers of financial burdens and provide them with efficient counseling and psychosocial management interventions.

Keywords: Job Stress Assessment, COVID-19 Pandemic, Financial Factors, Work-related Stress, Structural Equation Model.

I. INTRODUCTION

Infectious illness waves such as COVID-19 may lead to psychological stress and a range of mental disorders combined in the workplace. The workers have been affected, especially from the mental health, financial perspective, and work-related perspectives during the COVID-19 pandemic [1]. Posttraumatic stress (PTSS) signs may develop beyond human control after traumatic events such as poignant physical attacks,

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ISSN : 2717-8404 *https://dergipark.org.tr/en/pub/jster*

excruciation, mishaps, infringement, or natural catastrophes, and can be identified by persistent trauma, avoidance of stimuli, emotional numbness, and physiological hyperarousal [2]. More than a few studies have explored the work-related stress and effects on psychological healthiness on the PTSS in due course of former pandemics. For instance, during SARS, 3.7% of the public was found to have depression [3], while around 18 % of the medical employees had psychological symptoms [4], and 41% of the SARS survivors had lived through Posttraumatic stress disorder (PTSD) in due course of the outbreak [5]. A full-scale work in the U.K. showed that (PTSD) predominance during the prologue COVID-19 pandemic is about 4.4%, and no difference between the genders was found in this study [6]. For instance, current work by Liu *et al*. [7] divulged that most of the population in the areas hardest hit by the COVID-19 epidemic had PTSS within four weeks following the epidemic, with a higher predominance among females who had inadequate sleeping conditions.

Furthermore, some researchers have expressed their concerns about the extensive scale and transmission of COVID-19, which may cause an actual psychological health emergency, affecting work performance, particularly in nations with heavy workloads [8]. To achieve this, large-scale psychosocial initiatives will have to be implemented in the future and include psychological healthcare programs into catastrophe prevention strategies and practices. The experiences about COVID-19 regarding compatibility with the isolation circumstances, challenges, mental repercussions, financial impacts, work-related stresses, and psychological impact need to be researched in detail with the advanced approaches. It is worth mentioning that very few have examined the psychological impact, work-related stress, and financial impact on hospital workers, more importantly in due course of the pandemic.

The objectives of this study include;

- To examine the level of work-related, financial, and psychological stress among health workers during the COVID-19 pandemic
- To determine the factors that contribute to stress among health workers in Saudi Arabia
- To provide a practical recommendation that facilitates stress management among health workers

We established a conjecture that states COVID-19 causes trouble and negatively affects workers. This trouble and negativity have cause not only psychological effects but also had a financial impact and job-related stress on the staff employed in the hospitals. It also causes various mental disorders such as depression and anxiety signs. In our research, the predominance and characterization of possible variables that lead to psychological healthiness disturbances, financial outcomes, and work-related stress of healthcare workers at hospitals are carefully addressed. Findings from this research will inform the concerned authorities and help them develop strategies for early identification of distress and thus prevent work-related problems; performance diminishes, mental or psychological issues, and other difficulties among health care workers.

Hence the hypothesis is formulated as follows:

- Hypothesis 1 (H_1) = COVID – 19 has adverse effects on workers' performance
- Hypothesis 2 (H_2) = COVID – 19 does not have adverse effects on workers' performance

We used the SPSS package (version 27). Statistical tools were used to derive insights from the data set. First, we carried out a descriptive analysis to explore work-related stress, financial factors, psychological factors, and the distribution of demographic characteristics amongst the respondents. Secondly, cluster analysis and chi-square (bivariate analysis) was conducted to determine demographic factors' impacts on work-related stress. Lastly, a multivariate linear regression model and a multivariate structural equation approach were employed to examine the influence of financial and psychological factors on work-related stress during the COVID-19 pandemic.

Mainly, testing hypotheses about individual care effects will not be very significant since they are designated randomly. In this work, we are more interested in considering the population of remedies to test the hypotheses about the variance of components. This work carried out cluster analysis to find the homogenous distribution datasets. Hence, correspondence analysis was found for the levels in financial stress that have significant high dimensions across all levels of stress analysis. Linguistic terms such as "Moderate, high, low, etc." have been used to quantify and analyze the data and factors in this study. The survey participants who have "a little bit" financial burden also considered "a little bit" work stress. Those who claimed to have "moderate" psychological stress and high financial stress have been deemed to have high work stress, and those who claimed to have "high" work stress and "high" level financial problems were considered to have "high" psychological stress. Additionally, the structural equation model determined

that not all sociodemographic factors are linked to work-related stress among health workers.

Therefore, this study recommends that the official bodies investigate relieving health workers of financial burdens and provide them with efficient counseling and psychosocial management interventions. Viewed by the workers, the study also recommends that health workers avoid living alone and get COVID-19 information from reliable sources such as the ministry of health, T.V.s, and trusted journals to improve their work efficiency.

II. THE LOGICAL FRAMEWORK OF WORK-RELATED STRESS:

Cooper [9] determined six variables as accurate Occupational Stress Indicators (OSI) to assess the stress. They can be considered fundamental to the duty, organizing function, relationships with other peoples, organizing process and atmosphere, work/home integration, and career advancement. Hence, the stress-related factors can be divided into six categories: inheriting job stress, role within the management, career advancement, climate in the workplace, interpersonal relations within the organization, and individual variables [10]. The stress-creating factors can be put into four categories: job/organization-related, links at the workplace, and career advancement [11].

Various factors impacting employees' stress and work performance were examined in this study. A review of the literature was carried out to develop the theoretical background of this study. The elements employed for this study as the stress creators were identified, and then the association between the response and independent variables was predicted. The summary is given in Figure 1 and Figure 2, as follows:

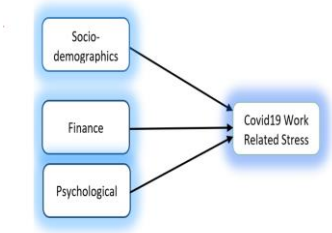

Figure1: The logic perspective of this study

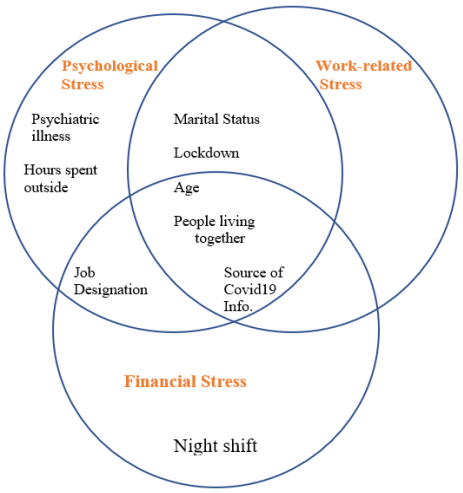

Figure. 2: The factors influencing work-related stress

III. LITERATURE REVIEW

A. The COVID-19 Pandemic:

After initially discovering it in Wuhan, Hubei Province in China, the COVID-19 virus, known as SARS-CoV-2, started transmission in due course of the study in the last month of 2019 and was formally diagnosed designated by the World Health Organization (WHO) in the commence of 2020. It has symptoms such as mild fever, dry cough, sore throat, severe acute respiratory syndrome (SARS), and an expanding range of associated circumstances associated with inflammatory diseases in kids [12]. The virus is readily transmitted from one to another globally, and several mutants have been discovered until now. After the WHO declared COVID-19 a pandemic, a large number of countries have started to adopt heightened social distance, enforcing "blockades" (i.e., prohibiting unneeded transportation, suspending education, and critical business activities), and ordering "wait-at-home [13]." The pandemic caused the highest amount of people simultaneously lockdowns/shutdowns in the past in the globe. It is estimated that by the beginning of April 2020, the lockdown would have affected 3.9 billion people, including 90% of the U.S. population [14] and more than 50% of the global population [15]. Although the vaccination has contributed a lot to reducing mortality, the number of cases increases with the new COVID-19 mutants, and there might be a further lockdown restriction. The health workers are directly affected by this virus.

There has been recent growing concern about the state

of psychological health globally; therefore, certain top-level survey activities have targeted average degrees of stress [16]. Another focus was on anxiousness and depressive disorders at elevated levels [17]. The others were concerned about the possibility of heightened self-injury and self-annihilation, given the recent studies on joblessness due to a former drop in the economy [18]. A general conclusion was reached in some studies that there was a 'perfect storm' of pandemic anxieties, social exclusion owing to lockdowns, layoffs, or the concern of unemployment that put American people's psychological wellness at risk during the pandemic. Many of these studies ignored the consequences of an abrupt switch to remote working during the pandemic. Company managers were already considering making work a standard feature of workers, despite the incomplete data [19].

B. Job-related stress:

After the announcement of the COVID-19 limitations implemented throughout the globe, people found themselves faced with significant alterations in their daily life, both at home and at work [20]. Chronic workplace stress has been demonstrated to have inverse influences on both the employee and the employer, particularly in the helping professions, such as nurses, psychologists, teachers, social workers, and even librarians [21-26]. Some insights were gained for those who unexpectedly moved to work remotely after conducting preliminary research that determined the causal link between distance employment and job-related stress. There are three insights provided by the analyses: the role-stress and role overwork in managing workplace and home challenges [27-29], the physical environmental effect on employee productivity [30], and the effect of an individual impression of time on workplace stress [31]. Each of these problems needs to be searched based on different theoretical frameworks that propose stress analysis affecting probably the "overload of roles" [28] and "spillover" from home-to-work and work-to-home [27], to generate or exacerbate work-family struggles [32, 33]. However, some research recommends that work-related activities positively affect households [34].

It is not surprising that the measurable, sentimental, and psychological factors associated with job stress are also related to job-related stress factors [35]. For instance, exhaustion is a mental symptom caused by prolonged, work-related, physiological, and psych emotional fatigue, which results in detachedness, skepticism, and a diminished sense of competence and achievement, leading to adverse effects on work productivity and motivation [22 24]. Medical and humanitarian vocations have extensively been studied for reasons for burnout since both roles tend to entail substantial levels of specialized competence and many interpersonal interactions [21-24, 26].

Sora et al. [36] suggested that personal feelings of job uncertainty and insecurity may be like an infection in an organizational structure, particularly those with a solid organizational structure. It can make employees less likely to interact within the organization and even cause employees to leave, which are signs of stress [27, 33, 37]. Women who work part-time and are in lower socioeconomic classes [33, 38] have higher stress levels mainly because of overburdened roles [27, 28] and inadequate assistance from their employers and colleagues [35], resulting in family-work tensions [37]. A recent study showed that women are severely affected by family-work stress throughout the COVID-19 restriction period, which is in line with the existing research and other recent COVID-19 results [38]. As the authors reported in their study, some employers (52%) emphasized more flexibility in their policies while only 35% of managers allowed for any accommodation.

C. Stress in organization

There are several reasons workers may have to deal with stress, including pressures or other kinds of requirements imposed on them [39]. Additionally, work-related stress has been demonstrated to adversely affect the performance of events and their constituents [40, 41]. People's performance is affected by stress because of their reaction to the environment. Stress from a job can cause differences in how demands on families are distributed among them, as well as those who can maintain their position [40], as well as those who feel their job security is uncertain (because they fear losing their job), or those whose marriage is strained. Stress occurs either huge or tiny in every organization or workplace and is so complex for several reasons, has been searched in the U.K. to deal with a specific scenario [43] to solve the problems. Eleven factors were found to constitute the background of stress: overburden, role uncertainty, pandemic, liability for employees, involvement, shortage of guidance, keeping pace with rapid technological advancement, entering a position of leadership, career

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progression, organizational design, environment, and periodic events. An overload is an unmanageable task or task beyond a person's capabilities [44-46]. Rose's view [47] revealed that employees are inclined to experience considerable stress in terms of time, spending long hours, which diminishes their desire to perform better. Managing approaches help reduce or contribute to increasing the tension of employees. Several explanations may cause stress on employees' families and contribute to intentions to leave [48, 49] the job. A few scientific investigations have shown a link between anxious stress and employee productivity, showing that employees at different administrative levels could improve their productivity under reduced nervous pressure [50].

IV. Research Design and Methodology

A. Study Design:

To gain data for the survey, a questionnaire was designed [51] to measure stress levels among employees and to categorize the factors which might cause stress under the circumstances. These allow the study of elements with the assistance of random samples of the target population and can be used to derive predictions about the intended people based on the sampling responses [52].

B. self-administrated questionnaire

Self-administered questionnaires have some potential benefits in comparison with conventional questionnaires. It is generally recognized that questionnaires, compared to interviews, are more cost-effective. In addition, the questionnaire is well suited for this project since it can carry out the social distance regulation induced by the pandemic. Furthermore, it is also beneficial in terms of saving resources. The other advantage is that questionnaires tend to be more diverse than interview schedules, given that questionnaires have the option to be as private as possible. This approach has several merits, such as asking hypersensitive or highly personal questions [53].

C. Population and sample

The study collected samples from health workers working at Saudi Arabia's Prince Mohammed Bin Abdul Aziz Hospital, run by the Ministry of National Guard's Health Affairs in Al Madina and Al-Hikma General Medical in Makkah. An appropriate sampling strategy has been used in the study. Conclusion: there are several agile methods for selecting participants, but one of the most effective methods is convenient sampling, which acts as a non-probabilistic method involving the invitation to only those capable and eager to participate in the study. Because of the current outbreak, Google forms were used to collect survey data. Remarkably, the sample was composed of health employees with diverse employment positions; the included clusters have no specific numbers. Thus, it can be inferred that a higher percentage of physicians can be found in the research than nurses. A researcher managed to contact the health workers and get their responses after gaining the cooperation of the hospital managers and directors without requiring anyone to identify themselves.

D. Data Collection Technique:

This study aims to perform an investigation project from the perspective of a health worker. This study involves a web-based questionnaire created with the help of Google forms to gather primary data. Google form is a useful web-based application that allows one to design forms that can be used to collect data. It is an online tool that can be used by students, academics, scientists, and individuals to create surveys or registration forms for activities. This form is multi-platform and allows users to share it with respondents in varied ways, including sending a link, emailing a message, or incorporating it as a part of a website or blog. A spreadsheet is usually used to record the information collected using the form. Amongst all the options for an Internet-based questionnaire software, Google Forms is an exceptional cost-free alternative.

E. Variables in the Study:

All respondents at the hospital were provided with a self-administrable questionnaire designed. Both English and Arabic versions of the questionnaire were provided. Each participant can select the language they wish to use in their responses. Several studies were reviewed to develop the questionnaire, and the survey was calibrated so it could be used with a previously-established accuracy [54 – 56].

Afterward, the questionnaire was examined and verified to ensure its accuracy. Also, the survey was reviewed for its content and relevance by several experts, a family medicine doctor, and a public health specialist who helped improve the survey questions before release. Four categories make up this questionnaire:

a. Several sociodemographic characteristics were addressed in the questionnaire, including gender, age, marital status, profession, number

of individuals residing in the home, and hours spent outdoors before the quarantine. Further, the questionnaire members answered whether they thought the lockdown was an intelligent decision.

b. The respondents were asked if they had any anxiety associated with COVID-19. On a five-point Likert scale, we evaluated participants' level of the psychological impact associated with the COVID-19 pandemic, with the scores of (0) "not at all," (1) "a little bit," (2) "moderate," (3) "quite a bit," and (4) "extreme." As part of the survey, we assessed the fear of being infected with COVID-19, the excessive use of antiseptic liquids, and the accessibility of knowledge regarding the pandemic.
c. Additionally, we asked if the worker's financial impact may have affected their work time and if such an impact may have affected their financial position.
d. Additionally, three questions relating to sleeping characteristics were incorporated into the study. Among them were "the nature of shift work," "whether it was common practice for employees to employ their mobile phones before going to bed," and 'the pandemic might have caused disruptions to their sleep or wake pattern before the quarantine was put into effect.
e. Moreover, the survey also contained questions that sought to understand better their moods and any possible depressive symptoms (these articles involved if they have regret feelings, whether they sense hopelessness and disinterest in their lifetime, and their sorrow and crying-bouts).

F. Dependent Variable

Several questions were asked about occupational stress. These consist of: 'Does the amount of work you have had experienced during COVID-19 impact your stress levels at work? Are you experiencing high levels of stress at the workplace due to poor managers? Does the shortage of assistance provided by your workplace throughout the pandemic impact your stress levels in the workplace? Do you experience high levels of stress due to poor management? Is the technology used at the hospital affecting your stress levels at work? Is teamwork a factor that affects your stress levels in the workplace?

G. Statistical Data Analysis

Research-based theory validation relies on applying statistical methods as its most crucial components. Statistics are indispensable because they are the ones that are essential to validate assumptions. Several statistical methodologies were used in this study to confirm our hypothesis and develop a scientific theory based on our findings. In total, there are 204 samples in this study. The analysis includes descriptive (frequency, charts, mean, and others), inferential analysis (chi-square and correlation), and predictive analysis (regression model). A statistical package called SPSS 27 is used to perform statistics, draw tables, plot graphs, and interpret results. Various techniques for multivariate analysis are also examined in further detail (Cluster analysis, Structural equation model, and multi-dimension scaling _ correspondence analysis). Some analyses are used to verify the results of other investigations.

V. RESULTS AND FINDINGS

Data were collected from the participants regarding their perceptions about the COVID-19 and its impact on psychological wellbeing, financial wellbeing, and work-related stress. Before the actual survey questionnaire, 13 demographic questions were asked to know participants' background characteristics. As seen in Figure 3, more than 51% (n = 105) of participants were female, and 74.5% (n = 152) of them were Saudi citizens. 70.6% (n = 144) of participants worked in Government Hospitals. In addition, the distribution of marital status is that 54% (n = 110) of participants were married.

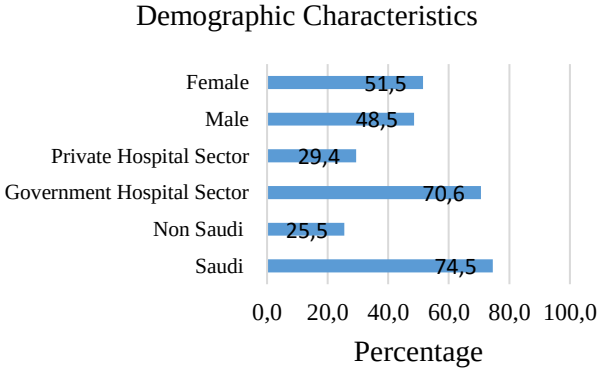

Figure 3. The distribution of demographic characteristics of participants

As presented in Table I, participants are mostly from medical field including: 20% nurses (n = 41), 10% doctors (n = 21), 9% health technicians (n = 19), 8% medical secretary (n = 16), and 22% dentists (n = 44), 6% Physiotherapist (n = 12), 8% medical secretary (n = 16). The participants working in hospital, but not in medical field are: 16% employee (n = 22), and 5% engineer (n = 11).

Table I. The percentage & number of job designation of the participants

Job Designation	N	%
Dentist	44	21.6
Nurse	41	20.1
Employee	22	10.8
Doctor	21	10.3
Technician	19	9.3
Pharmacist	18	8.8
Medical Secretary	16	7.8
Physiotherapist	12	5.9
Engineer	11	5.4

As shown in Table II, participants (39%) are mainly between the age of 31-40 years; 33% (*n* = 87) represent participants in the 18-30 age group. Almost 98% of participants have not been diagnosed with psychiatric illness. Thus, they were psychiatrically normal. 92% percent (*n* = 187) of participants believe that lockdown during COVID-19 is a good idea. Similarly, 3 out of every 10 (30%) participants said they are currently on the night shift. Concurrently, 4 out of every 10 (40%) participants claimed to be shift workers. Participants were also asked about where they got information about COVID-19. Around 41% (*n* = 83) reported that they got COVID-19 information from social media, while 30% got it from the internet and journals. The average family size in each participant's home is (5.57), which means most participants have (5-6) people living in the same house. On average, participants spend 7.44 hours with a standard deviation of 1.77 hours outside the home before the lockdown.

Table II. The frequencies, percentages, and mean of the sociodemographic distribution of participants

Socio-demography		Frequency	Percentage	Mean (S.D.)
Age	18-30 years	67	32.8	2.08 (0.994)
	30-45 years	80	39.2	
	45-55 years	31	15.2	
	55-70 years	26	12.7	
Diagnosed with psychiatric illness	No	199	97.5	0.02 (0.155)
	Yes	5	2.5	
Lockdown is a good idea	No	17	8.3	0.92 (0.277)
	Yes	187	91.7	
Currently on night shift	No	150	73.5	0.26 (0.442)
	Yes	54	26.5	
Shift worker	No	128	62.7	0.37 (0.485)
	Yes	76	37.3	
Source of COVID-19 information	Social Media	83	40.7	2.29 (1.195)
	Journal	20	9.8	
	Ministry of Health T.V.	60	29.4	
	Internet	41	20.1	
Time spends outside before lockdown	1-2 hours	3	1.5	7.44 (1.770)
	3-4 hours	8	3.9	
	5-6 hours	43	21.1	
	7-8 hours	97	47.5	
	9-10 hours	53	26	
Number of people living with participants	1-2 people	26	12.8	5.57 (2.255)
	3-4 people	30	14.7	
	5-6 people	73	35.8	
	7-8 people	57	27.9	
	9-10 people	18	8.8	

A. Psychological Impact

73% of participants feel that catching infection during their COVID-19 has the highest mean (2.98). Followed by 33% are using the phone or the internet before sleeping has a mean of (2.90). And then, getting morning sunlight exposure has a mean of (2.88). Conversely, collecting data about COVID-19 all day has the least mean of (0.47), as seen in Figure 4.

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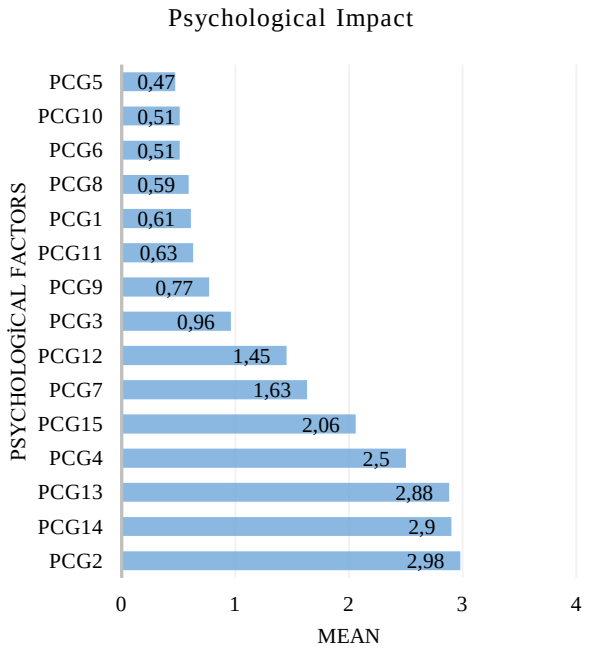

Figure 4. The mean of the psychological impact of questions

B. Financial Impact of COVID-19

The health workers were also asked questions related to financial stress faced during the COVID-19 pandemic. Six questions were asked to measure health workers' opinions about their financial stress during COVID-19, which indicated that COVID-19 had affected the economic status significantly more than 50% with a mean of (2.41). The distress follows this in job changes with a mean of (2.40). However, the impact of COVID-19 on mortgage and rent has the least mean of (1.25). There are not so many discrepancies in the mean of all questions asked under financial stress compared to psychological stress, as seen in Figure 5.

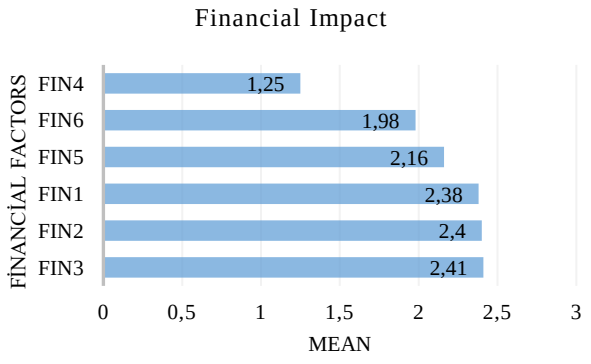

Figure 5. The distribution of financial factors

C. Work-related Stress

Most health workers, 73%, reported that their workplace stress level had affected their workload during COVID-19. This indicates that workload, poor managers, and lack of support have the highest mean (2.75) for work-related stress. On the other hand, teamwork and workplace technology has the least means of (1.02) and (1.37) respectively in Figure 6.

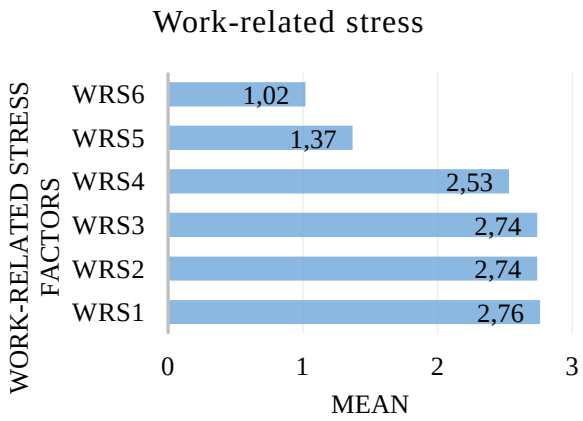

Figure 6. The findings o work-related stress

The effects of psychological and financial factors on Work-related stress can be stated that the economic level is 40.1% positively correlated with work-related stress, which is a higher financial burden, and the most increased work-related stress reported. Similarly, the psychological stress level is 37.6% positively correlated with work-related stress. Conversely, the number of people living together with the participants is 26.9% and is negatively associated with work-related stress .

D. Regression Model

As appears in Table III., all variables have P - values less than (0.05) except those spending four hours outside before lockdown. Regardless of the time spent outside, work-related stress is not improved or diminished. Implies that including hours spent outside before lockdown will not affect the level of work-related stress. This explains why the coefficient is extremely low, and the P-value is greater than 0.05. Conversely, when the financial burden increases by 1 unit, the work-related stress increases 0.289 on average. When psychological stress rises, the rise in work-related stress is 0.280 on average. The more people living with workers, the less work-related stress is observed in Table III.

Table III.
Summary of Regression Model

	B	Std. Error	Standardized Coefficients Beta	t	Sig	Tolerance	VIF	Decision
Constant	1.479	0.237		6.231	0			
PCG	0.28	0.077	0.244	3.622	0	0.826	1.21	Supported
FIN	0.289	0.066	0.29	4.401	0	0.865	1.156	Supported
People living with you	-0.045	0.017	-0.169	-2.66	0.008	0.931	1.074	Supported
Hour spent outside before lock down	-0.005	0.022	-0.169	-0.243	0.808	0.915	1.093	Rejected

Table IV shows that the regression model is valid and can make decisions and theories. The significant value is (0.000), which indicates that the R^2 is the coefficient of determination, which shows 0.252, implying that 25.2% of variations in work-related stress are explained by psychological anxiety, financial stress, people living together, and hours spent outside before lockdown.

Table IV. The summary of the regression model

R	R Square	Std. Error	F	Sig.
.502[a]	0.252	0.51901	16.735	0.00

The regression equation predicts the event given the same circumstances built upon. In the study, work-related stress is built upon financial stress, psychological stress, time spent outside before lockdown, and the number of people living together, as seen in Table III. If there is a scenario where all values of the predictors are retrieved, then the overall work-related stress can be predicted using Eq. 1 .

$$Work\ related\ stress = 1.479 + 0.280PCG + 0.289FIN - 0.045(people) - 0.005(hours\ outside) \quad (1)$$

The estimated coefficient for PCG is 0.280. This implies that, holding all other constraints fixed, when the overall psychological stress level increases by 1, work-related stress increases by 0.280 units on average.

E. Cluster Analysis

Using the K-means clustering algorithm, which uses a mean threshold. In other words, a cluster mean is specified, then cases within a certain threshold are grouped as one cluster. The data set was divided into two homogenous clusters; cluster 1 has 172 cases while cluster 2 has 32 points. These clusters have distinct features that can be ascribed to them. In the subsequent sub-heading, sets based on socio-demography are classified in Figure 7.

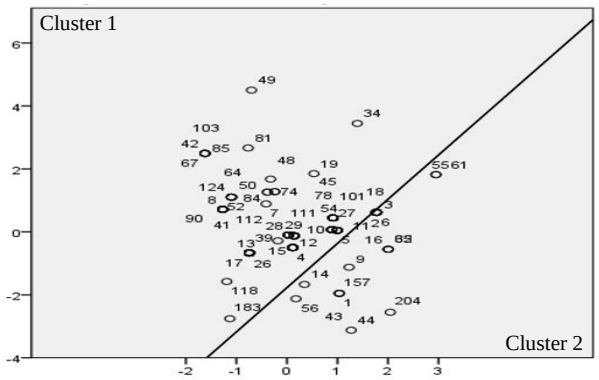

Figure 7. Cluster analysis of participants

F. Correspondence Analysis

The cluster analysis previously presented showed the relationship between the respondents (health workers). The correspondence analysis in this session demonstrates the relationship between the factors and the response rating of the variables. There exists less discrimination between the psychological stress. This implies that the levels are close to each other, and work-related stress has the most bias among the cases. Yet again, this means that the levels are far from each other. The groups in financial stress have a significant high dimension across all levels except for "moderate." For example, the "not at all" and "extremely" levels are far from the rest, as presented in Figure 8.

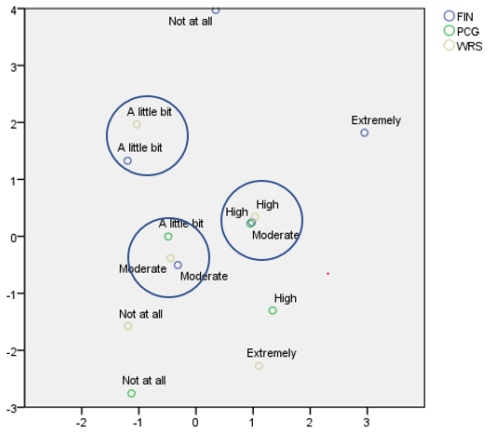

Figure 8. The correspondence analysis of psychological, financial, and work-related stress

G. Structural Equation Model

The path of the structural equation model of each latent variable's standardized regression weights to their measurement variable is presented. The connecting arrows between the measurement variables (factors) represent the correlation coefficients. The model fit measures CMIN/DF = 2.775, RMSE = 0.09 and p-value = 0.000 suggest that the model is fit and can be used for decision making. Conversely, the reliability CFI = 0.75 and GFI = 0.82 are slightly below the threshold fitness of the model. As shown in Table V, we can conclude that the model is a good fit.

Table V. The summary of regression model

Model fit index	χ^2/df	GFI	CFI	RMSEA	p-value
Model value	2.78	0.8	0.8	0.09	0
Recommended value	<5	>0.9	>0.9	<0.09	<0.05

The factor loadings thresholds can be formulated based on the sample size. According to Hair et al. (2006) [44, 45], for a sample size of 200, a standard factor loading of 0.35 to 0.4 seems adequate. In the initial model consisting of all the question items (WRS1, WRS2, WRS3, WRS4, PCG2, PCG13, and FIN5) which refers (workload, poor manager, lack of support, poor management, imagining catching infection, getting morning sunlight, and fund an emergency), respectively, have low regression weight and negative factor loadings. Hence, these variables were eliminated from the final model. The implication is that these items (questions) are not a significant measure of their respective variables.

Moreover, FIN3 and FIN6, which are "Has COVID-19 impacted you financially?" and "Has COVID-19 impacted you paying your debt?" respectively, have the highest effect – over 85% - on financial stress among health workers in Saudi Arabia. Of all 15 variables identified in the psychological factors, 'PCG10 and PCG11' refer to depression and pessimistic cases, stating that 'I sometimes cry along with losing motivation and interest in aspects of life' that affects over 80% of people. As for work-related stress, 'WRS5 and WRS6', ' the technology and Teamwork' respectively, have 70% effects on work-related stress, as seen in Table VI.

This structural equation model further reveals that financial stress does not significantly predict work-related stress among health workers in Saudi Arabia. This may be caused by the inner effects and correlation that are included in the structural equation model. Meanwhile, the correlation between the demographics and financial and psychological stress is negative and significant.

Table VI. The summary of the regression model

	Finance	Psychological Stress	Work-related Stress
Work-related Stress	0.204	0.664	0
WRS5	0.142	0.463	0.697
WRS6	0.152	0.495	0.745
FIN6	0.63	0	0
FIN4	0.412	0	0
FIN3	0.85	0	0
FIN2	0.466	0	0
FIN1	0.173	0	0
PCG1	0	0.59	0
PCG3	0	0.632	0
PCG4	0	0.393	0
PCG5	0	0.628	0
PCG6	0	0.482	0
PCG7	0	0.35	0
PCG8	0	0.606	0
PCG9	0	0.464	0
PCG10	0	0.848	0
PCG11	0	0.81	0
PCG12	0	0.39	0
PCG14	0	0.238	0
PCG15	0	0.346	0

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VI. CONCLUSION

People are different in many ways. There can be changes of opinion lifestyle changes at every stage of life. Also, each gender has its preference for career socioeconomic lifestyle. In our study, some sociodemographic lifestyles were significantly linked to work-related, psychological, and financial stress. Further investigation suggests that psychological stress plays a more significant role in the work-related stress of health workers in Saudi Arabia compared to financial stress. Sociodemographic factors that lead to psychological stress lead to work-related stress but not financial stress. However, not all sociodemographic factors are essential determinants of work-related stress. The analysis supported all three hypotheses in the framework of this study. This claim is also backed up by previous research. Financial burdens have shown the most substantial effect on work-related stress. When workers feel financially drained, they have a high chance feel stressed with their work which affects their efficiency. The impact of psychological stress is not far from financial stress. These two factors are undoubtedly essential to address for optimal health sector results. This is because the medical industry heavily relies on human resources rather than other resources. The sociodemographic factors are often cannot be changed by external factors. Instead, the reverse is possible. Socio-demography influences the other external factors. Therefore, it is imperative that even if age affects work-related stress, nothing can be done individually.

As one gets older, the work-life activities would balance up [46]. Also, one's belief about lockdown is a personal factor. This study has shown that accepting lockdown as an excellent way to curb the pandemic helps to relieve work-related stress. Significantly, getting the correct information about COVID-19 from a reliable source can impact the stress level. This study suggests that reading scientific journals about COVID-19 will reduce work stress by 29.1% relative to getting information from the internet. Finally, living within the family can help reduce psychological stress, which leads to decreased work-related stress. Increasing the number of people living together with the work decreases psychological stress by 21% and reduces work-related stress by 26.9%.

The demographic work showed that the number of people living with the health workers plays a crucial role in their general stress level. The health workers living with few people reported more stress overall. A disturbing fact is a psychiatric illness among the younger generations, which requires high-level attention. One leading cause can be excessive social media and the internet, as the younger health workers reported relying on social media and the internet as their primary source of COVID-19 information. In the psychological items, feeling sad and depressed (PCG10) and losing motivation (PCG11) are the leading causes of psychological stress. These two items are interwoven. Feeling sad and depressed due to the current pandemic can cause loss of motivation. As earlier mentioned, one way to curb this is to have more people around who can support and help in times like this—as for financial stress, not having enough credit (FIN3) and the weight of the debt (FIN6) are the two significant influences on overall financial stress. The study revealed that the work night shift and younger have more financial stress. It is often expected that financial problems can make health workers unwillingly work at night, especially when young and single.

A. Limitations

The sampling technique might not accurately picture work-related stress among health workers. This is because the job designations are not evenly represented. There are more doctors and nurses compared to other titles. The model also indicates 25.2% variations in work-related stress, which is explained by financial and psychological stress. This means that other factors truly affect work-related stress but were not included in the study to make the result accurate and the correlation coefficient (R^2) higher. In addition, some questions (item) in the study have shown to be insignificant. However, these questions have been validated in previous studies. Our results indicated that not all the questions accurately measure the variables (work-related, psychological, and financial stress). Also, some of the model fitness criteria are outside the required threshold.

CONFLICTS OF INTEREST

They reported no conflict of interest between the authors and their respective institutions.

RESEARCH AND PUBLICATION ETHICS

In the studies carried out within the scope of this article, the rules of research and publication ethics were followed.

ACKNOWLEDGMENT

The Deanship of Scientific Research (DSR) at King Abdulaziz University (KAU), Jeddah, Saudi Arabia has funded this project, under grant no. (KEP-MSc: 74-135-1443). Therefore, authors gratefully acknowledge technical and financial support.

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JOURNAL OF SCIENCE, TECHNOLOGY AND ENGINEERING RESEARCH
Bilim, Teknoloji ve Mühendislik Araştırmaları Dergisi, (2022) - 3(1): 24-31
ISSN: 2717-8404 *https://dergipark.org.tr/en/pub/jster*

RESEARCH ARTICLE

Investigation of Circular, Elliptical and Obround Shaped Vessels by Finite Element Method(FEM) Analysis under Internal Pressure Loading

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HIGHLIGHTS

- *FEA shows that deformed shape elliptical /obround under internal pressure is not uniformly enlarge due to non-uniform bending. But,circle deforms uniformly due to uniform curvature.*
- *It is found that stress in elliptical/obround shape much higher than circular.*
- *This is useful in selection of shape according to functional requirement.*

Keywords:

- Pressure vessel shape
- Circular
- Elliptical
- Obround
- FEM

GRAPHICAL ABSTRACT

The forms of pressure vessels applicable withinside the aerospace enterprise are starting from essential load-carrying imperative tank systems to small auxiliary tanks and pressurized cabins. Elliptical and obround stress vessels are used in which there may be a space-constrained. In the present work nonlinear (geometric and material within tensile strength) finite element evaluation is performed for the determination of its stress state in open-ended pressure vessels of various shapes (round, elliptical, and obround). A parametric examine has been completed and outcomes offered for different inside areas of vessel shapes and thicknesses of the cross-section. As the inside areas of the pressure vessel increases, the effective stress increases for a particular thickness. The deformed shape elliptical/obround under internal pressure might no longer be uniformly enlarged because of non-uniform bending. Effective stress in the elliptical/obround shapes are found higher than circular shape for a particular thickness and inside area of vessel (Table A).

Configuration	Location in figure A1, A2 & A3			
	A	B	C	D
Circular (Fig A1)	4.101	3.950	4.101	3.950
Elliptical (Fig.A2)	310.07	315.32	430.26	358.65
Obround (Fig.A3)	387.38	391.56	482.60	462.50

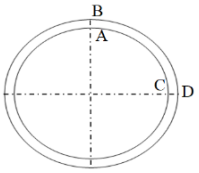

Fig.A1

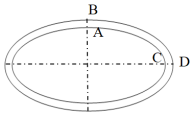

Fig.A2

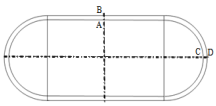

Fig.A3

Table A. Effective Stress(MPa) at various location for 2.5 mm thick for different shape pressure vessel(circular(Fig.A1), elliptical(Fig.A2) and obround(Fig.A3)) with 10000π inside area.

Article Info :

Received**:** 01 March 2021
Accepted**:** 04 April 2021

DOI:
10.53525/jster.1079858

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Aim of Article: *Evaluation of stress state in open ended pressure vessels of different shape (circular, elliptical and obround). Parametric study carried out by varying inside areas of vessel and thickness of cross sections.*

Theory and Methodology: *The numerical FEM method is used to find the results.*

Findings and Results: *The effective stress is very much higher in elliptical and obround pressure vessel as compared to circular. As the thickness of the cross section increases the stress value decreases.*

Conclusion: *Nonlinear (geometric and material within tensile strength) FEA is performed to capture more realistic behavior of structure. It has been shown based on FEA that, a pressure vessel with a non-circular cross-section will produce significantly higher wall stresses than that of a circular due to its change in shape. The future work will be aimed at determining failure pressure (instability pressure) of these shapes to known their capacity for a given inside area and thickness.*

JOURNAL OF SCIENCE, TECHNOLOGY AND ENGINEERING RESEARCH
Bilim, Teknoloji ve Mühendislik Araştırmaları Dergisi, (2022) - 3(1): 24-31
ISSN: 2717-8404 https://dergipark.org.tr/en/pub/jster

RESEARCH ARTICLE

Investigation of Circular, Elliptical and Obround Shaped Vessels by Finite Element Method (FEM) Analysis under Internal Pressure Loading

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Citation:
Chitaranjan, Pany. (2022). *Investigation of Circular, Elliptical and Obround Shaped Vessels by Finite Element Method(FEM) Analysis under Internal Pressure Loading*,Journal of Scientific Technology and Engineering Research, 3(1): 24-31.
DOI: 10.53525/jster.1079858

HIGHLIGHTS

- *A parametric examine has been carried out and outcomes presented for different inside areas of specific pressure vessel shapes and thickness of the cross-sections.*
- *FEA shows that the deformed shape elliptical /obround under internal pressure could not uniformly enlarge due to non-uniform bending. However, circle deforms uniformly due to its uniform curvature.It is found that obround/elliptical shape give higher stress than circular vessel.*
- *This analysis is useful in selection of shape of pressure vesslel in design according to functional requirement.*

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Received: 01 March 2021
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ABSTRACT

The forms of pressure vessels applicable withinside the aerospace enterprise are starting from essential load-carrying imperative tank systems to small auxiliary tanks and pressurized cabins. Elliptical and obround stress vessels are used in which there may be a space-constrained. In the present work nonlinear(geometric and material within tensile strength) finite element evaluation is performed for the determination of its stress state in open-ended pressure vessels of various shapes(round, elliptical, and obround). A parametric examine has been completed and outcomes offered for different inside areas of vessel shapes and thickness of the cross-sections. As the inside area of the shape of pressure vessel increases, the effective stress increases for a particular thickness. The deformed shape elliptical/obround under internal pressure might no longer be uniformly enlarged because of non-uniform bending. Deformation and effective stress in the elliptical/obround shapes are found higher than circular shape for a particular thickness and inside area of vessel.

Keywords: *Pressure vessel shape, Circular, Elliptical, Obround, FEM*

I. INTRODUCTION

A pressure vessel is a vessel designed to hold a pressure that is significantly different from the ambient pressure, either internally or externally. The class of pressure vessels associated with the aerospace industry is propellant tanks ranging from main load-carrying integral tank structures to small auxiliary tanks, storage tanks, motor cases, high-pressure gas bottles, and pressurized cabins. Commonly used shapes for pressure vessels are spheres, cylinders, and cones. The advantage of a spherical vessel over a cylindrical vessel is that for a given pressure and diameter, the spherical vessel requires a thinner wall than an equivalent cylinder. The design of the pressure vessel for a given ultimate pressure is mainly based on the diameter and thickness of the cylinder section. Optimal design means maximum enclosed volume for the storage with minimum structural mass. The most important point is to minimize the discontinuous stress at the junction. It is important to perform non-linear analysis of geometry and materials to capture structural behavior [1,2,3]. Elastic stress of pressure vessels with a mismatch in circumferential weld seam [4], presence of weld sinkage [5], and the

estimation of longitudinal seam mismatch to compare the test strain [6] have been studied. Finite element analysis (FEA) with modeling the measured profile of cylindrical shell compared strain close to measured strain in the circumferential direction [7].

Spheres and cylinders are two basic shapes generally used for internally pressurized vessels. The sphere will impart the lowest value of membrane stress on its walls as compared to any other shape. That's why, for a given enclosed volume, a sphere represents the most weight-efficient design. In many situations, a straight cylinder is the preferred shape, as it is much more easily fabricated than a sphere while still providing a reasonably weight-efficient design. However, there appear circumstances where neither a cylindrical or spherical vessel may be appropriate for a particular purpose. Situations encountered in the design of aircraft propulsion systems where the engine is incorporated into the airframe structure. In such situations, elliptical pressure vessels are used where there is a space-constrained such as propulsion systems with respect to the engine cavity [8]. In some situations, due to the limited space available, exit pipes are made of elliptical or obround shape [9-10]. Shells of circular and elliptical cross-sections [11] with equivalent volume comparison show that cargo tanks with elliptical cross-sections possess a lower center of gravity than those of circular cross-sections. Consequently, at the lower center of gravity, the chance of topple over is decreased. Having the same height for the center of gravity of two tanks, the elliptical cross-section tank will be able to carry more shipping material than a circular cross-section tank due to its larger lateral dimension.

Ansys finite element software was used to calculate the stress concentration factor of functionally graded round square cross-section and flattened tube cross-section (obround) [12].The ASME code [13] specifies two non-circular shapes, a rectangle, and a obround. The difference in behavioral between circular and non-circular pressure vessels is different. Limited studies have been reported in the literature on calculating stress in non-circular pressure vessels using numerical/analytical methods.

The linear FEM simplifies many things. For example, the material does not yield, creating unrealistic high stresses in the model. Also, because the non-linear shape is not taken into account, the state of the membrane is unpredictable (or very inadequate). Non-linear FEA, if properly defined, handles all these problems. When using linear analysis, solver assumes that a "small deformation". This actually means that two assumptions are made: (i) deformation does not affect the behavior of the structure (considering go in for membrane state), (ii) there is no impaired stability. This means that if a thickset solid actually needs to be analyzed, it will not be in a membrane state. Non-linear geometric analysis is not required in such cases. Therefore, to take care different shape of structure whose behavior is not known apriori (i.e. whether it will behave linearly or nonlinearly), nonlinear analysis is appropriate. But it doesn't mistreat either. What works linearly, using nonlinear geometry analysis gives the same results as linear analysis. In complicated vessel shapes the simple membrane-stress concepts do not enough to give adequate information of the true stress state. So, in the present article, nonlinear FEA using Ansys is carried out for the determination of stresses and deformations in open-ended pressure vessels of different shapes (circular, elliptical, and obround), which seems not carried out earlier[8,9,10]. Due to change in shape in elliptical or obround vessel, at the change in profile location high stress is expected. Therefore, to carry out more realistic and qualitatively analysis, both geometric and material analysis is performed. Further, a parametric study is carried out, by varying inside areas of various shapes of vessel and thickness of cross-section of the pressure vessel.

II. CONFIGURATION

The open ended pressure vessels of various geometries (Figure.1.) such as circular, elliptical and obround (circular half sections with flat plate walls) are used for the stress analysis.

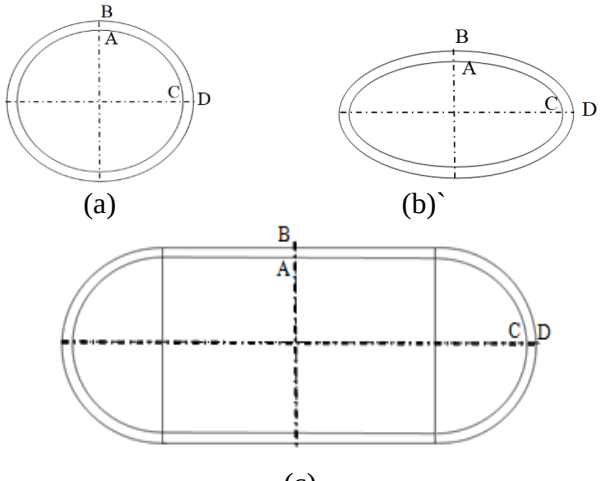

Figure. 1. Pressure vessels (a) circular (b) elliptical (c) obround

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III. FINITE ELEMENT ANALYSIS

Finite element software ANSYS [14], is used for the modeling of circular shape pressure vessel and geometric and material non linear [2,3,4] analysis performed. The plane 82 element has 8-nodes and having two degrees of freedom per node. A quarter models considered and symmetric boundary condition applied in the symmetric plane. Internal pressure (P) of 0.1MPa is applied and analysis is carried out for 5000π inside area of vessel and thickness (t) of 2.5 mm. Material is HSLA steel (YS=834 MPa, UTS=981 MPa., E=206010 MPa and ν=0.33). The material card supplied to Ansys as follows.

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MPTEMP,1,0
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A. *Mesh Convergence Study*

Convergence study is carried out to arrive at the appropriate finite element size.

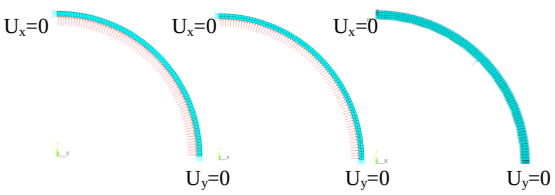

Figure.2. Finite element model of circular pressure vessel (a) one element across thickness (b) two elements across thickness (c) 4 elements across thickness

Table I. Mesh convergence study.

Mesh size	1x80	2x80	4x80
Hoop Stress in MPa	2.878	2.879	2.879

Based on above convergence study, it is seen that a mesh of 2 elements and 4 elements across thickness (Figure 2) do not change the values of hoop stress. Therefore, the mesh size of 2 elements across thickness is considered for present analysis.

B. *Validation of Finite Element Analysis*

The finite element model for a circular vessel (R=100mm, t=2.5mm) is shown in Figure 3. Hoop stress is responsible for change in diameter or radius. Longitudinal stress is responsible for change in length of cylinder. When the pressure vessel is open and free of end restraints, longitudinal stress will not be prodded into. It will develop only if the ends of vessel are closed. Radial stress is very small as compared to longitudinal and hoop stress. It can be neglected. Hence the radial stress is not shown in the paper.

The displacement and hoop stress are determined through analytical solution for circular pressure vessels.

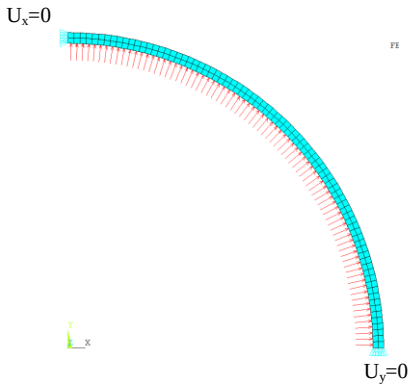

Figure. 3. Finite element model of circular pressure vessel

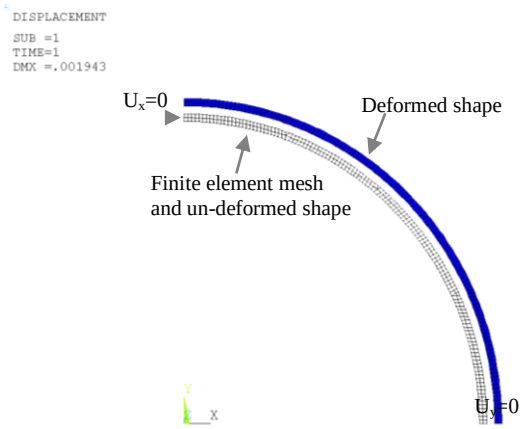

Figure.4. Deformed and un-deformed shape of circular pressure vessel with 10000π mm^2 inside area

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The radial displacement is calculated using formulae

$$\delta = \frac{PR^2}{2tE}(2\text{-}\nu) = 0.0018\text{mm}$$

Figure 4 indicates the deformed shape along with the un-deformed shape of the circular pressure vessel.

Hoop Stress = (P R)/t = (0.1 x 100)/2.5 = 4 MPa,

This is compared well to current finite element solutions (Figure 5, first principal stress) and with literature value[8-10].This validates finite element modeling and mesh size.

IV. RESULTS AND DISCUSSION

Circular pressure vessel: Effective stress (MPa) at various locations for the inside area of circular shape vessel of 5000 π mm^2 with different thicknesses is shown in Table II. Effective Stress (MPa) at the various locations for 2.5 mm thick circular pressure vessels with the different inside areas is shown in Table III. As inside area of vessel increases the effective stress increases. As thickness increases, the effective stress reduces. The deformed and un-deformed shape of the circular pressure vessel with 10000 π mm^2 inside area is shown in Figure 4.

The first principal stress (MPa) and effective stress of circular pressure vessels for 10000 π mm^2 inside area are shown in Figures 5 and 6 respectively. The effective stress at location A and C, B and D (Figure.1.) are close due to uniform curvature (Table II & Table III).

The effective stress for 5000 π mm^2, 10000 π mm^2 and 15000 π mm^2 inside areas are 2.930 MPa, 4.1 MPa and 4.999 MPa respectively (Table III).

Table II. Effective Stress (MPa)at various locations for circular shape with inside area of 5000 π mm^2 with different thickness.

Thickness in mm	Location in Figure 1			
	A	B	C	D
2.5	2.930	2.779	2.930	2.779
3.0	2.460	2.310	2.460	2.310
3.5	2.123	1.971	2.123	1.971
4.0	1.870	1.720	1.870	1.720

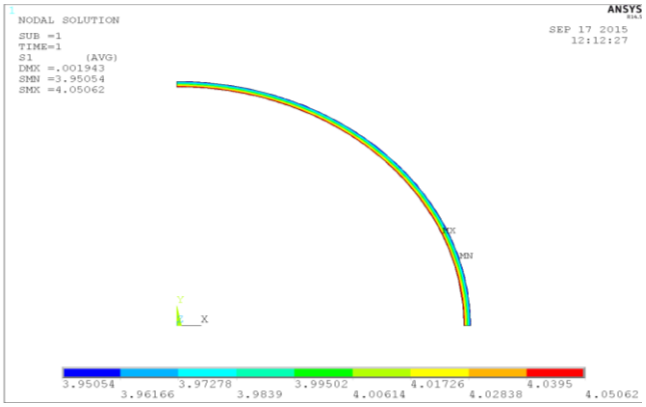

Figure. 5. First principal stress (MPa) in circular pressure vessel with 10000π mm^2 inside area.

Table III. Effective Stress (MPa) at various location with 2.5 mm cross sectional thickness for different inside area of circular shape pressure vessel

Inside area of vessel	Location in Figure 1			
	A	B	C	D
5000 mm^2	2.930	2.779	2.930	2.779
10000 π mm^2	4.101	3.950	4.101	3.950
15000π mm^2	4.999	4.849	4.999	4.849

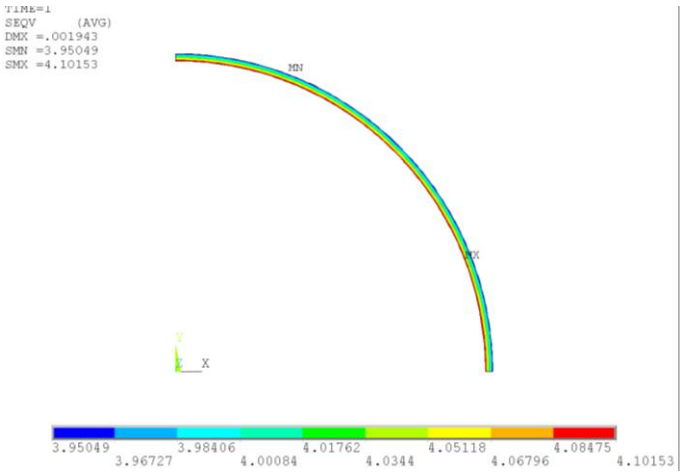

Figure. 6. Effective stress (MPa) in circular pressure vessel with 10000π mm^2 inside area

Elliptical Pressure Vessel: The finite element mesh with deformed and un-deformed shape of elliptical pressure vessel subjected to internal pressure (P= 0.1MPa) is shown in Figure 7. A quarter model considered and symmetric boundary condition applied in the symmetric plane. Effective Stress (MPa) at the various locations for 2.5 mm thick with the different inside areas of vessel is shown in Table IV. As inside

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area of vessel increases the effective stress increases. Effective Stress (MPa) at various locations of inside areas of vessel of 5000 π mm^2 with different thicknesses is shown in Table V. As thickness increases, the effective stress reduces. The effective stress (MPa) of a vessel is shown in Figure 8. Comparison of elliptical vessel results with circular vessel show that effective stresses are very much higher than that of the circular pressure vessel. The maximum deformation is higher than that of the circular pressure vessels.

The maximum effective stress is found for 10000 π mm^2 inside area of 430.26 MPa at location C (Table IV). The maximum stress is increased to 589.81 MPa for 15000 π mm^2 inside area (Table IV and Figure 8).

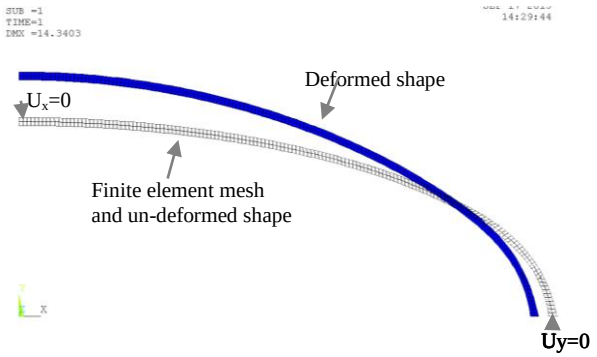

Figure.7. Deformed and un-deformed (FE mesh 2 elements across thickness) shape of elliptical pressure vessel with 15000π mm^2 inside area.

Table. IV. Effective Stress (MPa) at various locations with 2.5 mm cross sectional thickness for different inside areas of elliptical shape pressure vessel

Inside area of vessel	Location in Figure 1 A	B	C	D
5000π mm^2	219.11	222.22	327.19	167.25
10000π mm^2	310.07	315.32	430.26	358.65
15000π mm^2	414.95	421.73	589.81	361.32

Table. V. Effective Stress (MPa) at various locations for elliptical pressure vessel with different cross sectional thickness with inside area of 5000π mm^2

Thickness in mm	Location in Figure 1 A	B	C	D
2.5	219.11	222.22	327.18	167.25
3.0	165.80	168.34	281.25	98.31
3.5	115.54	124.82	182.71	68.31
4.0	97.32	99.33	181.67	42.27

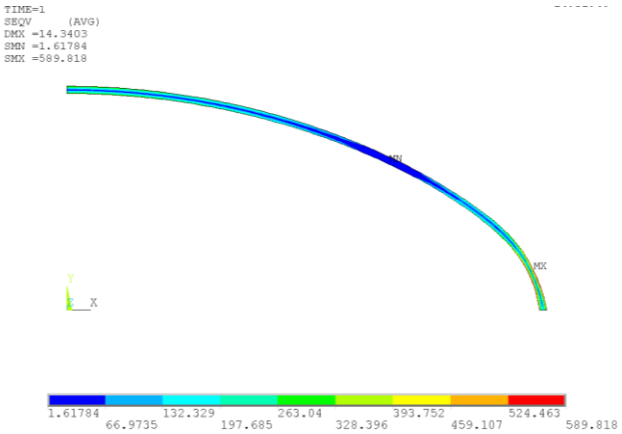

Figure. 8. Effective stress (MPa) of elliptical pressure vessel with 15000π mm^2 inside area.

Obround Pressure Vessel: The finite element model of an obround pressure vessel is shown in Figure 9. A quarter model considered and symmetric boundary condition applied in the symmetric plane. Internal pressure (P) of 0.1MPa is applied. The deformed and un-deformed shape is shown in Figure 10. Effective stress (MPa) at the various locations for 2.5 mm thick with the different inside areas of vessel is shown in Table VI. As inside area increases the effective stress increases. Effective Stress (MPa) at various locations with inside areas of vessel of 5000 π mm^2 and different thicknesses is shown in Table VII. As thickness increases, the effective stress reduces. The effective stress (MPa) of a vessel with 10000π mm^2 inside area of vessel is shown in Figure 11. From the above study, it is found that values of deformation and effective stresses are very much higher than that of the circular shape pressure vessel.

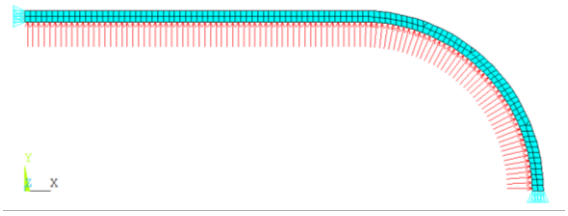

Figure. 9. Finite element model of obround pressure vessel

Table. VI. Effective Stress (MPa) at various locations with 2.5 mm cross sectional thickness for different inside areas of obround shape pressure vessel

Inside area of vessel	Location in Figure 1 A	B	C	D
5000π mm^2	196.24	199.30	242.64	228.67
10000π mm^2	387.38	391.56	482.60	462.50
15000π mm^2	588.96	592.95	696.71	679.80

Table.VII. Effective Stress (MPa) at various locations for obround pressure vessel with different cross sectional thickness with inside area of 5000π mm^2

Thickness in mm	Location in Figure 1			
	A	B	C	D
2.5	196.24	199.30	242.63	228.67
3.0	148.68	151.21	185.37	172.06
3.5	109.50	111.67	137.36	125.75
4.0	87.47	89.36	110.40	99.70

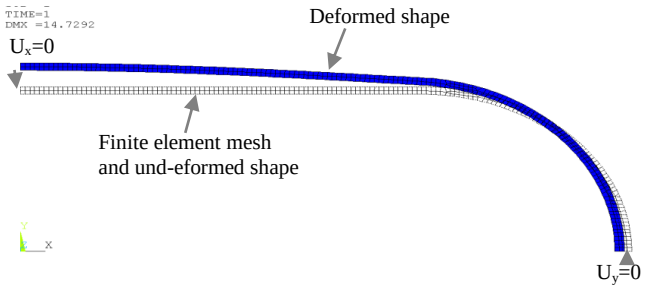

Figure. 10. Deformed and un-deformed shape of obround pressure vessel

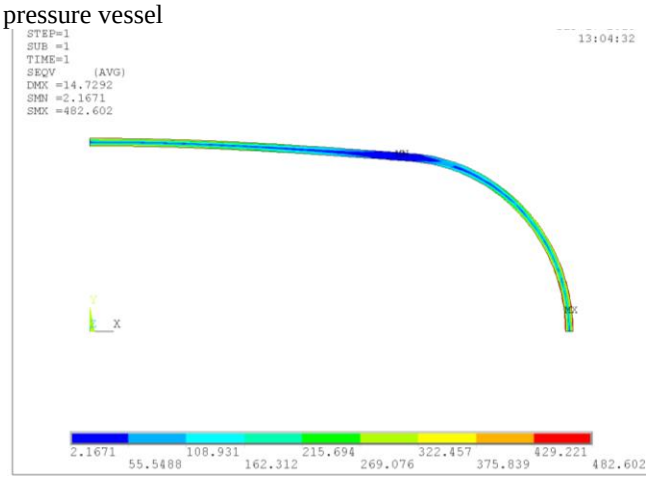

Figure.11. Effective stress (MPa) in obround pressure vessel with 10000π mm^2 inside area.

The maximum effective stress is found of 482.6 MPa for 10000 π mm^2 inside area of vessel at location C (Table VI, Figure. 11). The maximum stress is increased to 696.7 MPa for 15000 π mm^2 inside area (Table VI).

V. CONCLUSION

In the present article FEA detail is presented in open-ended specific shapes (circular, elliptical, and obround) pressure vessels for the evaluation of its stress state. Based on nonlinear FEA, it is determined that a pressure vessel designed with a particular thickness and inside area, non-circular cross-section will produce substantially higher wall stresses and deformation than that of a round or circular vessel because of the alternate in curvature. As the thickness of the cross-section will increase for a given inside area of the vessel, the stress value decreases. As the inside area of the pressure vessel increases the effective stress increases for a particular thickness.

In an elliptical and obround vessel, the internal pressure induces a bending moment at the wall. So, the elliptical / obround pressure vessel the deformed shape will no longer be deformed uniformly because of non-uniform bending. The center portion would be undergone a larger deflection than that of the corner. Therefore the total stress for a noncircular pressure vessel is the sum of the stress because of bending and the membrane stress. However, in the case of circle bending impact is absent because of its uniform curvature.

The future work will be aimed at determining of failure pressure (instability pressure) of these shapes to known their capacity for a given area of cross section and thickness. To carry out failure analysis of these structural shapes, the non-linear analysis is must to find out its capacity. This non-linear evaluation is to find out its pressure at instability. However, in the present article the stability point is not addressed (i.e. structural analysis is within tensile strength of material) and only non-linear analysis is performed to capture more realistic behavior of structure.

CONFLICTS OF INTEREST

There was no conflict of interest.

RESEARCH AND PUBLICATION ETHICS

In the studies carried out within the scope of this article, the rules of research and publication ethics were followed.

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ISSN : 2717-8404 *https://dergipark.org.tr/en/pub/jster*

RESEARCH ARTICLE

White Blood Cell Classification Using Convolutional Neural Network

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HIGHLIGHTS

- *A CNN based model with low number of trainable parameters for classification of white blood cell types has been provided.*
- *The proposed model's performance assessed using several optimizers such as RMSprop, Adam, and Adagrad.*
- *We have compared four pre-trained models such as MobileNetV2, DenseNet121, InceptionV3 and ResNet50 with our proposed model.*

Keywords:

- *White blood cells*
- *Blood Cell Classification*
- *CNN*
- *DenseNet121*

GRAPHICAL ABSTRACT

Unlike other studies, this paper provides a CNN based model with low number of trainable parameters for classification of white blood cell types. This model is made up of five convolution blocks, which are responsible for extracting the features, flatten layer, fully connected layers and a final FC layer with SoftMax activation function. Conv2D is used in the first convolution block, which is the input block, and SeparableConv2D (Separable convolutions) are used in the following convolution blocks. The proposed CNN model is shown in the below figure.

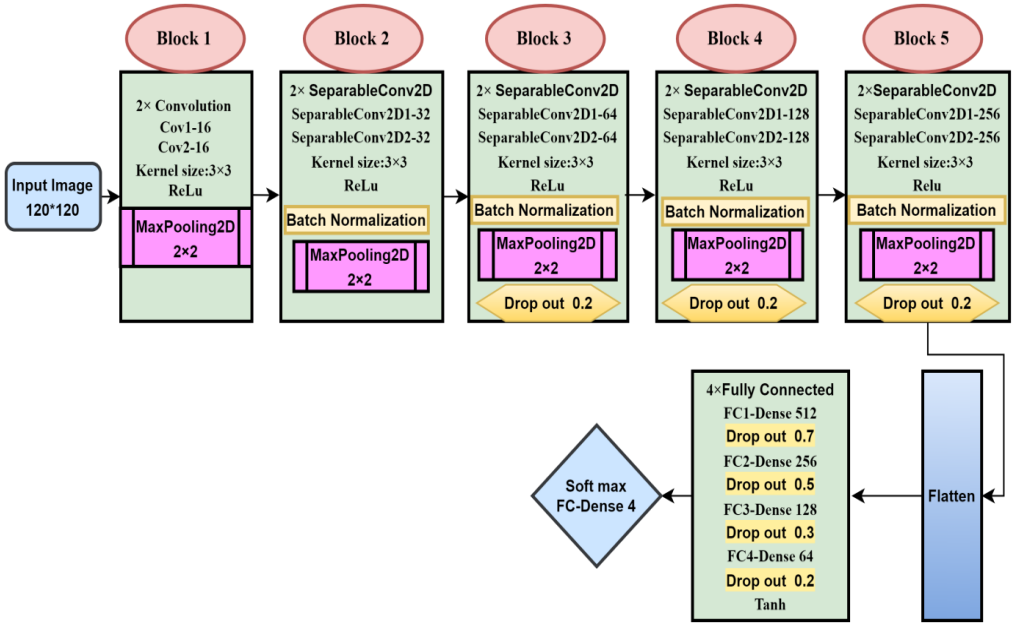

Figure. Proposed CNN model.

Article Info:

Received: 02 Nov 2021

Accepted: 16 Apr 2022

DOI: 10.53525/jster.1018213

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Aim of Article: *The key purpose of this study is to provide a CNN based model with low number of trainable parameters for processing white blood cells with the aim of classifying the type of these cells.*
Theory and Methodology: *A Convolutional Neural Network based model has been used in this paper which consists of five convolutional blocks.*
Findings and Results: *Compared to four pre-trained CNN models, and other related studies our proposed model with the lowest number of trainable parameters and training time shows the great results with 99.5% accuracy, 99% recall, 99% precision, and 99% F1 score.*
Conclusion: *We achieved the key purpose of this study, by building a CNN-based model with low number of trainable parameters for classification of white blood cell types.*

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RESEARCH ARTICLE

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Citation:
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ABSTRACT

White blood cells (WBCs) are a key element of the immune system and demonstrate resistance to a variety of illnesses, quantitative and qualitative examination of various kinds of white blood cells is critical. Counting and categorizing the types of WBCs can help doctors detect and treat different illnesses. As a result, one of the most important steps in analyzing and testing blood samples is counting and categorizing various types of WBCs. The main purpose of this study is to provide a CNN based model for processing of WBCs with the aim of classifying the type of these cells. Kaggle white blood cells images were used in this article, we built a CNN-based model for classifying white blood cell types and assessed the model's performance using several optimizers. We have seen that the RMSprop optimizer shows the best result in our proposed model. We have compared four pre-trained models such as MobileNetV2, DenseNet121, InceptionV3 and ResNet50 with our proposed model. Compared to four pre-trained CNN models, and other related studies, our proposed model with the lowest number of trainable parameters and training time shows the great results with 99.5% accuracy, 99% recall, 99% precision, and 99% F1 score.

Keywords: *White blood cells , Blood Cell Classification, ,CNN, DenseNet121.*

I. INTRODUCTION

The use of artificial intelligence (AI) algorithms, machine learning, and, in particular, deep learning methods in different medical and biological applications is quickly rising as the capacity of computer processors increases. These algorithms are utilized in various of disciplines, ranging from automated and semi-automated systems for analyzing medical pictures to big data processing algorithms for processing human genome information [1].

The quantitative and qualitative evaluation and analysis of microscopic images of blood samples is one of the applications of artificial intelligence (AI) in medicine [2]. The goal of microscopic blood sample analysis is to count various cells in blood samples, like red-white blood cells, and platelets, or to assess their quality [3].

In the meantime, since WBCs are a key element of the immune system and demonstrate resistance to a variety of illnesses, quantitative and qualitative examination of various kinds of white blood cells is critical. Counting

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white blood cells can help doctors detect and treat illnesses like AIDS and leukemia. As a result, one of the most important steps in analyzing and testing blood samples is counting various types of white blood cells.

Automatic and non-automatic methods can be used to analyze and count different kinds of white blood cells in blood samples. In non-automated methods, a blood sample is taken from a patient and examined by a specialist, in this method the analysis and counting of blood sample cells is a slow, tedious, time-consuming, and will be an inaccurate process. In contrast, there are several automated systems for the quantitative evaluation and WBC classification, based primarily on flowmeters and the chemical properties of the cells. These systems are often expensive and somewhat slow, providing only quantitative information about blood cells [4].

As a result, developing and implementing low-cost, quick, and reliable systems for evaluating, classifying, and counting various kinds of white blood cells is important. Processing microscopic images of blood samples are one of the most frequent approaches for building and implementing these systems.

The main purpose of this study is to implement a CNN based model for processing of WBCs with the aim of classifying the type of these cells. In this study, our focus will be on detecting the type of WBCs in white blood cell images.

Images of Kaggle white blood cells were utilized to do this. The collection contains 12,444 augmented microscopic images of eosinophils, monocytes, lymphocytes, and neutrophils, with almost 3,000 photographs for each of the four cell types [5].

In this article, we built a CNN-based model for classifying white blood cell types and assessed the model's performance using several optimizers such as RMSprop, Adam, and Adagrad. In addition, to evaluate the accuracy of our proposed model, we have been compared with four Pre-trained Keras models such as MobileNetV2, DenseNet121, InceptionV3 and ResNet50. The following is how the rest of the paper is structured: In part 2, we go through a few recent research on the classification of WBC types. The material and method are discussed in Section 3, experimental data from the study's dataset, as well as deep learning approaches, are discussed in this part. Part 4 contains the results and discussion, whereas section 5 contains the study's conclusions.

II. RELATED WORKS

This part of the paper is allocated to several scholars who have discussed issues relating to white blood cell types classification.

Cheque et al. [6], in 2021, suggested a multi-level and hybrid model for WBC classification. They utilized a Faster R-CNN network in the first stage to identify the region of interest in white blood cells and to separate mononuclear cells from polymorphonuclear cells. After that, they employed two parallel convolutional neural networks with the MobileNet structure, in the second stage to detect WBC subtypes. Their proposed model shows a performance metric of around 98.4% (accuracy, recall, precision, and F1-score) in Kaggle blood cells dataset.

In 2021 Çınar & Tuncer [7] have classified WBC using the CNN Alexnet-Googlenet-SVM hybrid model. In this combined model, the feature vectors of the last pooling layer both architectures are integrated. The properties obtained are classified by the SVM technique. Their model has been tested with Kaggle and LISC datasets, the accuracy of both datasets is 99.73 and 98.23, respectively. The entire number of parameters and trainable parameters that can be utilized to train the developed model is not mentioned in their article.

In 2021 Akiz et al. [8] Classified white blood cells using convolutional features and Support Vector Machines. finally, their proposed model shows 85.95% accuracy.

In 2020, Toğaçar et al. [9] utilized three pre-trained models for feature extractor purposes, including GoogLeNet, AlexNet, and ResNet-50, and used the quadratic discriminant analysis (QDA) classifier to identify white blood cells. As a consequence, they were able to classify different types of WBCs with a 97.95 percent success rate. The accuracy of the model is improved by employing feature selection in the classification step, according to the authors.

In 2019, Özyurt [10] introduced the CNN–MRMR–ELM hybrid model, which used pretrained CNN models such as AlexNet, GoogleNet, VGG-16, and ResNet to extract features. After integrating these features, he selected 400 important features using the MRMR feature selection technique. Then he classified

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white blood cells using the ELM algorithm, and his proposed model had an accuracy of 96.0.3 %.

In 2018, Tiwari et al. [11] classified white blood cell types using a CNN-based model, which is a Double Convolution Layer Neural Network (DCLNN) and compared the model's accuracy with Nave Bayes and SVM classifiers.

In their research, the DCLNN shows the best result and has an average precision of 0.88 in four classes and 0.93 in two class, in the white blood cell classification.

III. MATERIAL AND METHODS

The key purpose of this study is to provide a CNN based model for processing white blood cells with the aim of classifying the type of these cells.

The flow chart of the overall proposed model stages is described in Figure 1.

A. Dataset Description

Kaggle white blood cells images were used in this research. This dataset comprises 12,444 augmented microscopic images of eosinophils, lymphocytes, monocytes, and neutrophils, with approximately 3,000 images for each of the four cell types [5]. The entire image is saved in JPEG format and has a pixel size of 320×240.

Figure 2 shows distribution of the blood cells in the dataset and in the figure 3 the WBC images in a sample view is shown

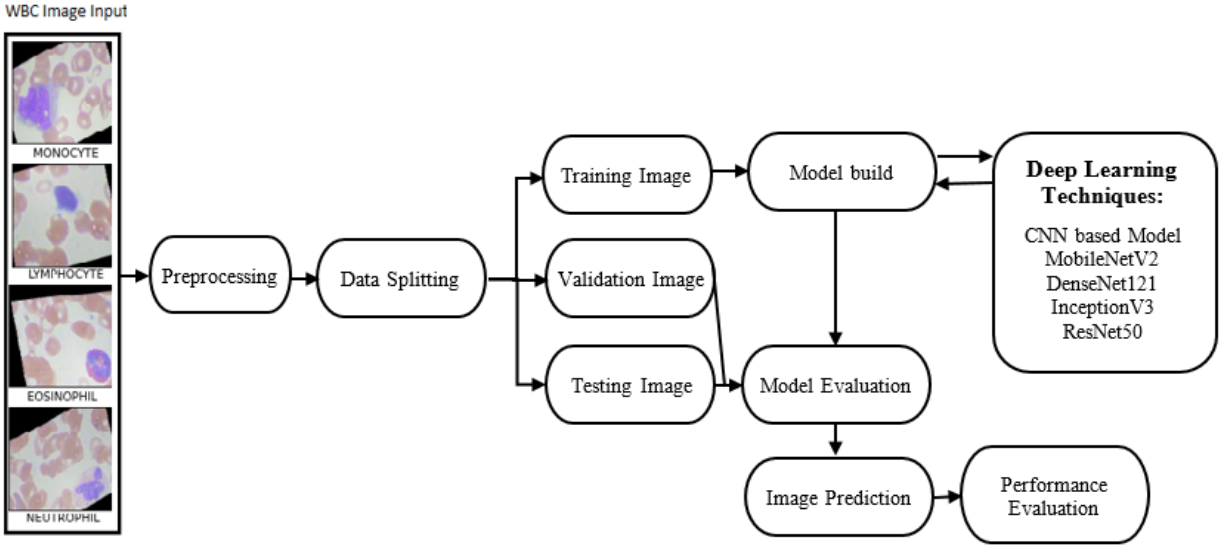
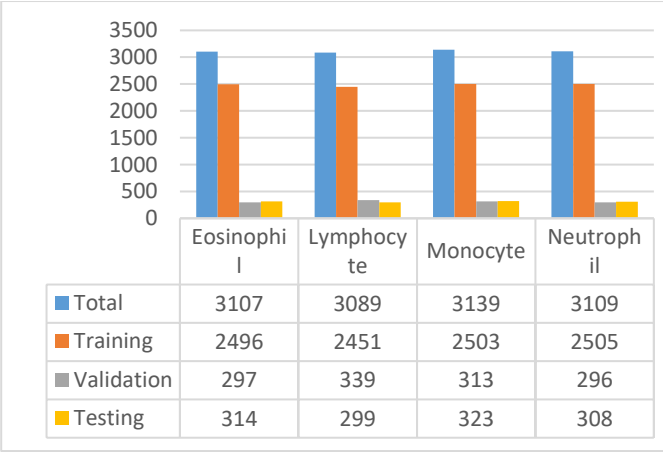


Figure 1. Proposed model stages.



	Eosinophil	Lymphocyte	Monocyte	Neutrophil
Total	3107	3089	3139	3109
Training	2496	2451	2503	2505
Validation	297	339	313	296
Testing	314	299	323	308

Figure 2. The distribution of the blood cells in the dataset.

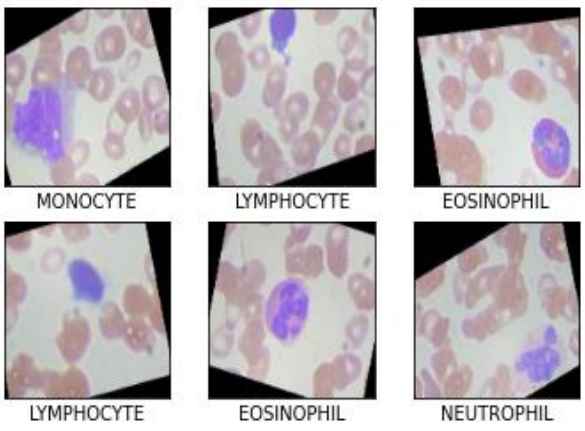


Figure 3. The WBC Image

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B. Data Preprocessing

One of the most critical and required stages in machine learning is data preparation. This technique is essential for reliable, accurate, and successful prediction outcomes when using machine learning algorithms in a dataset.

In pre-process stage, at first, we rescale the photos to 120 × 120 to enhance the training speed of the proposed model, and because the Pixel values are presented in RGB images with integers between 0-255, we change the Pixel values to 0 and 1 to increase computational speed.

After pre-processing the images, we combined and shuffled all the white blood cell images and, we used for training as size of 80%, validation as size of 10%, and testing as size of 10% images.

The following is a general breakdown of the number of data samples:

The total number of training samples is 9955.

The total number of validation samples is 1245.

The total number of test samples is 1244.

C. Deep learning Methods and Algorithms used for Classification

The capacity to automatically extract visual characteristics using the idea of deep learning is very important advantage of convolutional neural networks (CNNs). As a result, it has become extremely popular in the medical area in recent years for diagnosing various illnesses.

In this article too, we built a CNN-based model for classifying white blood cell types. Figure 4 shows the proposed CNN-based model. This model is made up of five convolution blocks, which are responsible for extracting the features, flatten layer, fully connected layers and a final FC layer with SoftMax activation function.

Conv2D is used in the first convolution block, which is the input block, and SeparableConv2D (Separable convolutions) are used in the following convolution blocks. Each convolution block comprises two layers of convolution, followed by a 2×2 Max-Pooling filter. A 3×3 filter is used in all these blocks of convolution, and the number of neurons is 16, 32, 64, 128 and 256, respectively. In addition, each block has a batch normalization layer, except for the input block. A dropout layer with a value of 0.2 is employed in the third, fourth and fifth blocks of convolution to prevent overfitting.

The last convolution block's output is flattened using a flatten layer, then four Fully Connected (FC) layers are applied, each with its own Dropout layer. For multi-class classification, a final FC layer with four units and a SoftMax activation is implemented. The task of each layer in proposed CNN model shows in Table I.

Table I.
The task of proposed CNN model layers [12].

Models Layers	Layer Task
Convolution Layer	Features Extraction in each block.
Pooling Layer	Reduce the number of parameters.
Batch Normalization	Normalize the output of convolution layers.
Dropout Layer	Prevent overfitting.
Flatten Layer	Flatten the output of last convolution block
Fully Connected layer	Perform mathematical operations and doing Classification with final FC layer.

In addition to the proposed model, this paper employed four pre-trained Keras models: MobileNetV2, DenseNet121, InceptionV3, and ResNet50. The most key characteristics of these models are listed in Table II.

Table II.
Models Key Characteristics [13,14]

Models	Number of Layers	Number of Trainable Parameters
MobileNetV2	53	3,504,872
DenseNet121	121	7,978,856
InceptionV3	48	23,817,352
ResNet50	50	25,583,592

The trainable parameter of the proposed model is 1,494,628, comparing with Table II. our proposed model has the lowest number of trainable parameters, which is mostly important in the model training phase.

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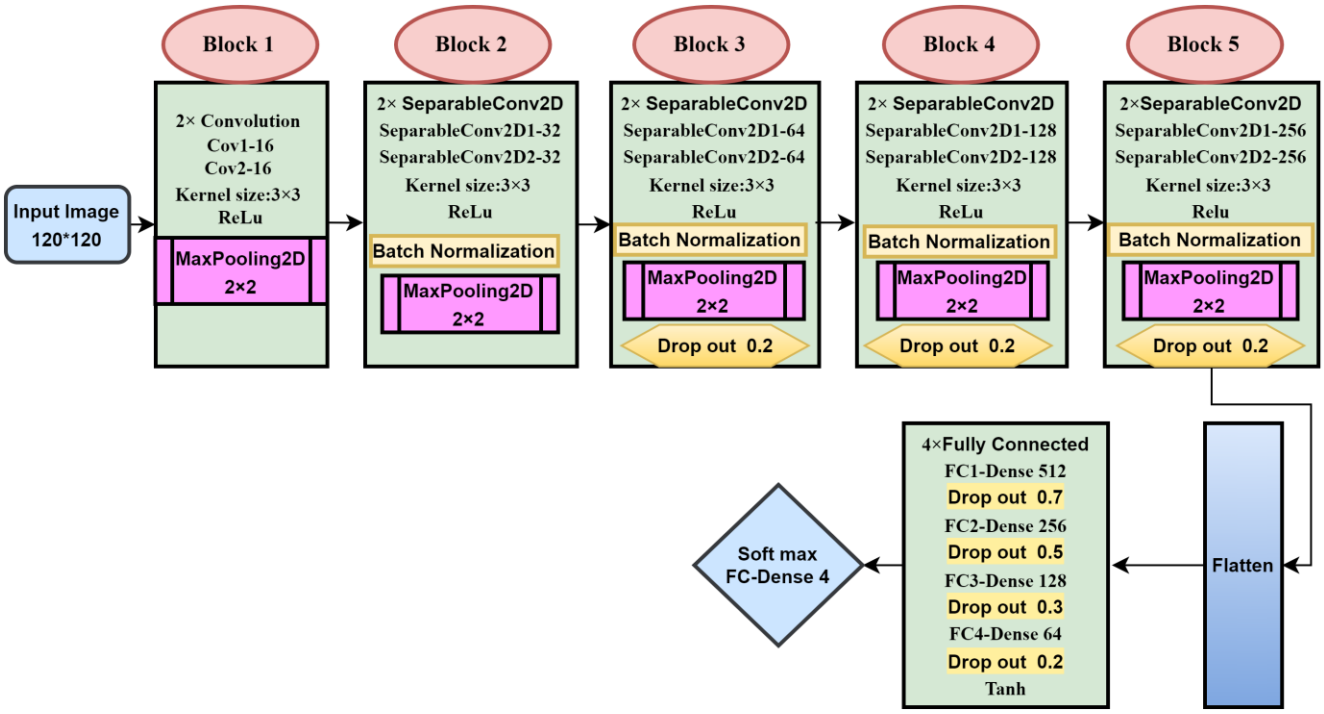

Figure 4. The proposed CNN based model.

IV. EXPERIMENTAL RESULTS AND DISCUSSION

In this part of the article, the performance of the proposed model for classifying different types of white blood cells with different optimizers, including RMSprop, Adam, Adagrad and four pre-trained models such as MobileNetV2, DenseNet121, InceptionV3 and ResNet50, has been evaluated.

The Experimental studies in this project, performed on a work station with the following specifications: Intel Core i7, 2.30 GHz, GB Nvidia GeForce RTX 3060 graphics and 16 GB Ram memory.

We trained our proposed model by selecting the ReLU as an activation function in the convolution block, 32 Batch size, 0.000001 learning rate in 50 epochs, and evaluated its performance with RMSprop, Adam and Adagrad optimizers. In Figure 5, which shows the performance of the suggested model, with the three mentioned optimizers, the RMSprop optimizer with 99 percent train accuracy and 99 percent test accuracy provides the best result. The Adam optimizer produces the best results after the RMSprop optimizer, whereas the Adagrad optimizer produces the poorest results in the suggested model.

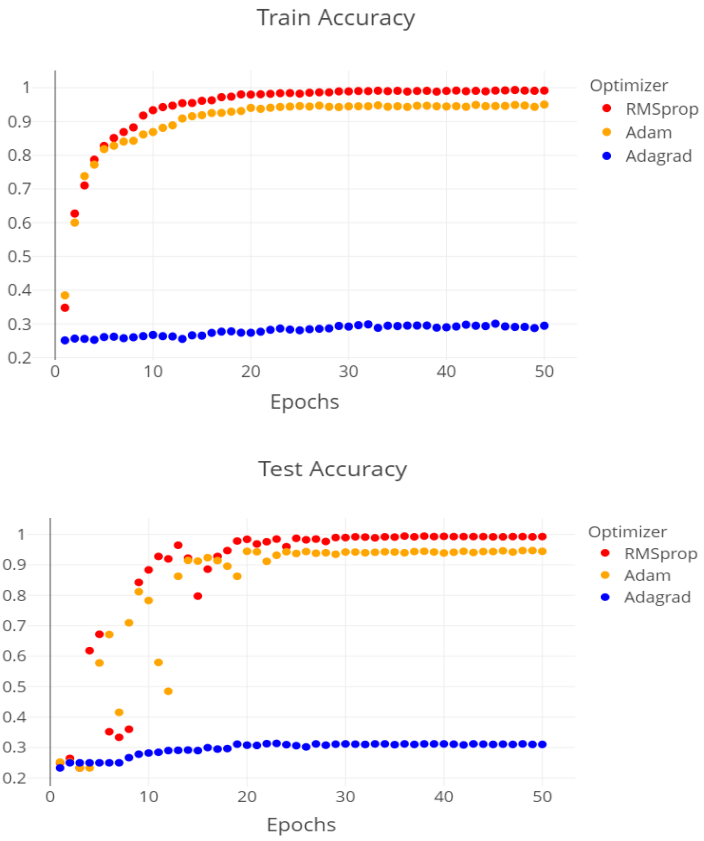

Figure 5. The performance of proposed model with three optimizers.

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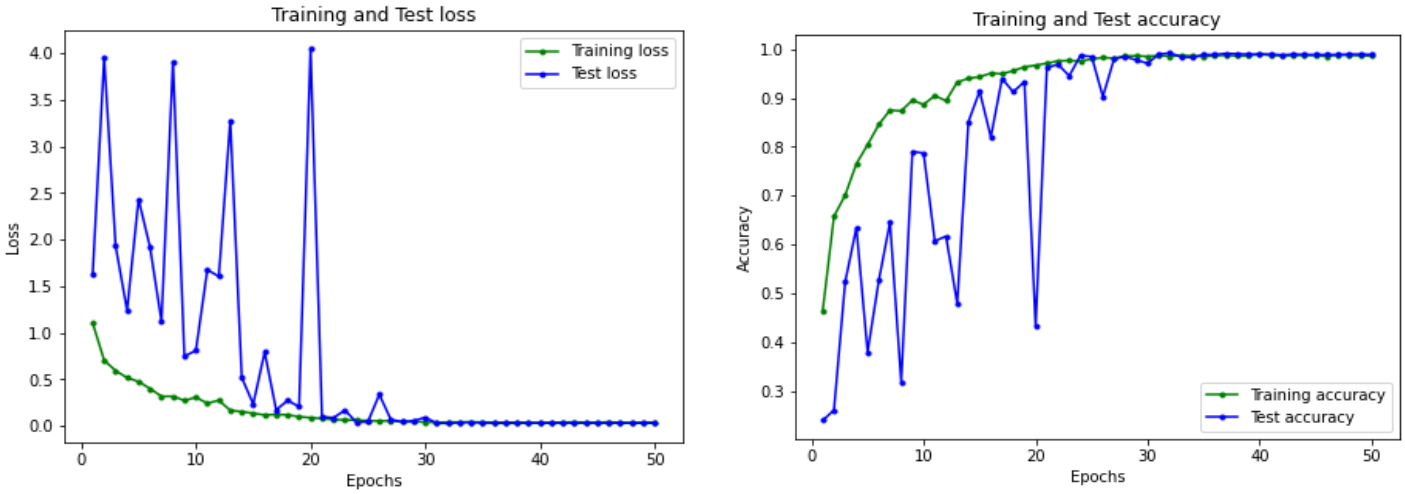

Figure 6. The training & validation accuracy and loss curve.

Curves of training and test accuracy, as well as the curves of training and test loss with 50 epochs, are shown as in Figure 6. With increasing epochs, both training set and test set exhibit great accuracy. Simultaneously, the loss curves of training and test show a decrease in the loss ratio when the epochs are increased.

The confusion matrix in machine learning is a table that is used to display the performance of the algorithm. Accuracy, Precision, Recall, and F1-Score characteristics are used to evaluate the proposed approach's performance. The definitions and metrics for the confusion matrix parameters are listed in Table III.

Table III.
Confusion matrix parameters and metrics.

Forecasted values		Actual values: Positive (1)	Actual values: Negative (0)
	Positive (1)	TP	FP
	Negative (0)	FN	TN

$$\text{Accuracy} = \frac{TP+TN}{TP+TN+FP+FN} \quad (1)$$

$$\text{Recall} = \frac{TP}{TP+FN} \quad (2)$$

$$\text{Precision} = \frac{TP}{TP+FP} \quad (3)$$

$$\text{F1-score} = \frac{2*Recall*Precision}{Recall+Precision} \quad (4)$$

TP- The forecasted value is positive, and it is right
TN- The forecasted value is negative, and it is right
FP - The forecasted value is positive, and it is wrong
FN- The forecasted value is negative, and it is wrong

The proposed model's confusion matrix is shown in Figure 7 The suggested model's accuracy, precision, recall, and F1 score are computed by using this matrix [15]. The confusion matrix shows that 307 photographs of eosinophils are properly predicted out of 314, all 299 photographs of lymphocytes and all 323 photographs of monocytes are successfully predicted, and 303 photographs of neutrophils are correctly predicted out of 308.

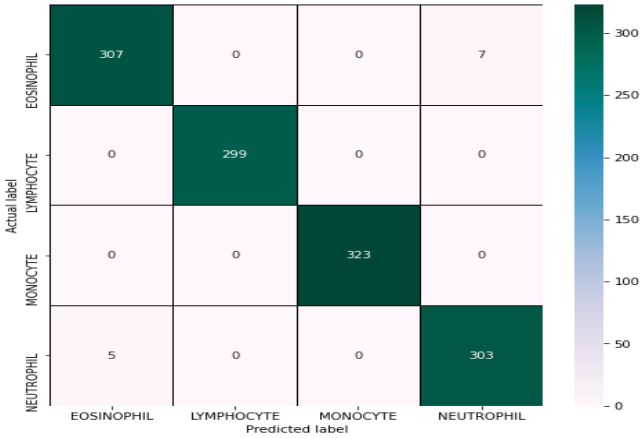

Figure 7. Confusion matrix of proposed CNN model.

Table IV.
Proposed Model Classification Result.

Class Name	Accuracy	Precision	Recall	F1 score
Eosinophils	99%	98%	98%	98%
Lymphocytes	100%	100%	100%	100%
Monocytes	100%	100%	100%	100%
Neutrophils	99%	98 %	98%	98 %
Overall	99.5%	99%	99%	99%

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Table IV. shows the proposed model classification result which is computed according to confusion matrix of the model, in here we can see that the Lymphocytes and Monocytes images have been 100% correctly classified, and the overall accuracy of model is 99.5 %.

Table V.
Different CNN Models Result.

CNN Models	Accuracy	Precision	Recall	F1 score	Training Time (Second)
CNN Based Proposed Model	99.5%	99%	99%	99%	10 min 52 sec
MobileNetV2	99.75%	100%	99.99%	100%	15 min 30 sec
DenseNet121	100%	100%	100%	100%	26 min 36 sec
InceptionV3	99.75%	99.93%	99.93	99.93	18 min 31 sec
ResNet50	99.99%	100%	100%	100%	21 min 30 sec

Table V. displays the results of the various CNN models used in this paper; we can see that all pre-trained models have shown the best results, especially DenseNet121 with 100 percent accuracy, precision, recall, and F1.

According to Table II. and Table IV. It's worth to mention, that pre-trained models have extremely high trainable parameters, which increases the training time of the model. While our proposed CNN model with low number of trainable parameters and training time, among the mentioned models, shows considerable accuracy in classification of white blood cell, which is 99.5 %.

Table VI. compares the results of other research papers in the field of white blood cell classification with our paper.

Table VI.
The result comparisons of different research studies with our study.

Research Studies	Number of Classes	Methods	Accuracy
Cheque et al. [6]	4	Multi-level hybrid model, Faster R-CNN and MobileNet structure	98.4%
Çınar & Tuncer [7]	4	CNN Alexnet-Googlenet-SVM hybrid	99.73%
Akiz et al. [8]		Convolutional features and Support Vector Machines.	85.95%
Toğaçar et al. [9]	4	GoogLeNet, AlexNet, and ResNet-50 for feature extraction, and (QDA) for classification	97.95
Özyurt [10]		CNN–MRMR– ELM hybrid model	96.0.3 %
Tiwari et al. [11]	4	Double Convolution Layer Neural Network	An average precision of 0.88 in four classes and 0.93 in two class
Karthiyayini [16]	4	Fused convolutional neural network (CNN)	90.39%~90.79%
Jeyavathana and R. Balasubramanian [17]	5	CNN based Model	97%
Su et al. [18]	5	MLP	99.11%
This Paper	4	CNN Based Proposed Model	99.5%
		MobileNetV2	99.75%
		DenseNet121	100%
		InceptionV3	99.75%
		ResNet50	99.99%

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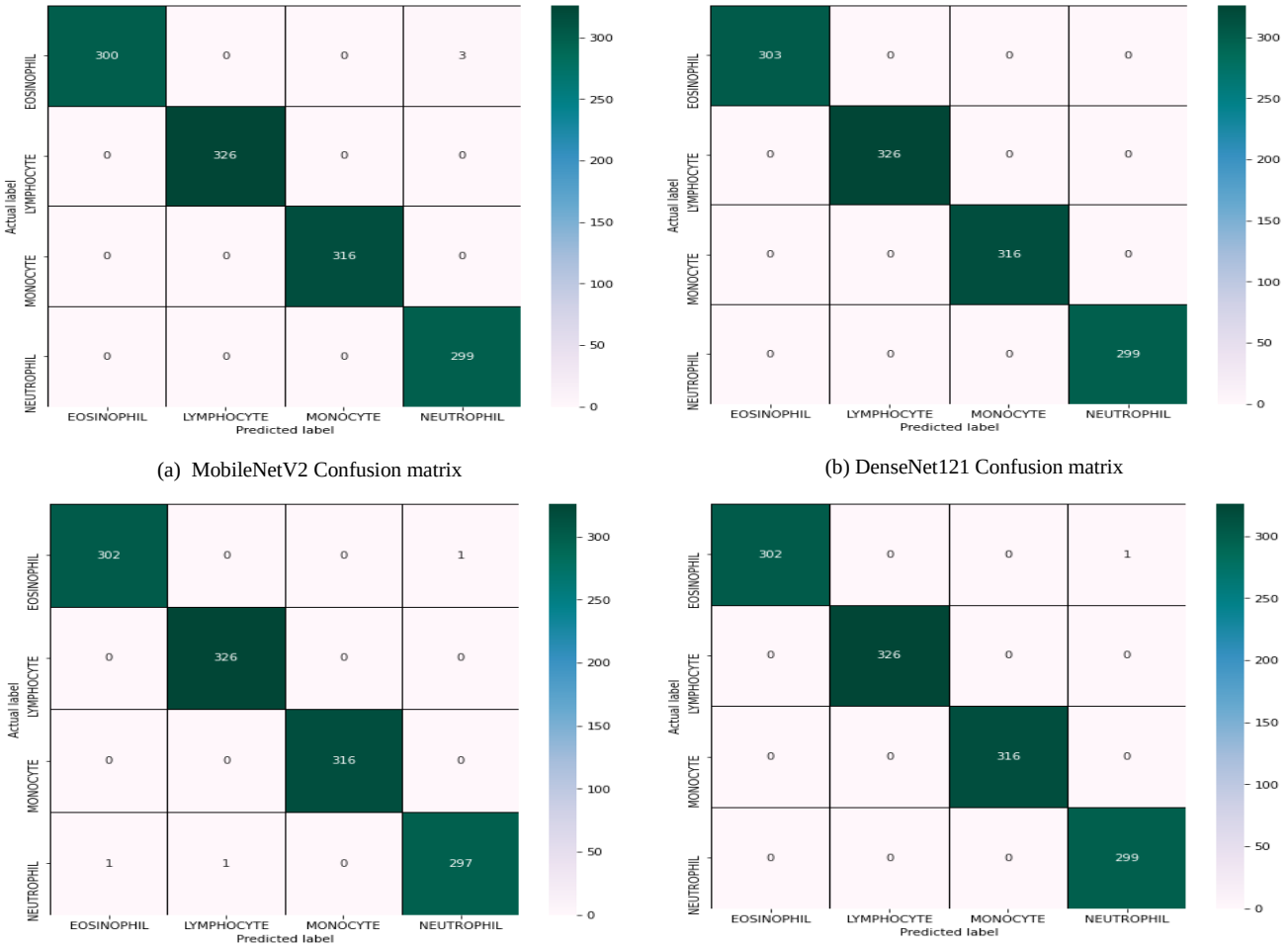

(a) MobileNetV2 Confusion matrix

(b) DenseNet121 Confusion matrix

(c) InceptionV3 Confusion matrix

(d) ResNet50 Confusion matrix

Figure 8. Confusion matrix of Pre-trained CNN models.

V. CONCLUSION

White blood cells (WBCs) are a key element of the immune system and demonstrate resistance to a variety of illnesses, quantitative and qualitative examination of different kinds of WBCs is critical.

The main purpose of this study is to implement a CNN based model for processing of WBCs with the aim of classifying the type of these cells. We achieved this purpose by building a CNN-based model with low number of trainable parameters and training time for classification of white blood cell types and assessed the model's performance using several optimizers such as RMSprop, Adam, and Adagrad.

We have seen, that the RMSprop optimizer shows the best result in our proposed model. We have compared four pre-trained models such as MobileNetV2, DenseNet121, InceptionV3 and ResNet50 with our proposed model, that the DenseNet121 with 100 percent accuracy, precision, recall, and F1 score have shown the best result.

Compared to four pre-trained CNN models, and other related studies, our proposed model with the lowest number of trainable parameters and training time shows the great result with 99.5 percent accuracy, 99% recall, 99% precision, and 99% F1 score.

CONFLICTS OF INTEREST

There is no conflict of interest in this study.

RESEARCH AND PUBLICATION ETHICS

In the studies carried out within the scope of this article, the rules of research and publication ethics were followed.

JOURNAL OF SCIENCE, TECHNOLOGY AND ENGINEERING RESEARCH
Bilim, Teknoloji ve Mühendislik Araştırmaları Dergisi, (2022) - 3(1): 32-41
ISSN : 2717-8404 *https://dergipark.org.tr/en/pub/jster*

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