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Effects of Load and Deceleration

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Highlights

Optimizing Energy Consumption

Advanced Motion Tracking System

Discovering Thoughts, Inventing Future

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Evaluating the Risk of Injury for Aircraft Attendants using Virtual Reality and Advanced Motion Tracking System Integrated with Ergonomics Analysis

By Xiaoxu Ji, Ethan Swierski, Maria A. Arenas, Ranuki O. Hettiarachchige, Xin Gao & Jizhou Tong

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Evaluating the Risk of Injury for Aircraft Attendants using Virtual Reality and Advanced Motion Tracking System Integrated with Ergonomics Analysis

Xiaoxu Ji [α], Ethan Swierski [σ], Maria A. Arenas [ρ], Ranuki O. Hettiarachchige [Ѡ], Xin Gao [¥] & Jizhou Tong [§]

Abstract- Aircraft attendants are at a high risk of occupational injuries and illnesses, leading to substantial compensation costs and staff shortages in the aviation industry. To address this issue, this study introduces an innovative virtual reality technique and advanced motion tracking system integrated with ergonomics tools to effectively evaluate the risk of musculoskeletal disorders (MSDs) among aircraft attendants during their routine tasks. The study involved twenty-two participants who performed two common tasks: opening/closing the passenger door, and lifting luggage from the floor and placing it into the overhead compartment. The inappropriate postures were identified, which resulted in excessive strainon the participants' lower back. By analyzing the impact of biomechanical variables, such as object weight, body height, and trunk motion, on the lower back, the study provides valuable insights that can inform the development of safety training programs and real-time monitoring approaches for injury prevention. Additionally, this innovative technology can be applied to other occupational fields.

Keywords: aircraft attendants; injury risk; virtual reality; xsens motion tracking; jack siemens; ergonomics.

I. Introduction

Aircraft attendants in the aviation industry are exposed to various challenging and hazardous situations. Unfortunately, they face a higher risk of workplace injuries and illnesses. According to the U.S. Bureau of Labor Statistics [1], aircraft attendants experienced 4,980 nonfatal workplace injuries and illnesses in 2019, with a rate of 517 per 10,000 full-time workers. Additionally, since 2003, 34% of all aircraft attendants have been injured on the job, and one in four have lost work time due to an injury [2]. Studies have shown that primary risk factors for these injuries and illnesses include aircraft attendant seating, handling of passenger luggage, service trolley design and maintenance, and galley design. Besides external factors, exerting forces and postures while pushing the serving cart, bending and twisting the upper body to pick up luggage, and reaching for items can contribute to musculoskeletal disorders (MSDs). The most commonly affected areas are the shoulders and back due to poor biomechanical techniques and chronic fatigue[3].

To evaluate and prevent injuries in the aviation industry, various companies and research groups have developed injury assessment methods for aircraft attendants. Delta Airlines, a leading aviation airline, used Marsh's Ergonomics Practice to conduct a comprehensive review of ergonomics risks for aircraft attendants. This practice assessed the body forces, movements, and repetitions that aircraft attendants perform during their shifts [4]. In [5], this study developed a questionnaire that uses the 6-digit North American Industrial Classification System (NAICS) code and 2-digit Workers Compensation Insurance Organizations (WCIO) code to analyze injury characteristics, such as body part injured, nature of the injury, and cause of injury, in the aviation industry. A study among Sri Lankan aircraft attendants [6] analyzed various factors in their questionnaire, including sex, ethnicity, duration of service, height, weight, ergonomic training, nature of the injury, manner of injury, part of the body affected, and whether the injury required time off to recover. In [7], this study developed another self-made questionnaire that covers personal and work-related information, work environment, pain occurrence site and intensity, and workplace stress. While these studies help to understand the strains that come with being an aircraft attendant, more research is needed to comprehensively understand how anthropometric and biomechanical factors impact aircraft attendants' health.

Virtual reality (VR) technology is currently being utilized to investigate the effects of external factors such as vision and sound on the body. By simulating real-life situations, individuals can make spontaneous movements in a safe environment without risking injury. For instance, in one study [8], VR was used to design innovative interiors that enhance passenger comfort and well-being on future business aircraft by improving privacy during travel. Another study [9] employed the

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virtual fit trials to assess the impact of seat width, load factor, and passenger demographics on airline accommodation. VR is also an essential component of aircraft attendant training mandated by the Federal Aviation Administration and can last anywhere from two to eight weeks, depending on the airline and aircraft type. During training, candidates must perform routine duties and safety drills under direct supervision to pass a safety, emergency, and evacuation procedure test [10,11]. A recent study [12] focused on aviation safety procedural training, which uses a VR environment with a 3-D virtual aircraft attendant as an instructor to demonstrate and provide feedback on each procedure. However, an additional study should be conducted to examine the human factor and ergonomic aspects of the exerted forces on the lower back of aircraft attendants during their routine activities using VR technology.

Accordingly, the primary objective of this study is to introduce an innovative technology to effectively evaluate the risk of MSDs among aircraft attendants during their routine tasks. To achieve this goal, a VR environment of an aircraft has been developed using Unity 3D software and an Oculus Quest headset. Simultaneously, an advanced motion tracking system has been integrated with ergonomic software to assess the back strains that can cause injuries in real time. By determining the spinal forces, a preventive approach will be devised by analyzing the impact of biomechanical variables on the lower back and improving improper movements of aircraft attendants, ranging from small actions such as serving food to passengers to significant strain-inducing actions like opening/closing the cabin door.

II. Methods

a) Virtual Reality (VR) Environment

The VR environment in Unity 3D (Unity Technologies, San Francisco, US)[13] comprises several elements, including the fuselage, food trolley, cabin door, passenger seats, and kitchen cabinets and drawers. These elements were designed by Igor Yerm [14] and are illustrated in Figure 2.1. The game elements that the player interacts with are the cart, cabin door, and kitchen cabinets and drawers, while the fuselage and seats contribute to creating a realistic scene and enable interaction with the VR world. Each element requires a unique setup to complete its task, and the specific details for each task are listed below.

To prepare the VR environment and ensure that all Unity packages were installed correctly, the fuselage file was imported as an asset and placed in the game space. Its position was set to (0, 0, 0) without any rotation, and it was scaled by a factor of 11.3 to match the dimensions of the cabin, which is 2.23m high, 3.71m wide, and 27.48m long [15]. To enable participants to enter the VR world, both of the Oculus integration App and the extended reality (XR) interaction toolkit were installed to allow the use of the Oculus Rift within Unity. The XR plug in management was selected for version 3.2.16, the spatializer plugin was selected for the Oculus, and the Oculus VR rig was added to the game to provide an in-game camera. Its initial setup was also at (0, 0, 0).

To enable interaction with game objects, rigid bodies, and colliders were added to both VR hands. Rigid bodies provide mass to entities, while colliders define their shape and boundaries. A mass of 0.6kg was added to the hand anchors on both left and right sides, and a radius of 0.06m was added to a sphere collider, based on the average weight and length of human hands [16]. The hand anchors match the controller motion in-game. Furthermore, the trigger on the controller was selected under the sphere collider to enable grabbing actions. To synchronize the movement of VR hands, the same process of adding a rigid body and sphere collider was applied to the controller anchors, which are located under the children of the hand anchors.

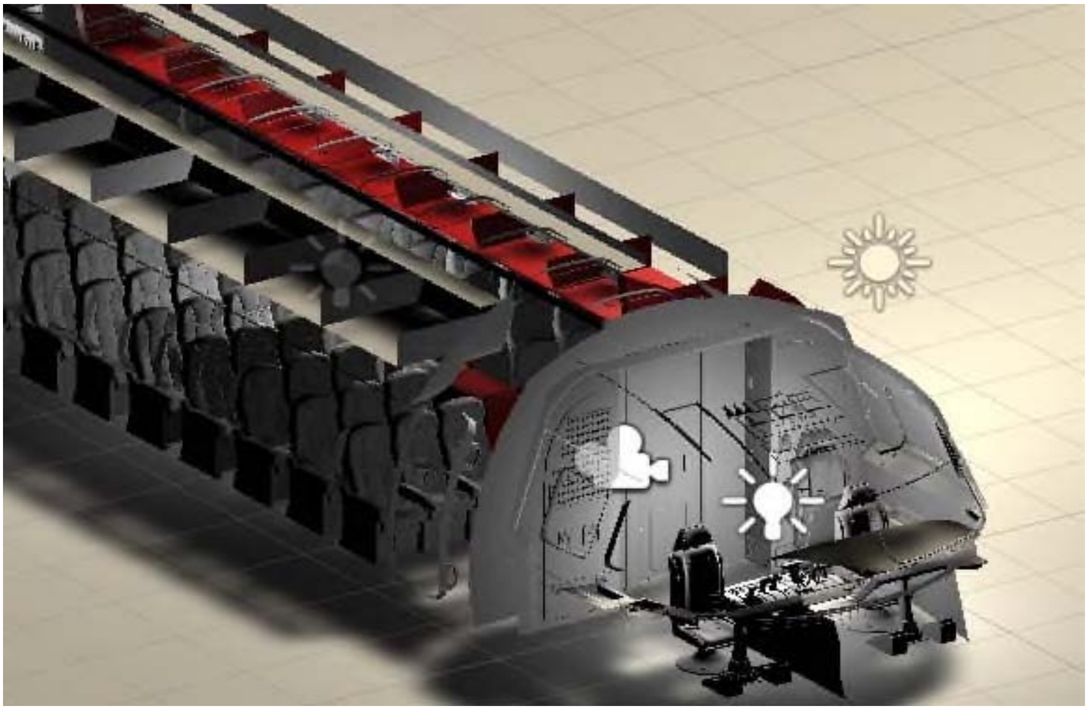


Figure 2.1: The VR Environment in Unity 3D for Participants to Complete Tasks

b) Subjects and System Setup

A total of twenty-two subjects were recruited for this study, and their body height and weight are presentedby the mean value ± standard deviation (11 males: 179.6±3.4cm (height), and 78.1±5.7kg (weight); 11 females: 164.6±4.2cm (height), and 67.2±7.9kg (weight)). During the orientation session, all subjects were informed of the study protocols. Anthropometric data, including hand, lower arm, upper arm lengths, arm span, ankle height, foot, shank, and thigh lengths, as well as shoulder and hip widths, were measured for each subject before movement collection.

The Xsens MVN Awinda (Xsens 3D Motion Tracking Technology, Netherlands)[17] was used to capture the actual movement of each subject during their task performance in this study. Figure 2.2 (a) illustrates the use of individual digital human models (DHM_Xsens) created in the Xsens Analyze software to represent the digital versions of the subjects.

A second digital human model (DHM_JACK, Figure 2.2 (b)) was created in JACK simulationtool (Siemens PLM software)[18] to evaluate the forces exerted on the lower back of subjects, based on the anthropometric data collected in the orientation section. The trajectory of kinematic motion data from the DHM_Xsens was exported into JACK, which has a unique feature that allows alignment of the skeletal segments of DHM_Xsens to the anatomical joint centers of DHM_JACK, thus achieving actual human movement in DHM_JACK.

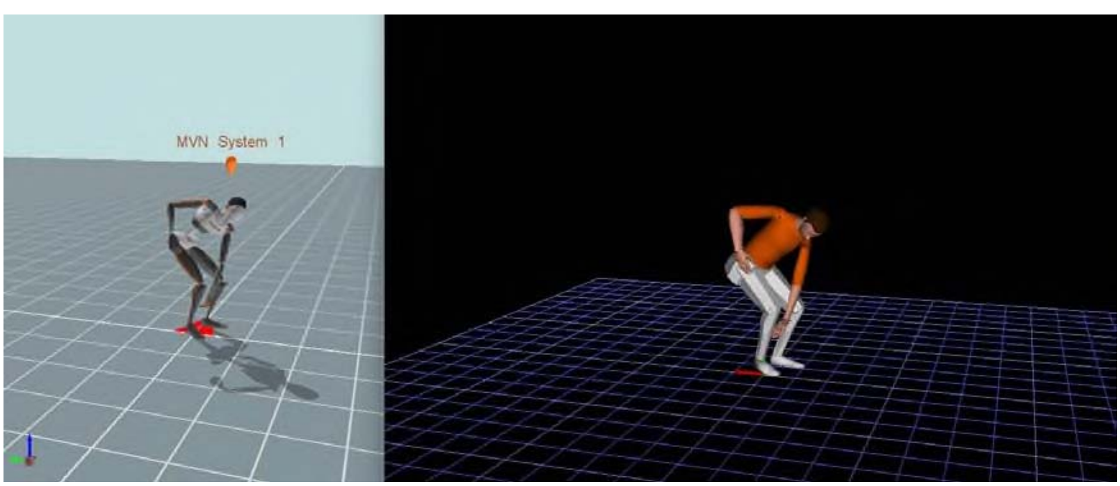


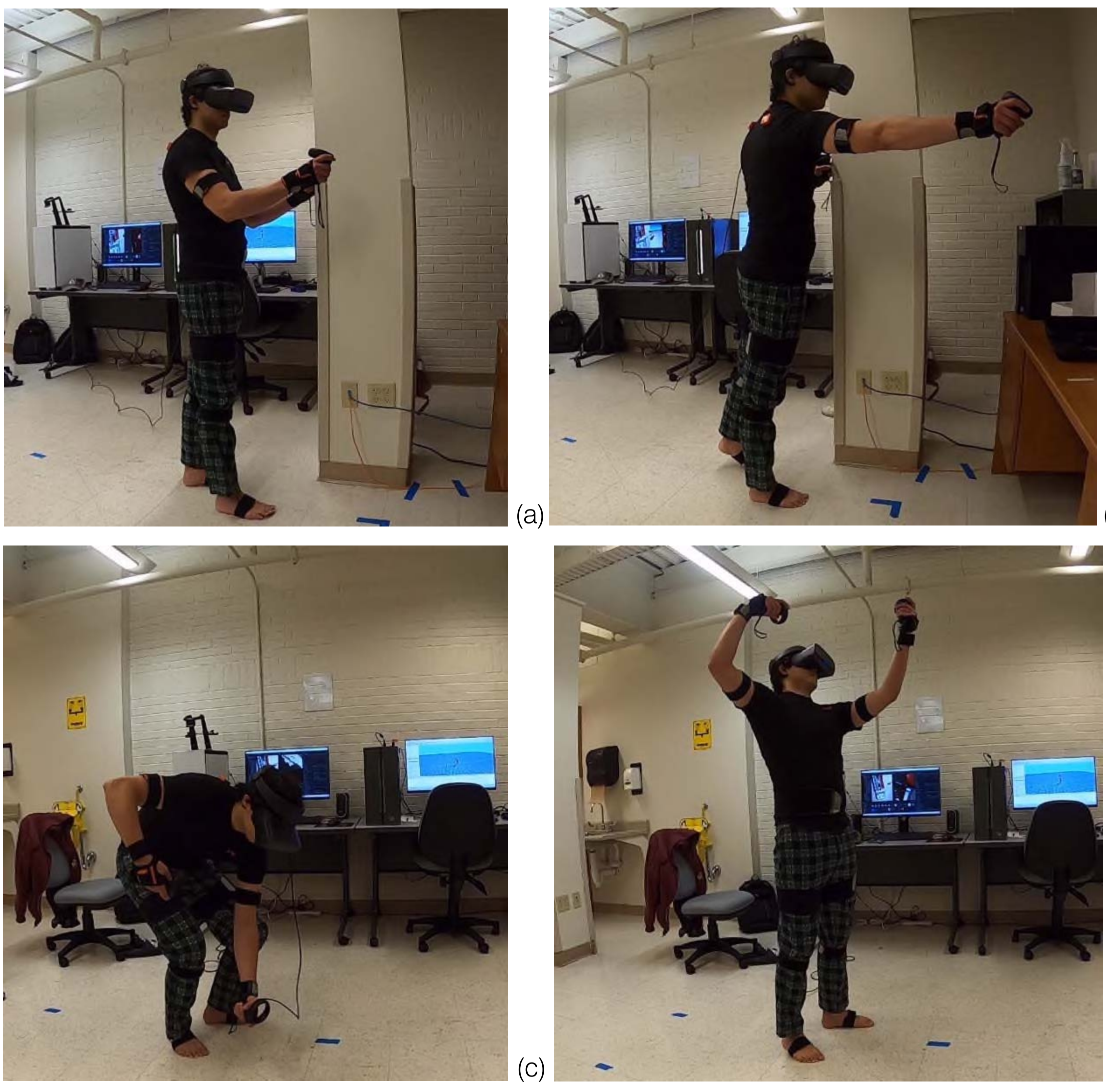
Figure 2.2: The Integration of Xsensawinda Software (Left) with JACK Siemens Ergonomics Software (Right). The Motion of Both Dhms is Synchronous

c) Operational tasks

Two common tasks were designed for subjects: 1) opening the cabin door from the inside of the aircraft, and 2) lifting a carry-on luggage for passengers, as shown in Figure 2.3. Each task was repeated four times to ensure the high reliability of the collected data.

Task#1: A mass of 158kg [19] was added to the cabin door, and the hinge joint in the door was set to velocity tracking for movement. An anchor was used to set the axis of rotation of the door, and an angular drag of 1000N was set to provide resistance and prevent the door from moving freely or swinging after being pushed. To realistically imitate the door opening task, each subject's left hand needed to be pressed against the real physical wall, while their right hand needed to grab the VR door to open it. Rotational limits were set in the program at the fuselage and 90 degrees open to ensure the same ending position for all subjects. After completing the task, the subjects were required to close the cabin door to its original position.

Task#2: The task is a two-hand lifting task that involves lifting the luggage. The luggage was designed in Autodesk Fusion 360 and imported as an asset, but it only had a visual mesh and did not allow for interaction. Therefore, convex mesh colliders were added to the luggage, and giving it a rigid body with a mass of 10kg [20]. The luggage handle was chosen as the first grab point, and a cube was made as a subunit of the main luggage with a collider added, which was placed at the bottom of the luggage as the second grab point. The overhead compartment was given a mesh collider so the luggage could be placed inside it.



(a) (b) (c) (d)

Figure 2.3: Two Common Tasks for Subjects to Perform. (a) Opening the Passenger Door; (b) Closing the Passenger Door; (c) Lifting the Luggage from the Floor; (d) Placing the Luggage into the Overhead Compartment

d) Data Analysis

The focus of this study was on identifying postures that could put aircraft attendants at a high risk of injury during task performance. Specifically, four postures were detected where excessive forces were exerted on the 4th/5th (L4/L5) lumbar spine.

Pose#1 in Task#1: The first pose where the excessive force was detected was observed when the subjects began to open the cabin door, as depicted in Figure 2.4 (a). For safety considerations, a force magnitude of 140N [21,22] was applied to the palm of the dominant right hand, with a pushing forward direction.

Pose#2 in Task#1: The second posture that may put the subjects at risk was identified when they started closing the door, as shown in Figure 2.4 (b). The magnitude of the applied hand force was also set to 140N, with its direction perpendicular to the door and pointing towards the left side.

Pose#1 in Task#2: The first pose of interest was observed as the subjects initiated the lifting of the luggage from the floor, as shown in Figure 2.4 (c). To conform with the airline luggage regulations, we used a luggage weight of 10kg [20]. The magnitude of force applied to each hand was determined to be 50N ($F=m \times a/2$) to maintain consistency across subjects, with the direction of force being vertically upward.

Pose#2 in Task#2: The second pose was detected as the subjects placed the luggage in the overhead compartment, as shown in Figure 2.4 (d). We assumed that the magnitude of the applied hand force was still 50N for each hand, and the direction was upward.

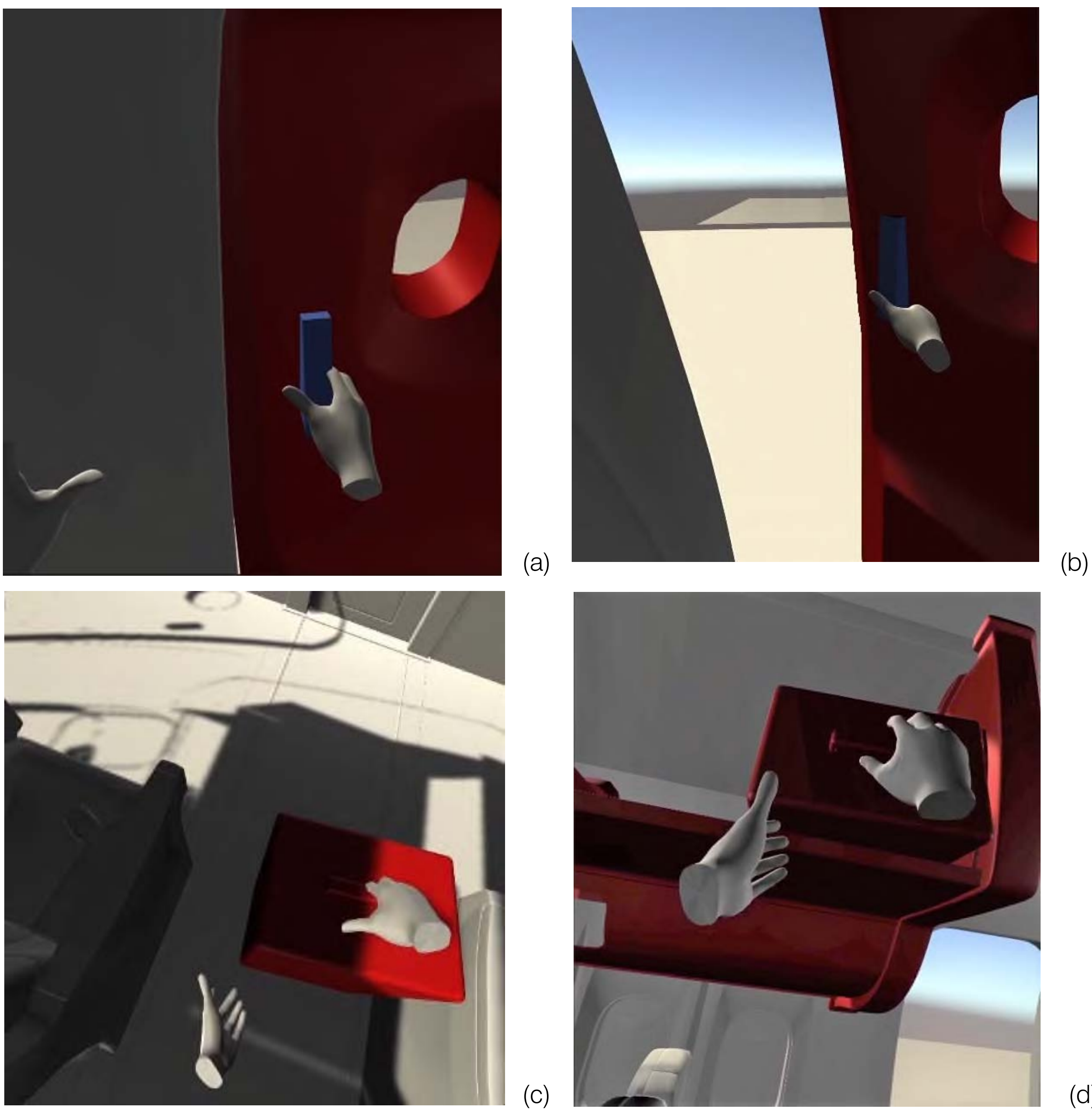


Figure 2.4: The Four Detected Postures had Excessive Forces Exerted on the L4/L5lumbar Spine.(a) Opening the Passenger Door; (b) Closing the Passenger Door; (c) Lifting the Luggage from the Floor; (d) Placing the Luggage into the Compartment

e) Statistical analysis

For each task, we conducted a two-way analysis of variance (ANOVA) to determine the significant difference in exerted spinal forces on L4/L5 between the two detected poses and genders. We further performed a t-test to analyze the variables of compressive force, AP shear force, and each anatomical joint angle, to understand the differences between males and females at each pose. The statistical significance level was set at 0.05. Additionally, we analyzed the cross-correlation (*R*) between key anthropometric variables such as body weight, body height, joint angles, and the exerted spinal forces to identify the effect of these variables on the risk of MSDs for aircraft attendants.

III. Results

a) Task#1: opening and closing the passenger door

Figure 3.1 illustrates the spinal forces applied to the L4/L5 spinal disc. A significant variation in spinal forces ($p<0.05$) for two specific poses was displayed in Table 3.1. However, in a comparison between genders, a significant difference was only revealed in the compressive spinal force, which was presented in Tables 3.2 and 3.3.

Figure 3.2 illustrates the anatomical joints at two specific poses in Task#1. Most joints have significant differences, except for the trunk and right hip, which were shown in Tables 3.1-3.3. During pose #1, when the subjects open the passenger door, only the trunk shows a significant difference between males and females. Pose #2 exhibits a significant difference in the trunk and right shoulder flexion/extension between genders.

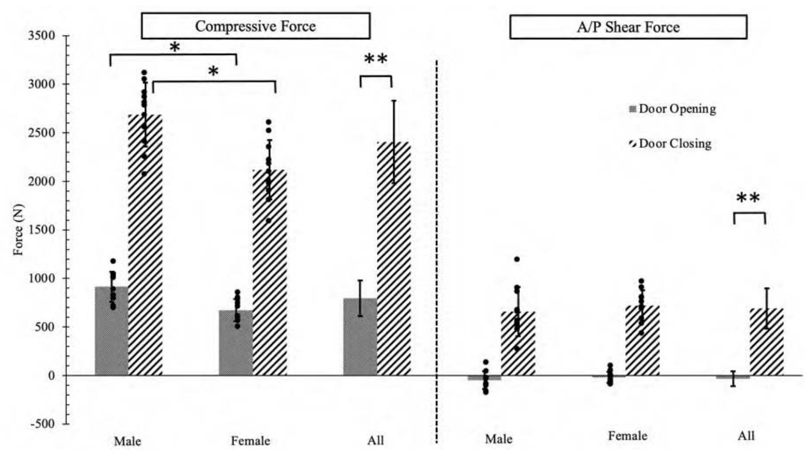
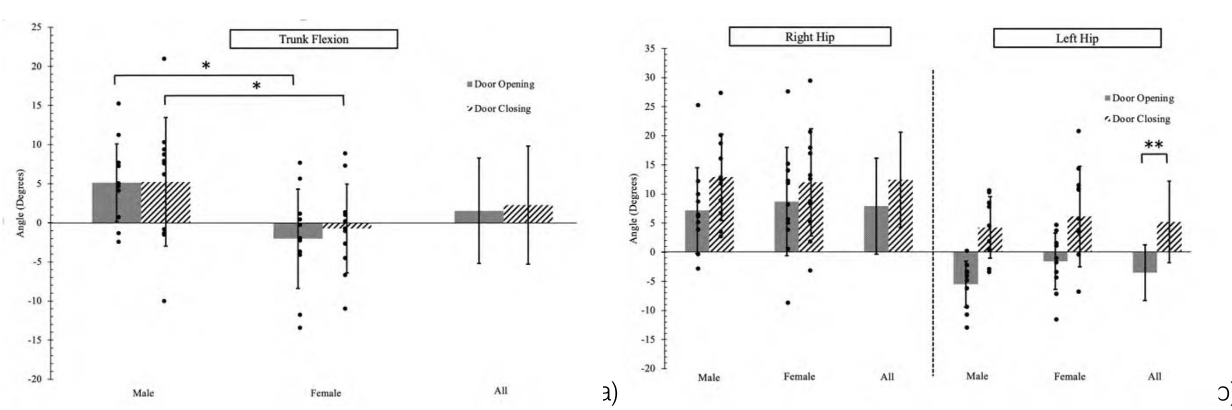


Figure 3.1: The Spinal Forces Exerted on the Lower Back at Two Poses for Task#1



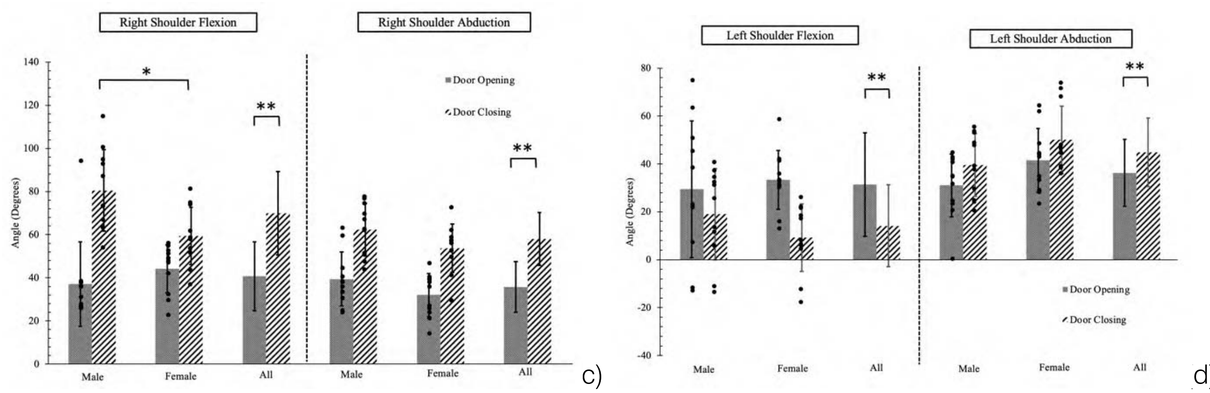


Figure 3.2: The Joint Angles at Two Poses in Task#1.(a) Trunk; (b) Hips; (c) Right Shoulder; (d) Left Shoulder. The Positive and Negative Values for the Trunk, and Hips Indicate Flexion and Extension

Table 3.1: All the Statistical p Values for the Two Specific Poses were Listed. T1 Represents Task#1; Trunk_Flex Represents Trunk Flexion and Extension; R_Sh_Flex Represents Right Shoulder Flexion/Extension; R_Sh_Abd Represents Right Shoulder Abduction/Adduction; L_Sh_Flex Represents Left Shoulder Flexion/Extension; L_Sh_Abd Represents Left Shoulder Abduction/Adduction. All the p Values Less than 0.05 were Bolded

T1	Compressive	AP Shear	Trunk Flex	Right Hip	Left Hip	R_Sh_Flex	R_Sh_Abd	L_Sh_Flex	L_Sh_Abd
Pose#1	795.2	65.0	1.5	7.9	-3.5	40.7	35.8	31.4	36.3
Pose#2	2404.0	691.2	2.3	12.4	5.2	70.0	58.0	14.1	44.8
P values	**7.3×10^{-24}**	**3.1×10^{-18}**	0.72	0.08	**1.9×10^{-5}**	**4.6×10^{-7}**	**1.3×10^{-7}**	**6×10^{-3}**	**0.04**

Table 3.2: The p Values Between Males and Females are Listed For Task#1 at Pose#1

T1_P1	Compressive	AP Shear	Trunk Flex	R_Hip	L_Hip	R_Sh_Flex	R_Sh_Abd	L_Sh_Flex	L_Sh_Abd
Males	916.4	80.3	5.1	7.2	-5.5	37.1	39.5	29.4	31.0
Females	673.9	49.8	-2.0	8.7	-1.6	44.2	32.1	33.3	41.5
P values	**5×10^{-4}**	0.38	**9×10^{-3}**	0.67	0.06	0.31	0.14	0.68	0.08

Table 3.3: The p Values between Males and Females are Listed for Task#1 at Pose#2

T1_P2	Compressive	AP Shear	Trunk Flex	R_Hip	L_Hip	R_Sh_Flex	R_Sh_Abd	L_Sh_Flex	L_Sh_Abd
Males	2688.7	659.6	5.2	12.9	4.3	80.5	62.3	19.0	39.6
Females	2119.2	722.7	-0.7	12.0	6.1	59.4	53.7	9.2	50.1
P values	**4×10^{-4}**	0.49	**0.05**	0.81	0.54	**7×10^{-3}**	0.1	0.19	0.09

Tables 3.4 and 3.5 present the results of the correlation coefficient analysis. It appears that the variable body height of the subjects has a relatively high correlation with the compressive spinal force. Additionally, the flexion/extension of the right hip is correlated with spinal forces at Pose#2. The R values for all the correlations are listed in the tables.

Table 3.4: The Cross-Correlation between Variables at Pose#1 in Task#1 is Listed. T1_P1 Represents Task#1 at Pose#1; BW Represents Body Weight; BH Represents Body Height

T1_P1	BW	BH	Trunk Flex	Right Hip	Left Hip	R_Sh_Flex	R_Sh_Abd	L_Sh_Flex	L_Sh_Abd
Compressive	0.25	**0.50**	0.20	-0.36	-0.18	-0.14	0.41	-0.40	-0.14
AP Shear	0.16	0.32	0.45	-0.16	0.27	-0.23	0.05	0.20	0.04

Table 3.5: The Cross-Correlation between Variables at Pose#2 in Task#1 is Listed. T1_P2 Represents Task#1 at Pose#2

T1_P2	BW	BH	Trunk Flex	Right Hip	Left Hip	R_Sh_Flex	R_Sh_Abd	L_Sh_Flex	L_Sh_Abd
Compressive	**0.69**	**0.81**	0.32	**0.52**	0.11	0.41	0.20	0.43	-0.42
AP Shear	-0.02	-0.12	-0.02	**0.60**	0.24	-0.27	-0.39	0.30	0.25

b) Task#2: Lifting the Passenger Luggage

Figures 3.3 and 3.4 illustrate the variables tested for significance at two specific poses. Nearly all the variables show a significant difference, except for the right and left shoulder abduction/adduction when subjects lifted the passenger luggage from the floor and placed it into the overhead compartment. The corresponding p values for the two poses are listed in Table 3.6. In the comparison between genders, the compressive force exerted on the lower back of participants and the trunk flexion/extension are significantly different at both poses. At Pose#1, the AP shear force is also statistically different between males and females, as indicated in Tables 3.7 and 3.8.

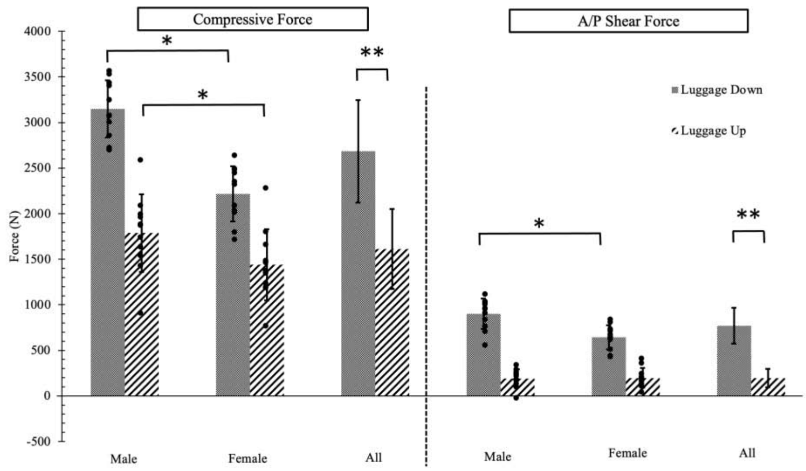


Figure 3.3: The Spinal Forces Exerted on the Lower Back at two Specific Poses For Task#2

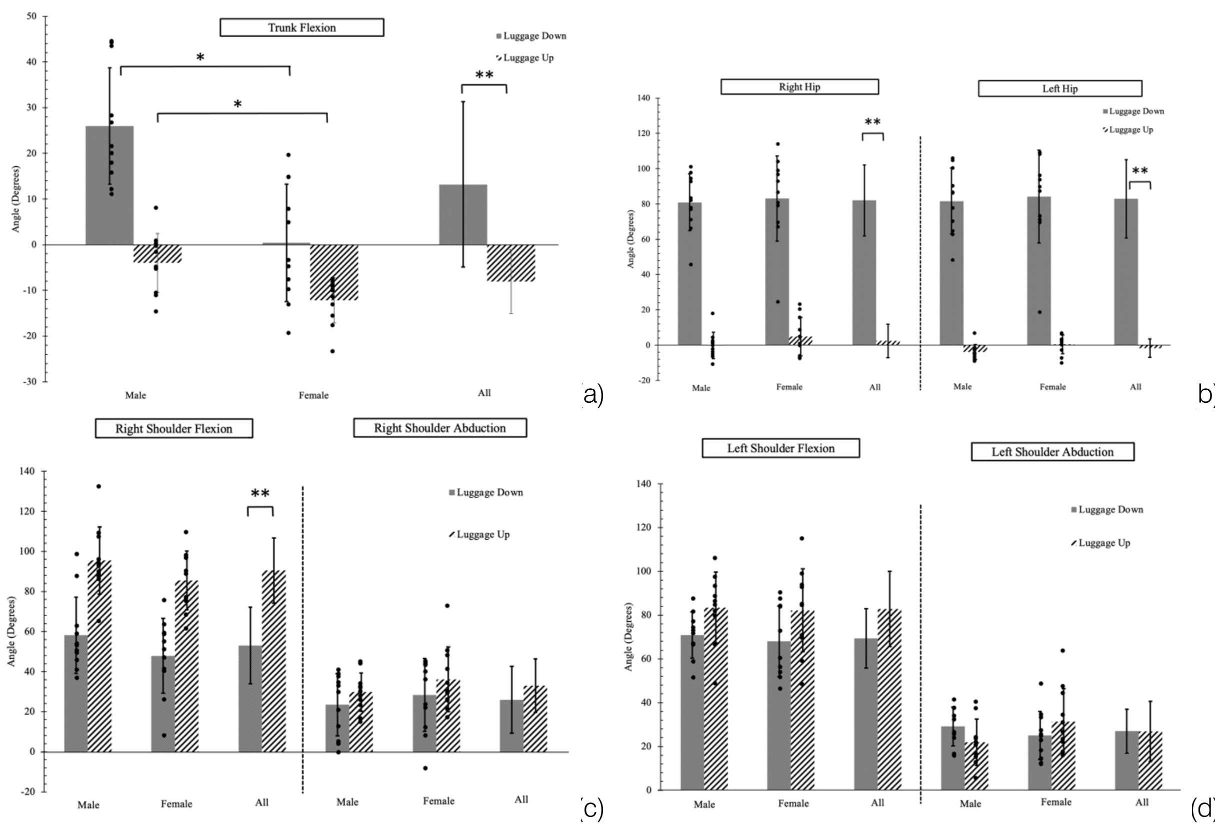


Figure 3.4: The Joint Angles at Two Poses in Task#2.(a) Trunk; (b) Hips; (c) Right Shoulder; (d) Left Shoulder. The Positive and Negative Values for the Trunk, and Hips Indicate Flexion and Extension

Table 3.6: All the Statistical p Values for the Two Specific Poses were Listed. T2 is used to Represent Task#2

T2	Compressive	AP Shear	Trunk Flex	Right Hip	Left Hip	R_Sh_Flex	R_Sh_Abd	L_Sh_Flex	L_Sh_Abd
Pose#1	2683.9	771.3	13.2	82.0	82.9	53.0	25.9	69.4	27.0
Pose#2	1613.1	194.6	-8.1	2.4	-1.7	90.5	32.9	82.8	26.8
P values	**3.3×10^{-12}**	**9.2×10^{-18}**	**1.3×10^{-8}**	**1.6×10^{-9}**	**6.2×10^{-20}**	**1.2×10^{-8}**	0.13	**0.7×10^{-2}**	0.89

Table 3.7: The p Values between Males and Females are Listed for Task#2 at Pose#1

T2_P1	Compressive	AP Shear	Trunk Flex	R_Hip	L_Hip	R_Sh_Flex	R_Sh_Abd	L_Sh_Flex	L_Sh_Abd
Males	3149.9	900.3	26.0	80.9	81.6	58.1	23.4	70.9	29.2
Females	2217.9	642.3	0.4	83.1	84.2	47.9	28.3	68.1	25.0
P values	**7.3×10^{-7}**	**7.1×10^{-4}**	**1.4×10^{-4}**	0.8	0.8	0.22	0.5	0.62	0.33

Table 3.8: The p Values between Males and Females are Listed for Task#2 at Pose#2

T2_P2	Compressive	AP Shear	Trunk Flex	R_Hip	L_Hip	R_Sh_Flex	R_Sh_Abd	L_Sh_Flex	L_Sh_Abd
Males	1787.7	191.8	-4.0	-0.1	-3.9	95.4	29.7	83.4	21.9
Females	1438.5	197.4	-12.2	4.8	0.5	85.5	36.1	82.2	31.3
P values	**0.05**	0.9	**3×10^{-3}**	0.23	0.05	0.16	0.27	0.87	0.1

Tables 3.9 and 3.10 present the results of the correlation coefficient analysis. The variable body height remains highly correlated with spinal forces, particularly at Pose#1 when subjects flexed their upper body to lift luggage from the floor. Moreover, body weight and trunk flexion also show a correlation with the exerted spinal forces at both poses. Other variables do not show a high correlation with spinal forces. The tables list all the R values for the correlations.

Table 3.9: The Cross-Correlation between Variables at Pose#1 in Task#2 is Listed. T2_P1 is used to Represent Task#2 at Pose#1

T2_P1	BW	BH	Trunk Flex	Right Hip	Left Hip	R_Sh_Flex	R_Sh_Abd	L_Sh_Flex	L_Sh_Abd
Compressive	**0.52**	**0.86**	**0.64**	0.07	0.11	0.17	-0.20	-0.08	-0.24
AP Shear	**0.52**	**0.72**	**0.50**	0.28	0.34	0.10	-0.01	-0.04	-0.24

Table 3.10: The cross-correlation between variables at Pose#2 in Task#2 is listed. T2_P2 is used to represent Task#2 at Pose#2

T2_P2	BW	BH	Trunk Flex	Right Hip	Left Hip	R_Sh_Flex	R_Sh_Abd	L_Sh_Flex	L_Sh_Abd
Compressive	**0.61**	**0.53**	**0.71**	-0.13	-0.11	0.10	-0.17	-0.44	-0.10
AP Shear	0.41	0.15	0.43	0.09	0.15	-0.01	-0.15	-0.28	-0.03

IV. Discussion

In this study, we have effectively evaluated the spinal forces exerted on the lower back of aircraft attendants by integrating advanced motion-tracking techniques with Virtual Reality (VR). This integration was also combined with the Siemens ergonomics software, which allows us to assess the risk of injuryaccurately.

During Task#1, which involved opening and closing the passenger door, we found a significant difference in the compressive and A/P shear forces on the spine at two specific poses. As the difference between the two poses was noticeable, we observed significant variations in nearly all the joints.

In the gender comparison, we observed a significant difference in the compressive force at both poses, which could be attributed to trunk flexion. On average, male participants demonstrated approximately 7 degrees more trunk flexion than female participants. Furthermore, since the average body weight of males was considerably higher than females, the additional trunk flexion likely resulted in greater compressive force on the L4/L5 spinal disc for males [23,24]. Conversely, females, who had relatively lighter body weight and slight trunk extension at both poses, experienced a significant decrease in the exerted spinal forces. Our study confirms the positive correlation (R=0.69) between compressive force and body weight. To minimize the risk of injury, it is essential to maintain a neutral trunk position.

At pose#2, the p-value for the right shoulder flexion joint was less than 0.05, indicating a significant difference between male and female participants in their ability to close the passenger door with a fixed handle position. Because of the significant difference in body height between genders, male participants may need to increase their right shoulder flexion when they have relatively higher trunk flexion than females to close the door.

Additionally, in Task#1, a moderate correlation was observed between the right hip and spinal forces, which only occurred at pose#2. Although this correlation was not strong enough in this study, other studies [25,26] have shown that large hip flexion during the push or pull tasks can lead to a significant spinal force, which may increase the risk of lower back injury. Therefore, it is essential to avoid large movements of hip joints to eliminate the risk of injury.

It is important to note that a hand force of 140N was used in Task#1 for safety reasons [21,22] to determine the spinal forces. Assuming a friction coefficient of 1.0, the weight of the passenger door was approximately 14kg. However, the actual weight of the door ranges from 120kg to 500kg[27]. Therefore, the applied hand force needed to open the door could be much larger than the 140N used in Task#1. At pose#2, the average A/P shear was 691.2N when the exerted hand force was 140N, which is very close to the recommended safety threshold value of 700N [28]. This suggests that there is a high likelihood of injury to aircraft attendants when opening real passenger doors with larger weights. Thus, the design of the door hinge is a critical factor in preventing injury to aircraft attendants.

In Task#2, which involved lifting the luggage from the floor and placing it into the overhead compartment, most of the variables exhibited significant differences between two specific poses, except for the right/left shoulder abduction/adduction. This may be due to the constraints of the two grabbing points on the luggage. The angles of trunk and hip flexion were identified as factors that led to a significant difference in spinal forces exerted on the lower back [24,26].

At Pose#1 in Task#2, the male participants exerted approximately 30% higher spinal forces than the females. From the cross-correlation analysis, it was observed that trunk flexion was correlated to the spinal forces, including compressive and A/P shear forces, with R values of 0.64 and 0.50, respectively. It appeared that while lifting the luggage from the floor, males flexed their trunks more than females, with both genders having a large hip flexion. This could be attributed to body height differences, as the 15cm gap in height made it easier for male participants to flex their trunks and reach the luggage [26]. The statistical analysis supported this conclusion, as evidenced by the R values of 0.86 and 0.72 for the correlation between body height and spinal forces.

Although the amplitude of spinal forces decreased at Pose#2, there was still a significant difference in compressive force exerted on the lower back between genders. The correlation between trunk movement and spinal forces remained relatively high, with R values of 0.71 and 0.43. To complete the task, subjects had to extend their trunk to put the luggage into the overhead compartment. Trunk extension is beneficial in reducing the risk of lower back injury during the lifting task [29,30]. Due to their relatively shorter body height, female participants had to reach further and extend their trunks more than male participants to place the luggage, resulting in less compressive spinal force being exerted on them. As participants placed the luggage into the compartment, they adopted a nearly neutral pose, which caused the weight of their upper body and the objects to be supported by their lower back. Consequently, the magnitude of compressive force at this specific pose showed a moderate correlation with the variable body weight, with an R value of 0.53.

In Task#2, the maximum hand force was predicted to occur when the load exerted on the lower back was greater than the recommended safety threshold for the either compressive force of 3400N [31] or the safety threshold for the shear force of 700N [28]. Our results indicated that this might cause a high risk of injury for aircraft attendants if the predicted force exerted by each hand reached 48N. In this case, the weight of the luggage should not exceed 10kg. However, airlines have different requirements for carry-on luggage, and the weight ranges from 7kg to 15.75kg [20]. To prevent injuries to aircraft attendants, the weight of carry-on luggage should be limited.

V. Conclusion

We have successfully assessed the risk of injury to aircraft attendants during their routine tasks by identifying key factors that could lead to injuries, such as objects with heavy weight, and postures adopted by attendants that may affect the spinal load exerted by the lower back. To reduce the risk of injury, it is crucial to reduce the weight of objects and to minimize upper body flexion for aircraft attendants, especially when assisting passengers in lifting luggage into the overhead compartment. Our study provides an opportunity for airline companies to monitor the injury risk of aircraft attendants and develop safety training programs based on real-time ergonomic results. Furthermore, this innovative fusion technology can be applied to other occupational fields, such as underground mining and manufacturing assembly lines, to prevent injuries and ensure worker safety.

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Investigating the Effects of Load and Deceleration on Non-Pneumatic Tire Deformation and Stress during Braking

By Rahman Wijaya, Faizal Adinegoro, Muslim Mahardika & Rachmat Sriwijaya
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Abstract- The Non-pneumatic tire (NPT) is a unique tire design that was introduced in 2005 and had the potential to replace traditional tires. Unlike conventional tires, the NPT uses flexible rods called spokes instead of air to maintain its shape. Several spoke models, such as tweel, honeycomb, and Bridgestone designs, have been developed and tested for static loads using numerical analysis. In this study, the behavior of the NPT was investigated under braking forces. The finite element method (FEM) was used to calculate load results, and the deformation of the NPT was measured with variations in load and deceleration values. Results showed that stress and deformation in the NPT increased with higher loads or deceleration values.

Keywords: *non-pneumatic tire (NPT), finite element method (FEM), braking forces, deformation, stress.*

GJRE-G Classification: *LCC: TL240, TL259, TL315, TL319*

INVESTIGATINGTHEEFFECTSOFLOADANDDECELERATIONONNONPNEUMATICTIREDEFORMATIONANDSTRESSDURINGBRAKING

Strictly as per the compliance and regulations of:

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Keywords: non-pneumatic tire (NPT), finite element method (FEM), braking forces, deformation, stress.

I. Introduction

The tire is a critical component of a vehicle. It is the only part that makes contact with the road surface and enables the engine's rotation to be converted into axial motion. The most commonly used type of tire is the pneumatic tire, which is filled with pressurized air to produce a certain level of stiffness that can be adjusted to meet the vehicle's needs. However, pneumatic tires have a well-known weakness: they can lose pressure due to air leaks or bursting, rendering the tire unusable. To address this issue, researchers have developed non-pneumatic tires (NPTs), which have been extensively studied since their introduction in 2005 [1].

Several spoke geometries had been proposed for NPTs, including the tweel, honeycomb, and Bridgestone designs [2]. According to previous research, the honeycomb structure provides more evenly distributed contact pressure, low rolling resistance, and high load capacity, making it a promising option for NPTs [3] and [4]. However, it is still unclear how NPTs will perform under dynamic loads, such as hard braking, and what types of stresses the spokes will experience [5]. In addition, maintaining a safe distance between vehicles is crucial for safe driving, especially during sudden braking. Vehicle weight, the center of gravity, coefficient of friction, wheelbase length, and other factors all play a role in determining the stopping distance of a vehicle [6]. The standard safe distance between cars at a given speed can be found in traffic safety guidelines [7]. Overall, the development of NPTs holds great potential for overcoming the weaknesses of conventional pneumatic tires. Further research is needed to obtain the benefits and potential drawbacks of NPTs, particularly under dynamic load conditions.

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II. Literature

Recent studies have further emphasized the importance of maintaining a safe distance between vehicles. Muslim and Itoh (2019) investigated driver behavior during overtaking maneuvers, which can be particularly dangerous for drivers who fail to maintain a safe following distance. Benterki et al. (2021) developed a method for estimating driver intention to facilitate autonomous vehicles' safe and comfortable operation.

Fountas et al. (2020) found that visibility-related weather conditions can significantly affect the severity of crashes, highlighting the importance of maintaining a safe following distance in adverse weather conditions. Bunn et al. (2003) reviewed area-wide traffic calming measures for preventing traffic-related injuries, highlighting the importance of reducing speeds and providing clear signage and road markings to help drivers maintain a safe following distance.

The study by Feng et al. (2010) provides an in-depth exploration of the factors involved in calculating following safe distances and offers a new approach to addressing this important aspect of traffic safety. Tang (2017) investigates the impact of different vehicle operating parameters on braking distance, such as speed, brake force, road surface conditions, and vehicle load, which significantly impact braking distance.

Overall, the literature highlights the continued importance of maintaining a safe following distance for driving safety and suggests further research on the topic to understand better the impact of various factors on driving behavior and safety.

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III. Calculation and Simulation

Hard braking occurs when a vehicle is forced to stop at a shorter distance than it is safe. Hard braking can cause the vehicle to tip forward. Hard braking is done by pressing the brake pedal to the maximum, forcing the wheels to slide on the road. During hard braking, the position of the vehicle's center of gravity (CG), the friction coefficient between the road and the wheels, the wheelbase's length, and the vehicle's weight are essential factors that affect the stopping distance.

To calculate the CG and longitudinal load transfer, standard references such as Milliken and Milliken's (1995), Wong's (2002), and Kiencke and Nielsen's (2005) can be consulted. The simulation method and analysis can be based on Kohnke (2013), Bathe (2006), and Zienkiewicz et al. (2005). The equation for the center of gravity and longitudinal load transfer are shown in equations 1-3.

$$X = \frac{\sum xi\,.Wi}{\sum Wi} \tag{1}$$

$$Y = \frac{\sum yi\,.Wi}{\sum Wi} \tag{2}$$

$$Z = \frac{\sum zi\,.Wi}{\sum Wi} \tag{3}$$

where,

xi: center of the mass point of an object in the x-axis (m); *yi*: center of the mass point of an object in the y-axis (m); *zi*: center of the mass point of an object in the z-axis (m); *W*: weight of the object (N).

Several variables, such as vehicle wheelbase length and weight, also affect the value of longitudinal load transfer, as shown in Figure 1 [20]. Equation 4 uses to calculate the amount of load transferred.

$$longitudinalloadtransfer = gx\frac{wx\ h}{L} \tag{4}$$

where,

g: deceleration (g); w: vehicle weight (kg); h: height of the vehicle's center of gravity (mm); L: wheelbase length of the vehicle (mm).

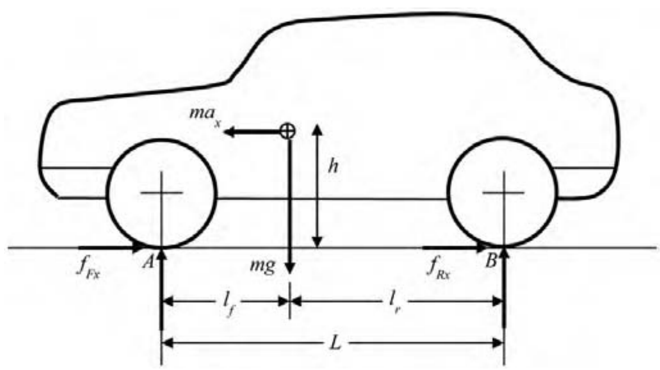

Figure 1: Free body Diagram Applied on the Vehicle During Braking [20]

The value of G in calculating the longitudinal load transfer is the ratio of deceleration to acceleration due to gravity, which is 9.81 m/s^2. The variable that most affects the vehicle's deceleration value is the coefficient of friction between the tire and the road, as shown in equations 5-7.

$$\Sigma F_x = m\, a_x \tag{5}$$

$$\Sigma F_y = ma_y \tag{6}$$

$$-\mu_k g = a_x \tag{7}$$

where,

m is the vehicle's mass (kg), a is the deceleration (m/s^2), g is the acceleration due to gravity (m/s^2), and μk is the coefficient of kinetic friction.

The NPT design with a honeycomb spokes model and 5 mm thickness by Sriwijaya and Hamzah (2019) is used as a reference for the study. The materials used for each component of the NPT are detailed in Table 1. A static simulation was performed on the NPT with a vehicle weight of 8000 N. The simulation's output was then compared to the results of previous research to achieve an accuracy rate of over 95% by adjusting the actual spoke deformation and von Mises stress values as a validation step (Figure 2). The validated simulation results were then subjected to various longitudinal loads caused by a moment of force in the same direction as the vehicle's speed.

Table 1: Composition of NPT Materials [21]

Property Material	*Polyurethane (spokes)*	*Rubber (tread)*	*Structuralsteel (ringhub)*
Density (kg/m^3)	1.200	1.150	7.800
Poisson's ratio	0,49	0,49	0,2
Yield stress (MPa)	145	16	1240
Young's modulus (MPa)	32	11,9	210.000

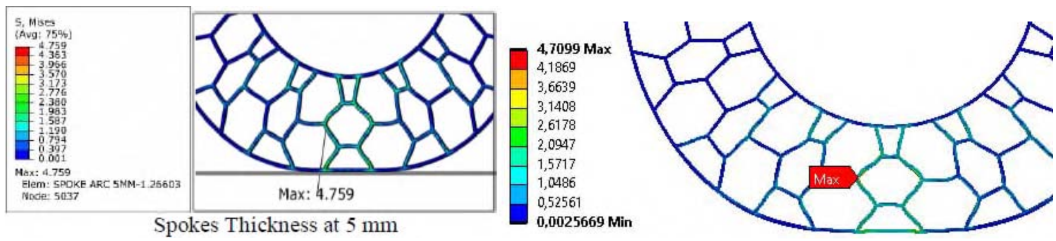

Figure 2: Validation Process [21]

For determining the friction force (Ffr), the actual value is 0.8, which is the coefficient of friction between the asphalt and the tire[22]. However, due to limitations of the constraints, a simplification process was carried out, resulting in the contact between the NPT and the road being considered fixed. The simulation scheme can be seen in Figure 3, with W as the vertical load acting on the Y-axis. The value of W is divided by the number of wheels on the vehicle. On the X-axis, there is F which is the force generated by the car during braking, and the value of force F is opposite to the friction force Ffr.

On the underside of the asphalt, it is constrained to be a fixed component. Calculations from equations 4 and 5 can obtain the value of the force on the X-axis. However, a specific vehicle model is needed to obtain the CG value so that the value of longitudinal load transfer can be known. An SUV was used as a reference model for calculating the CG. The CG of each part is plotted and then calculated by the weight of each piece to get the CG of the vehicle without passengers (Table 2).

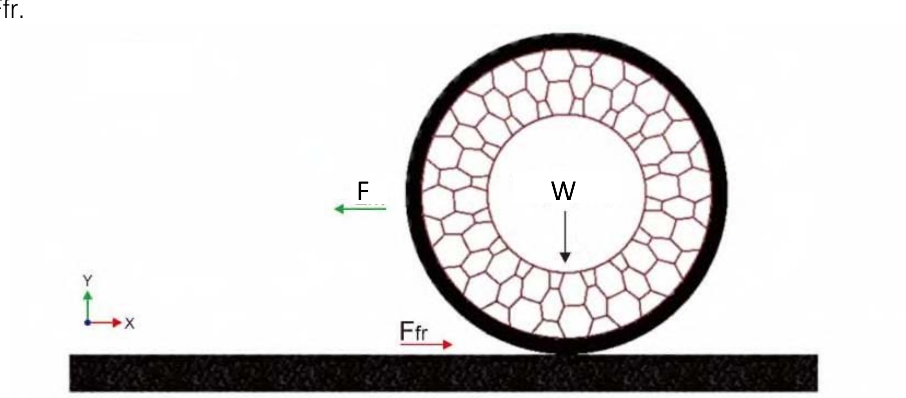

Figure 3: Loading Scheme

Table 2: CG Data for Each Part [23]

No.	Components	Mass (kg)	CG Height (mm)	M x CG (kg mm)
1	Front tire*	40,2	362	14552,4
2	Steering	16,2	362	5864,4
3	Front brake*	32,4	362	11728,8
4	Front suspension*	27,7	609	16869,3
5	Rear tire*	40,2	362	14552,4
6	Rear brake*	32,4	362	11728,8
7	Rear suspension*	49,3	482	23762,6
8	Spare wheel	20,1	476	9567,6

9	Electrical system	48,6	745	36207
10	HVAC	48,6	745	36207
11	Engine	210,5	562	118301
12	Axle	76,1	362	27548,2
13	Transmission	80	462	36960
14	Driveshaft	25,4	385	9779
15	Body structure + closure + exterior	631,4	529	334010,6
16	Control system	24,3	963	23400,9
17	Fuel	52,2	460	24012
18	Fuel tank	21	460	9660
19	Exhaust system	23,8	385	9163
20	Driver and 1st-row seat	30	706	21180
21	2nd-row seat	25	751	18775
22	3rd-row seat	0	0	0
23	Airbag	9	963	8667
24	Knee airbag	10	1602	16020
25	Front interior	21,5	963	20704,5
26	Upper interior	9,2	1602	14738,4
27	Extra curbs weight	14	462	6468
28	Driver	0	896	0
29	Passenger 1	0	896	0
30	Passenger 2	0	940	0
31	Passenger 3	0	940	0
32	Passenger 4	0	940	0
33	Passenger 5	0	0	0
34	Passenger 6	0	0	0
35	Baggage	0	846	0
	Total	1619,1	-	880427,9
	CG (mm)		543,7	

Based on Table 2, the column shows the mass values for each passenger. The weight of passengers affects the CG because the vehicle has a suspension system with a specific spring coefficient (Kf), so each load variation has a different CG height. The suspension's spring coefficient (Kf) is assumed to be 73750 N/m. The process of taking von Mises stress data is by reviewing the von Mises stress contour on the spokes section as a whole, while displacement data is taken from points A, B, and C, as shown in Figure 4.

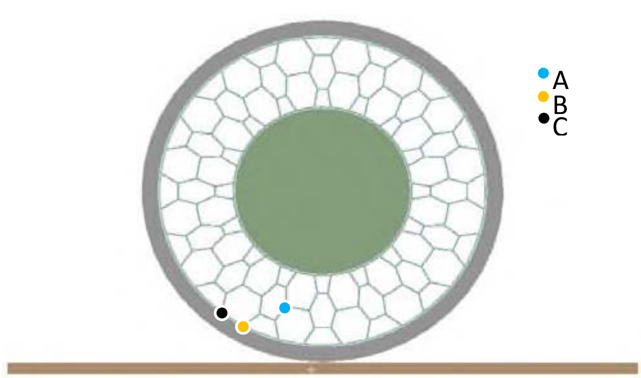

Figure 4: Points for Taking Displacement Data

IV. Result and Discussion

The A and B results on the NPT were analyzed using a finite element method. The deformation behavior was examined based on the Von Mises stress distribution on the NPT. Figure 5 shows the contour of the Von Mises stress on loading A, indicating that the NPT is deformed in the direction of the load. The maximum Von Mises stress position appears in the middle column supporting the loading condition, as noted in [24], due to stress concentration focused on one elbow.

The value of Von Mises stress in all loading A models appears to have increased compared to the validation model, as reported in [21], where the weight supported by the tire in the validation model, which is equivalent to 800 kg, becomes a variation of weights with values between 480-530 kilogramsor equal to 4700-5200N. The increase in the value of Von Mises stress is in the range of 39-53% from the original value of 4.759 MPa to 6.62 MPa to 7.31 MPa, as reported in [17] and [18](Figure 6).

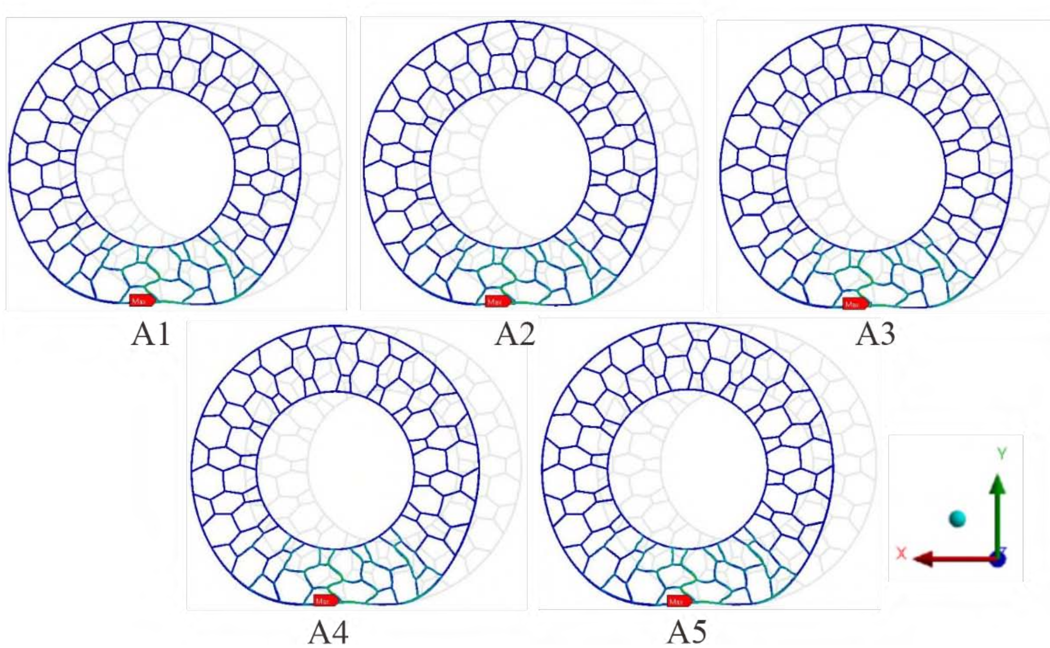

Figure 5: The Contour of Von Mises Stress on Loading A

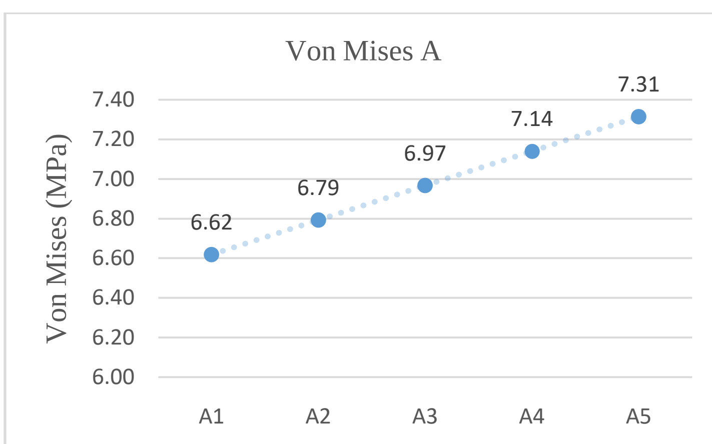

Figure 6: Graph of Von Mises Stress on Loading A

The results show that loading B on the NPT results in a deformation contour similar to loading A, as shown in Figure 7. Increasing the value of G in the loading B model causes a significant increase in the Von Mises stress value. Comparing the stress value in B1 with the validation model reveals a decrease of 9.5% from the original value of 4.759 MPa to 4.35 MPa, as reported by [17] and [18]. In contrast, the stress value in B2 to B5 increases by 7% to 53%, as reported in [21] (Figure 8). The increasing linear trend of loading B can be observed in the graph, where every increase of 0.1G results in an increase in the stress value by 0.74 MPa, as described in [24].

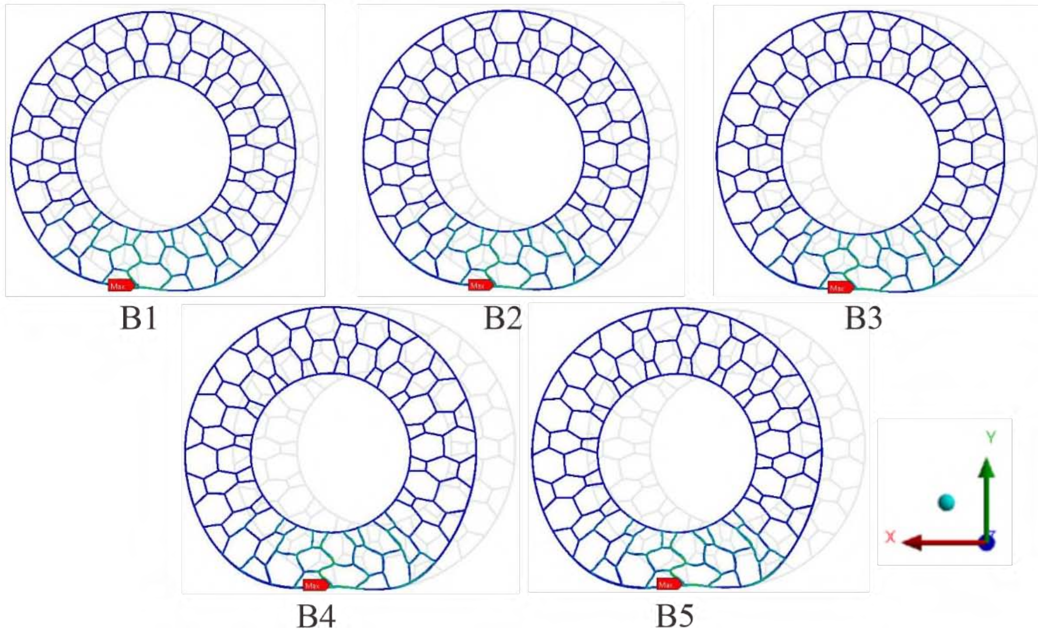

Figure 7: The Contour of Von Mises Stress on Loading B

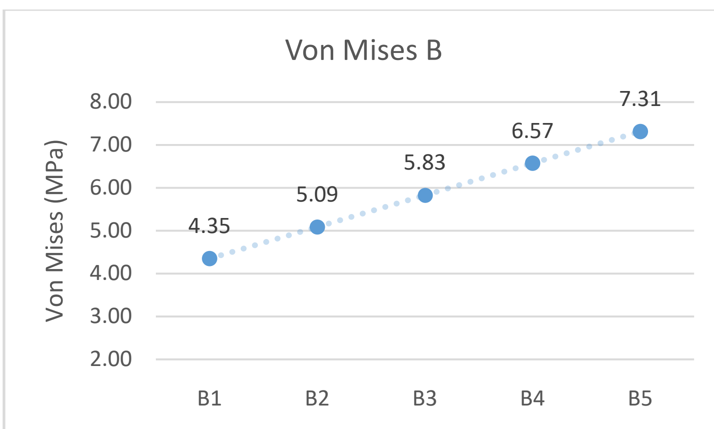

Figure 8: Graph of Von Mises stress on loading B

The results indicate that loading A and B produce a similar deformation contour. However, the stress value on the spokes with loading A increases less steeply than with loading B. This is because packing A only involves a 50 kg increase in passenger weight, equivalent to 2.6% of the vehicle weight. At the same time, loading B has an independent deceleration variable where a rise of 0.1G has a value of 12.5%. To compare the variables that affect loading A and B, the forces acting on the tire are calculated and presented in Table 3. The data in the table show that the detail working on the tire is much higher in loading B than in loading A.

The deceleration variable in loading B is the primary cause of the higher forces. The values in Table 3 also reveal that the vertical load on the tire is higher in loading B, as is the friction force, which is a function of the coefficient of friction between the tire and the road surface. Based on the data in Table 3, it can be seen that loading B has a more significant effect on the NPT than loading A due to the higher forces acting on the tire. These forces, in turn, lead to higher levels of Von Mises stress in the spokes. The difference in stress values between the two loadings highlights the need for further research to explore the effects of different types of loads on the NPT.

Table 3: Comparison of the resultant force angle

Load Variations	The total weight (kg)	Deceleration (G)	Longitudinal Load Transfer (Kg)	FX (N)	FY (N)
A1	1919	0,8	333,7	3765,3	6343,6
A2	1969	0,8	343,9	3863,4	6516,1
A3	2019	0,8	353,9	3961,5	6687,5
A4	2069	0,8	363,6	4059,6	6857,9
A5	2119	0,8	373,1	4157,7	7027,4
B1	2119	0,4	186,6	2078,8	6112,3
B2	2119	0,5	233,2	2598,6	6341,0
B3	2119	0,6	279,9	3118,3	6569,8
B4	2119	0,7	326,5	3637,9	6798,6
B5	2119	0,8	373,1	4157,7	7027,4

V. Conclusion

Based on the study's results, it can be concluded that the non-pneumatic tire (NPT) experiences increased stress and deformation as the load and deceleration values increase. Loading B was found to have a more significant effect on the NPT than loading A due to the higher forces acting on the tire, which resulted in higher levels of Von Mises stress in the spokes. The difference in stress values between the two loadings highlights the need for further research to explore the effects of different types of loads on the NPT. The study provides valuable insights into NPT performance under dynamic loads, which is critical for developing NPTs for commercial use.

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Photosensitive Structure with Schottky Barrier Based on Nickel-Silicon Silicon Contact

By E. A. Kerimov
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Abstract- Measured resistivities of produced silicide showed their good conductive properties. The calculation of technological route for obtaining thin silicide contacts (<100A0) in multilayer metallization of Si substrate was carried out, and the optimal technological regimes for obtaining Pd, Pt and Ni silicide in single-layer metallization of Si substrate were determined.

Keywords: resonant-frequency method, optical constants, multibeam interferometry method, quartz element.

GJRE-G Classification: LCC: TK7874

PHOTOSENSITIVESTRUCTUREWITHSCHOTTKYBARRIERBASEDONNICKELSILICONSILICONCONTACT

Strictly as per the compliance and regulations of:

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Abstract- **Measured resistivities of produced silicide showed their good conductive properties. The calculation of technological route for obtaining thin silicide contacts (<100A^0) in multilayer metallization of Si substrate was carried out, and the optimal technological regimes for obtaining Pd, Pt and Ni silicide in single-layer metallization of Si substrate were determined.**

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I. Introduction

In a metal-semiconductor contact, depending on the ratio between the values of the electron yield work in the metal ψ_m and in the semiconductor $\chi+V_n$, electrons as a result of internal emission may pass from metal to semiconductor or vice versa. In this case, a part of electrons from the metal (silicide) goes to the semiconductor (Si) until thermodynamic equilibrium occurs and the Fermi levels in the metal and in the semiconductor are equalized [1,2].

In the vicinity of the semiconductor-metal interface in the semiconductor an area of depleted charge carriers arises, an area of bulk charge of uncompensated negative acceptor ions whose electric field prevents the further emission of electrons from metal to semiconductor, the semiconductor energy bands bend downwards.

If the thickness of the intermediate layer is atomic distance, then the magnitude of the curvature of the height of the potential barrier equals the contact potential difference

$$\psi_{mS} = \Phi_S - \Phi_m + (E_f - E_v) = X + E_g - \Phi_m,$$

where, the second term is the difference between the yield work of the metal and the electron affinity of the semiconductor.

Under the influence of IR radiation two types of electronic transitions can take place in such a structure. If the incident photon energy $h\nu \geq E_g$, then electron-hole pair generation occurs when it is absorbed in the semiconductor. In this case, as well as in an ordinary photodiode on a p-n junction, carriers of different sign on the junction field separate and photo-electric power arises. It is obvious that the long-wave limit of such a process cannot be less than the band gap width of the semiconductor, and from this point of view the Schottky barrier photodiodes do not differ from p-n photodiodes or their own photoresistors. If $h\nu<E_g$ then infrared absorption in a metal film excites valence electrons to states above the Fermi level, leading to holes, some of which have energy greater than the barrier height Ψ_{ms}. Then either the hole is emitted from the metal to the semiconductor, or the electron moves from the semiconductor to the metal, filling the empty state [3,4]. To overcome the metal-to-semiconductor barrier, the energy of the excited hole must be greater than the height of the barrier. The long-wave boundary of such a process can be changed by selecting the appropriate metal. Therefore, from the point of view of creating silicon-based IR photodetectors the greatest interest is the photoemission from metal to semiconductor.

a) Experiment

In the first step, the 0,5 μm thick SiO_2 oxide layer was grown on p-type (100) silicon wafers (KDB-10). Before this operation the silicon wafers were degreased with trichloroethane, acetone and alcohol and cleaned in a CCl_4 boiling solution. Before metal (Ni) sputtering, windows of 2·2 mm and 4·4 mm were opened in the SiO_2 film using photolithography techniques. Metal sputtering was carried out thermally in a vacuum of 10^{-5} mmHg. The substrate temperature was maintained at 200^0 C. Immediately before loading into the vacuum chamber Si wafers were pickled by buffer solution of HF (34,6%NH_4F + 6,8%HF + 58,6%H_2O) with the following washing of wafers in deionized water and drying in isopropyl alcohol vapor. After metal deposition the silicon wafers were annealed at T_{ann} = 510^0 C and T_{ann}= 900^0 C for t = 30 min in N_2 atmosphere to obtain NiSi - Si and $NiSi_2$ - Si structures. Fig. 1 shows the cross-section of the investigated structures. Photoconductivity spectra of the obtained NiSi - Si and $NiSi_2$ - Si structures with the Schottky barrier were studied.

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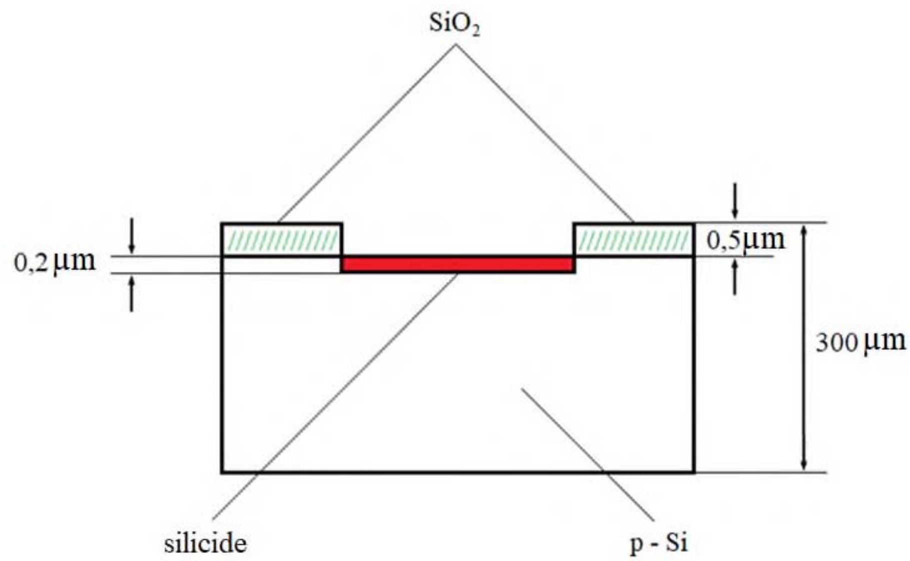

Figure 1: Cross Section of Nickel Silicon-Silicide NiSi - Si Structure

II. Discussion of Results

Figures 2 and 3 show the V- Icharacteristics of the NiSi - Si and $NiSi_2$ - Si structures, and figures 3 and 4 show the inverse V- I characteristics of the NiSi - Si structures in the absence of incident radiation. 3 and 4 the inverse V- I characteristics of NiSi - Si structures in the absence and presence of incident radiation. Figures 2 and 3 show that the V- I characteristics of NiSi - p - Si and $NiSi_2$ - p - Si structures at room temperature are very different.

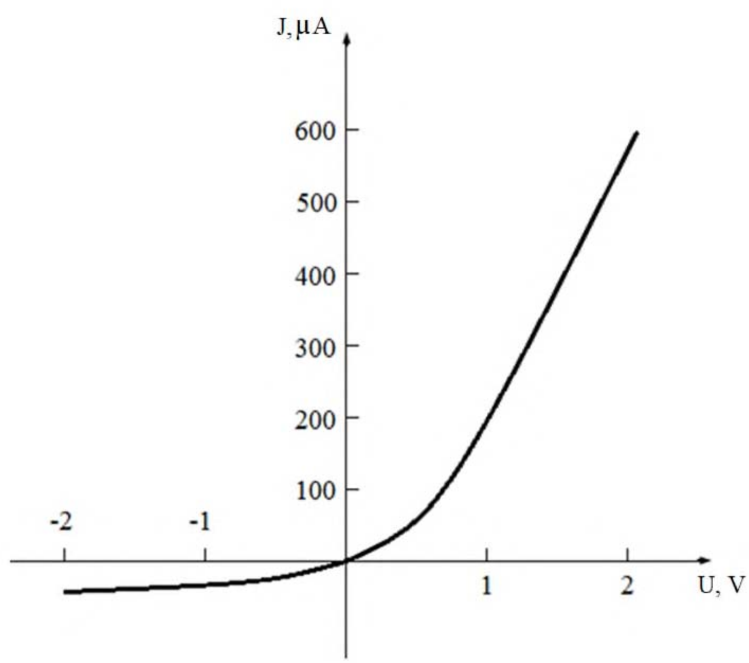

Fig. 2: The V- I Characteristic of NiSi - p - Si Structure at T = 300 K

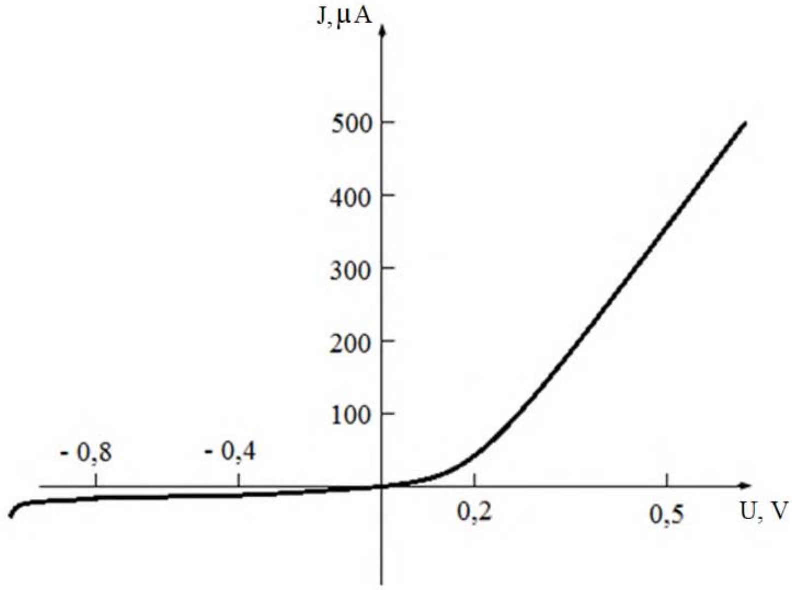

Fig. 3: The V- I Characteristic of $NiSi_2$ - p - Si Structure at T = 300 K

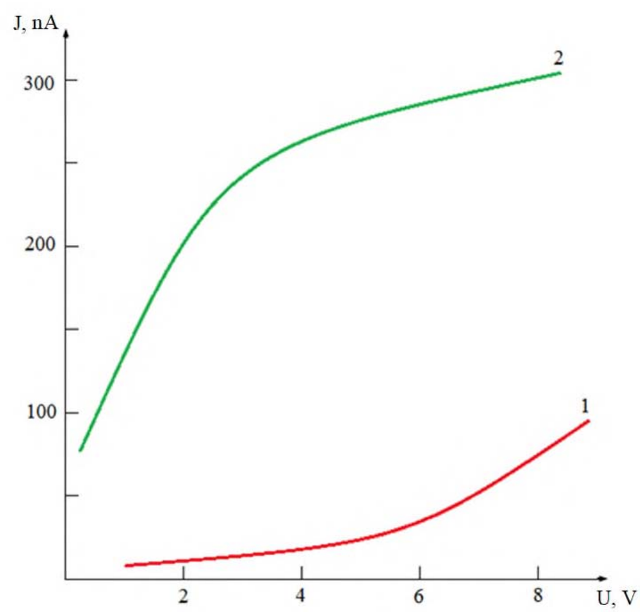

Fig. 4: Inverse V- I Characteristics of NiSi - p - Si Structure: 1 - in Absence of Illumination, 2 - with Light Illumination λ = 2 μm

Inverse currents differ by more than an order of magnitude and it was found that for the $NiSi_2$ - p - Si structures the V- I characteristic does not change its appearance up to frequencies of 100 kHz, but for the NiSi - p - Si structures at frequencies above 1 kHz strong distortions of the V- I characteristic are observed. A spectrophotometer IKS-14A tuned to a wavelength λ = 2 μm was used as a light source. The light hits the silicide from the Si side (back illumination).

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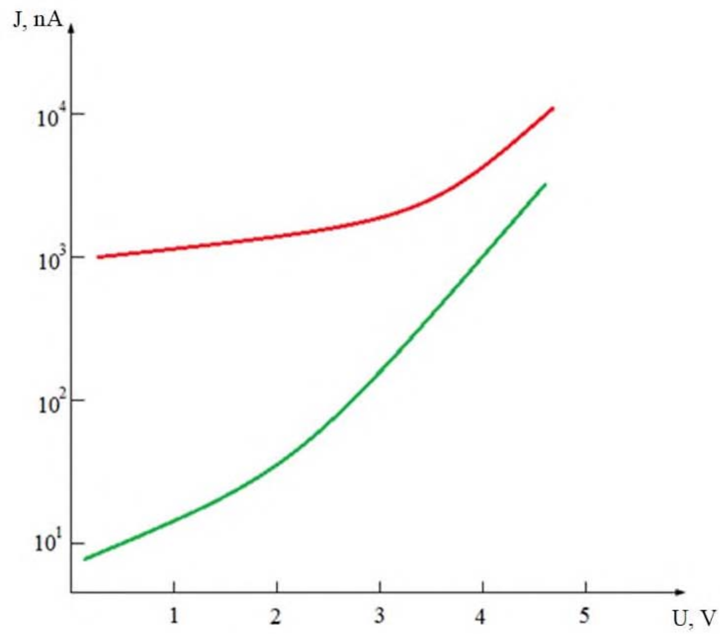

Fig. 5: Inverse V- I Characteristicsof $NiSi_2$ - p - Si Structure: 1 - in Absence of Illumination, 2 - with Light Illumination λ = 2 μm

As can be seen from fig. 4 and 5 a considerable change of a current through the investigated structures at illumination is observed: the current through the investigated structures at illumination increases in 100 - 200 times at small values of the applied reverse voltage (V_R = 200 - 800 mV), in 10 - 50 times at higher reverse biases (V_R = 1 - 2 V); at voltages 4 - 6 V a current change makes only 1,1 - 5 times, i.e. the best mode of structures with the Schottky barrierNiSi - p - Si V_R = 1 - 2 V. At higher voltages the leakage currents increase and also breakdown of investigated samples occurs. For structures NiSi - p - Si and $NiSi_2$ a considerable change of current at illumination at wavelength λ = 2 *μ*m at various values of applied reverse bias (V_R = 0,1 - 5 V) was observed.

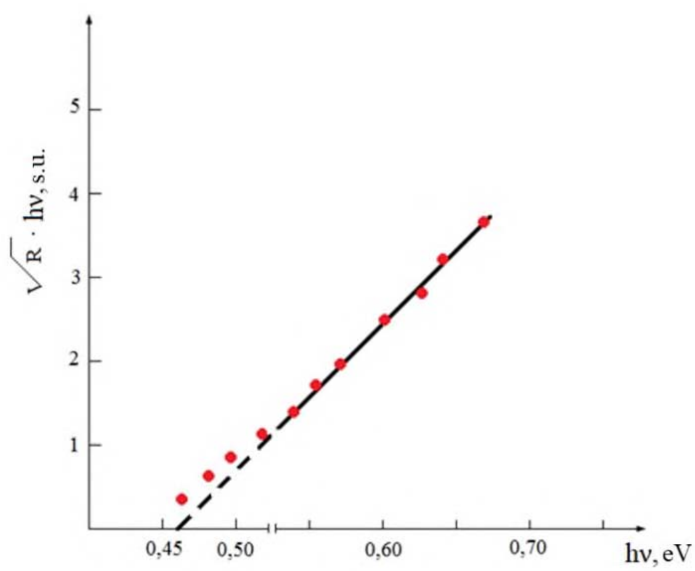

Fig. 6: Dependence of $R^{1/2} \cdot h\nu$ Value on Barrier Height for NiSi - p - Si Structures: T = 80 K; V_R = 154 mV

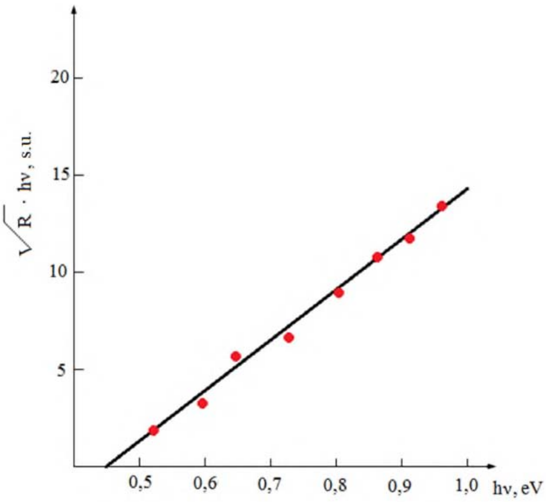

Fig. 7: Dependence of $R^{1/2} \cdot h\nu$ Value on Barrier Height for NiSi - p - Si Structures: T = 80 K; V_R = 380 mV

The experimental results for photosensitivity are in accordance with the refined Fowler formula [5]. These data were used to determine the Schottky barrier height. Figures 6, 7 and 8 the dependences $R^{1/2} \cdot h\nu$ on the incident photon energy hν are plotted. The point of intersection with the energy axis gives the barrier height, which is for NiSi - Si structures Ψ_{ms} = 0.46 eV.

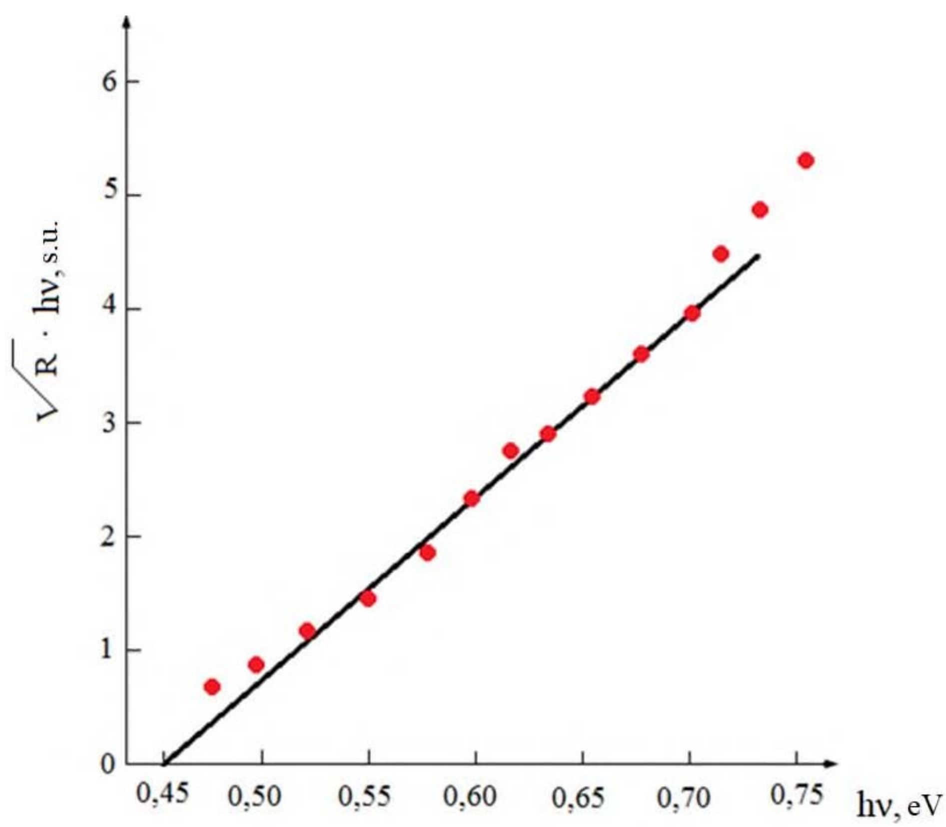

Fig. 8: Dependence of $R^{1/2} \cdot h\nu$ Value on Barrier Height for NiSi - p - Si Structures: T = 80 K; V_R = 0 mV

Figures 9, 10 and 11 show experimental dependences of sensitivity of structures PdSi - p - Si, Pt_2Si - p - Si and PtSi - p - Si at temperature T = 77(80 K) at constant incident radiation power. The measurements were made on a spectrophotometer IKS-31 (temperature of the global bar T = 500 ^{0}C).

Samples PdSi - p - Si and PtSi - p - Si were made according to previously described technique. Figures 9, 10 and 11 show that the wavelength dependence of photosensitivity is approximately described by Fowler formula.

The Schottky barrier height determined from the photoelectric measurements obtained from the dependence $R^{1/2}\cdot h\nu = f(h\nu)$ was $\Psi_{ms} = 0{,}38$ eV for PdSi - p - Si and $\Psi_{ms} = 0{,}26$ eV for PtSi - p - Si (fig. 11). The values of the Schottky barrier heights obtained in this way were also confirmed by photoelectric measurements. A study of the annealing temperature dependence for the PtSi - p - Si and PtSi - n - Si structures has shown that φ_B for the first type structure weakly depends on the annealing temperature, while for the second type structure this dependence passes through a maximum. The latter character of the dependence has found its explanation in the multicontact theory [6,7].

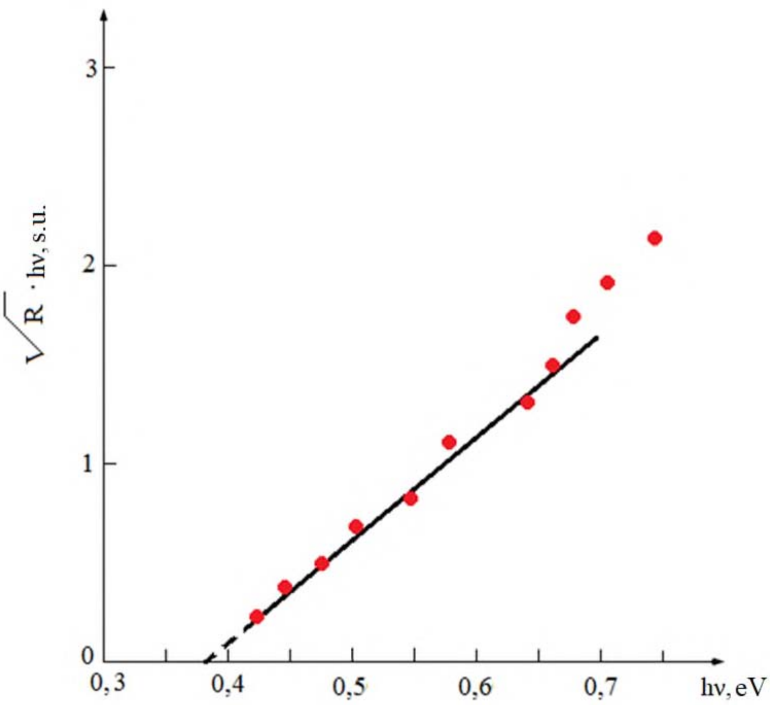

Fig. 9: Dependence of $R^{1/2}\cdot h\nu$ Value on Incident Photon Energy for PdSi - p - Si Structure at T = 77^0 K

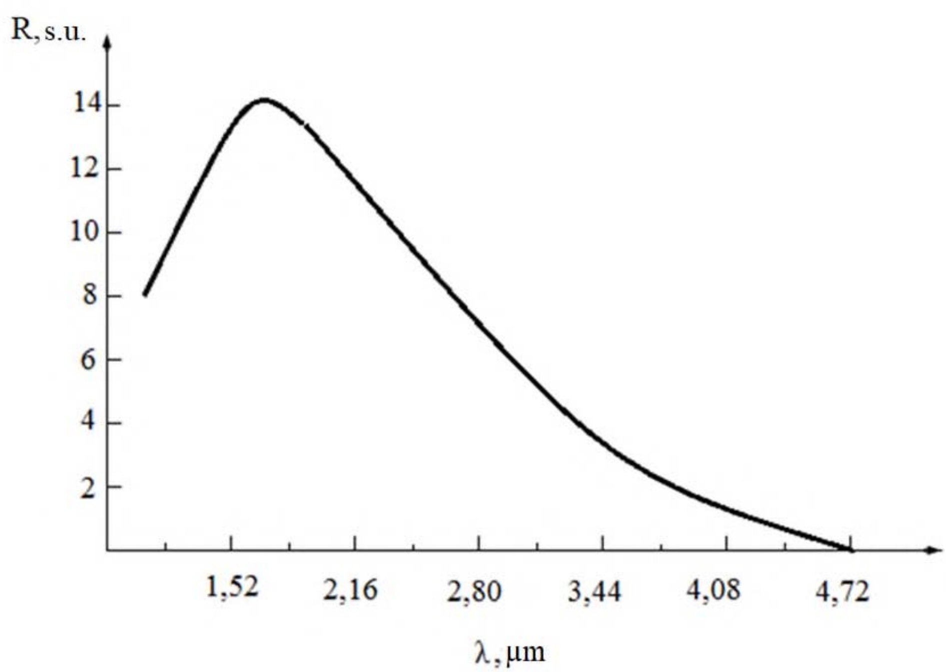

Figure 10: Spectral Dependence of Sensitivity of Pt_2Si - p - Si Structure at T = 80 K

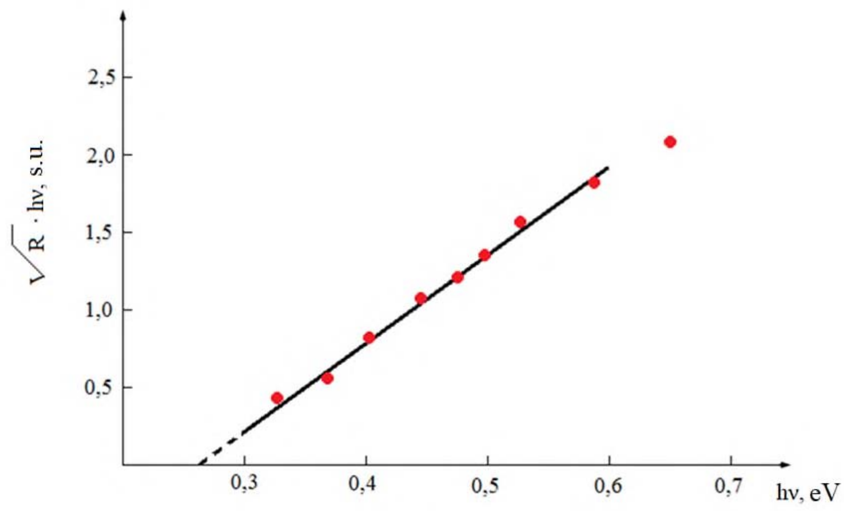

Fig. 11: Dependence of $R^{1/2}$·hν Value on Energy of Incident Photons for PtSi - p - Si Structure at T = 80 K

It is shown that the direct currents of these structures are proportional to their active area. It is found that all characteristic parameters of contacts made on Si substrate (111) are somewhat lower than those of contacts made on Si substrate (100).

III. Conclusion

It is found that the sensitivity of the NiSi - p - Si structure is significantly higher than that of the $NiSi_2$ - p - Si structures. In addition, an increase in sensitivity with decreasing nickel silicide thickness was observed. The optimum mode of operation of the NiSi - p - Si structure and its photosensitivity at a wavelength of 2 μm, which was R = 0,05 – 0,1 mA/W, were determined.

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Modeling and Optimization of Corrosion Penetration Rate in Crude Oil Pipeline using Response Surface Methodology based on Aspen HYSYS Simulation Software

By Sulayman H. Ameitiq & Omar M. Aldenali
University of Benghazi/Libya

Abstract- This study aims to investigate the influence of a number of related parameters namely temperature, pressure, flow rate and pH on the corrosion penetration rate (CPR) of crude oil transportation process by pipelines. It intends the mathematical model of these parameters as independent variables with corrosion penetration rate as a dependent variable. The model was used to establish the best values of these parameters using the response surface methodology. Aspen HYSYS software was utilized to simulate the experiments and to calculate the corrosion penetration rate for each experiment. The experiments designed based on the central composite experimental design (CCD) using Minitab 17 software. The mean absolute percentage error was used to determine the conformance of the developed mathematical model. Its value was 0.02%, this indicates that the developed mathematical model was consistent.

Keywords: *corrosion penetration rate (CPR), aspen hysys, response surface methodology (RSM), modeling, optimization.*

GJRE-G Classification: *LCC: TN879.5.P55*

MODELINGANDOPTIMIZATIONOFCORROSIONPENETRATIONRATEINCRUDEOILPIPELINEUSINGRESPONSESURFACEMETHODOLOGYBASEDONASPENHYSYSSIMULATIONSOFTWARE

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Sulayman H. Ameitiq [α] & Omar M. Aldenali [σ]

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Keywords: corrosion penetration rate (CPR), aspen hysys, response surface methodology (RSM), modeling, optimization.

I. Introduction

Corrosion has a very important economy impact in the oil and gas industry. Oilfield production environments can range from practically zero corrosion to extremely high rates corrosion. The most predominant form of corrosion encountered in oil and gas production is the one caused by CO2. Dissolved carbon dioxide in the produced brines is very corrosive to carbon and low alloy steel tubular and to process equipment used in this industry. The costs of corrosion control are significant and are mainly related to materials replacement and corrosion control programs. Approximately 60% of oilfield failures are related to CO2 corrosion mainly due to inadequate knowledge/predictive capability and the poor resistance of carbon and low alloy steels to this type of corrosive attack. CO2 can cause not only general corrosion but also localized corrosion, which is a much more serious problem [1, 3].

Pipelines whether buried in the ground, exposed to the atmosphere, or submerged in water, are liable to corrosion. Without proper maintenance, every pipeline system will eventually deteriorate, and a corroded pipe is unsafe as a means of transportation because of the associated failure risks. These failures in pipelines and flow lines lead to shutdown of facilities and platforms. Corrosion results in the deterioration of a metal and weakens its structural integrity as a result of chemical reactions between it and the surrounding environment [2]. Corrosion in pipelines occurs where there is loss of metal from an exposed surface in a corrosive environment. The majority of pipeline failures are caused by localized corrosion, and its mechanism can be induced by flow, metallurgy, deposits, internal stresses, and microbiologically influenced corrosion (MIC) among others. The internal corrosion of carbon steel is a noteworthy problem for the oil and gas industry because of its frequency of occurrence. Although high cost corrosion resistant alloys (CRAs) are often developed to resist internal corrosion, carbon steel is still the most cost effective material used for oil and gas production. Issues of possible corrosive species encountered in the oil and gas industry have been documented in so many literatures. The reports on the significance of CO2 in corrosion of metal have also been reported; and, there seems to be a consensus on the significance of CO2 in corrosion of flow lines [2]. Corrosion control is an ongoing dynamic process; therefore, an effective model for predicting pipeline corrosion is essential. Corrosion models give early caution signs of impending failures; they are developed correlations that relate processes and their corrosive effects on systems which help to diagnose a specific problem and in turn evaluate the effectiveness of any corrosion control measure/prevention technique applied to improve the service life of the target metal [2].

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Corrosion has been one of the primary mechanisms causing failures of infrastructure in the oil and gas industry. The corrosion phenomenon can be found in all stages of oil production and transportation and processing. In addition to downhole tubulars, corrosion has been a vital threat to integrity of the above-ground pipelines [4].

II. Literature Review

Aspen HYSYS software for on-site simulation research was used to analyze the corrosion rate in the collection pipeline and to predict CO_2 corrosion in the natural gas pipeline system. Different models were employed to estimate the CO_2 corrosion such as NORSOK standard M-506, and De Waard model 1991 and 1995. The study's goal was to look at the influence of operating circumstances, inhibitors, pipe characteristics, and flow system on CO_2 corrosion. When the working pressure is more than 10 MPa and the solution contains 0.85 kmol/m3 of iron carbonate, raising the operating pressure causes a rise in pH and a drop in CO_2 corrosion rate. By comparing the data of simulation with field corrosion rate data, the feasibility of the numerical simulation method was proved [3].

Carbon dioxide corrosion in natural gas collection pipelines was predicted through the use of Aspen HYSYS simulation software and the effect of operating pressure, temperature, pH solution, pipeline length, flow regime, and pipe inclination on the CO_2 was examined. The findings showed that raising the operating pressure raises the partial pressure of carbon dioxide and accelerates corrosion. The temperature influences the formation of the protective layer, as the maximum rate of carbon dioxide corrosion is 2.96 mm/year at 40 °C. As the concentration of dissolved carbon dioxide decreases along the pipeline, so does the corrosion rate. High speed results in effective confusion, preventing the formation of the protective layer and increasing carbon dioxide erosion [5].

The effect of many operational events (temperature, partial pressure of carbon dioxide, flow rate, and acidity) in the erosion of oil and gas lights was studied. A multi –lines slope was used to examine field data from wild oil and gas fields to assess the rate of corrosion dependence on operational transactions. ANOVA, P value test, and multiple regression coefficients were used in statistical analysis of data, while previous experimental results used De Waaard-Milliams models and the De Waaard-LOTZ model to verify exceptional well erosion rates. According to the survey, operational transactions represent about 26 % of the deterioration of wells. The expected corrosion models were also compatible with field data and Dideaard-Lotz models [6].

To estimate the rate of carbon steel corrosion, the response surface methodology (RSM) was utilized. Response surface methodology (RSM), a form of statistical model, has demonstrated a successful way for decreasing the number of runs. The influence of the pH, CO_2 pressure and temperature on corrosion rate of carbon steel were considered. The NORSOK corrosion software with the second order model has 98 % of coefficient determination. Moreover, the results show that the second-order model was confirmed using experimental data, indicating an excellent correlation [7].

Response surface methodology (RSM) was employed to study, model, and optimize the effect of some operation parameters of crude oil transportation processes, by pipeline, on the corrosion penetration rate (CPR). The parameters pressure, temperature, and pH were studied, and their ranges were determined. The predicted values obtained using the developed model were compared with the actual values calculated using NORSOK M-506 standard software based on the mean absolute error(MAE). The value of the MAE was 0.047467 which indicated that the model was reliable and significant [8].

The influence of many operational parameters (temperature, pressure, shear stress, and pH) were analyzed on the corrosion penetration rate, and optimal values of process parameters were determined. The response surface methodology (RSM) and fuzzy logic (FL) were used to predict the corrosion penetration rate that occurs during the process of transporting crude oil through the pipeline. The optimum values of operating conditions were the temperature is 44.4 ° C, the pressure is 34.28 Pascal, pH is 5.51 and the shear stress is 1 bar to achieve the lowest CPR of 2.16 mm/year [9].

It is considered that the Aspen HYSYS software can simulate the transportation of oil and gas through pipelines and produce results that are extremely close to reality. Response surface methodology is used for modeling and analysis.

This study aims to simulate crude oil transporting pipelines using the Aspen HYSYS software, afterwards design experiments using (RSM) and applying them through simulation, then using the results to create a model to predict corrosion penetration rate inside the pipeline and identifying the most suitable values for operating conditions.

III. Materials and Methods

a) Material

Many elements influence CPR. The influence of the factors temperature, pressure, flow rate, and pH on the corrosion penetration rate was investigated in this study utilizing RSM.

The pipeline considered in this study is according to AGOCO from the Sarir field to Hrayqa oil port in Tobruk, the entire distance of pipeline is 514 km, pipeline diameter 34 inch, and mole percent of CO_2 was set at 0.8% for the period between 01/01/2019 and 01/01/2023 for oil pipeline. Table 1 shows the operational parameters and related ranges in the Sarir field over the period.

Table 1: Experimental Ranges in Terms of Uncertain Parameters

No.	Parameters	Notation	Unit	Range	
				Lower value	Upper value
1	Temperature (ºF)	T	ºF	100	130
2	Pressure (psig)	P	psig	360	580
3	Flow Rate (bbl/day)	FR	bbl/day	150,000	240,000
4	pH	pH	-	5.51	5.65

b) Method

In this work, the variables considered are those most critical to CPR; temperature, pressure, flow rate, and pH. The experimental design was conducted according to the CCD method in Minitab 17 program for four factors and one response. CCD determined total experimental runs of 31 as shown in Table 2. To carry out these experiments, the reality was simulated using Aspen HYSYS V10 by creating a 514 km pipeline, filled with the chemical composition of raw oil, and calculating the corrosion penetration rate using the De Waard 1995 method, as shown in Figure 1.

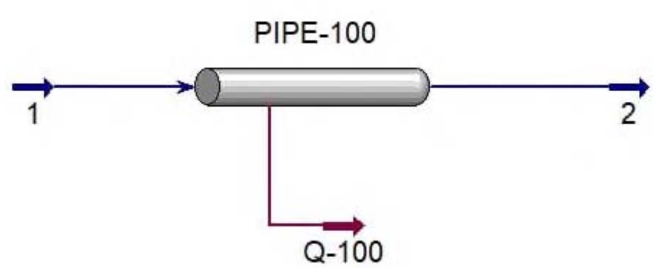

Fig. 1: Simulation of the Oil Pipeline using Aspen HYSYS

Table 2: Design of Experiment and its Actual Values of CPR

Run Order	Temperature (ºF)	Pressure (psig)	Flow Rate (bbl/day)	pH
1	115	470	240,000	5.58
2	115	470	195,000	5.58
3	115	360	195,000	5.58
4	100	360	240,000	5.65
5	115	580	195,000	5.58
6	130	360	240,000	5.65
7	115	470	195,000	5.51
8	130	360	150,000	5.51
9	115	470	195,000	5.58
10	115	470	195,000	5.58
11	100	580	150,000	5.65
12	100	360	150,000	5.51
13	100	470	195,000	5.58
14	100	580	240,000	5.51
15	115	470	195,000	5.58
16	100	360	150,000	5.65
17	130	580	150,000	5.51

18	100	580	150,000	5.51
19	100	580	240,000	5.65
20	130	360	150,000	5.65
21	130	580	150,000	5.65
22	100	360	240,000	5.51
23	115	470	195,000	5.58
24	130	470	195,000	5.58
25	130	580	240,000	5.65
26	115	470	150,000	5.58
27	115	470	195,000	5.58
28	130	360	240,000	5.51
29	130	580	240,000	5.51
30	115	470	195,000	5.58
31	115	470	195,000	5.65

IV. Discussion of Results and Optimization

a) Results

The response data were calculated by the Aspen HYSYS model. Then, the data were entered in the Minitab worksheet, and after that the predicted values of CPR were calculated as shown in Table 3.

Tables 3: Actual Values by Aspen HYSYS Model and Predicted Values by RSM

Run Order	Temperature (ºF)	Pressure (psig)	Flow Rate (bbl/day)	pH	Actual CPR (mm/year)	Predicted CPR (mm/year)
1	115	470	240,000	5.58	5.6578	5.6555
2	115	470	195,000	5.58	5.1139	5.1161
3	115	360	195,000	5.58	5.0475	5.0397
4	100	360	240,000	5.65	4.8703	4.8502
5	115	580	195,000	5.58	5.0855	5.0883
6	130	360	240,000	5.65	6.0183	6.0394
7	115	470	195,000	5.51	5.2187	5.2129
8	130	360	150,000	5.51	4.8189	4.8133
9	115	470	195,000	5.58	5.1139	5.1161
10	115	470	195,000	5.58	5.1139	5.1161
11	100	580	150,000	5.65	4.1568	4.1357
12	100	360	150,000	5.51	4.1388	4.1472
13	100	470	195,000	5.58	4.6811	4.7307
14	100	580	240,000	5.51	5.3160	5.3243
15	115	470	195,000	5.58	5.1139	5.1161
16	100	360	150,000	5.65	3.9784	3.9871
17	130	580	150,000	5.51	4.6784	4.6993
18	100	580	150,000	5.51	4.3237	4.3030
19	100	580	240,000	5.65	5.0553	5.0613
20	130	360	150,000	5.65	4.6749	4.6675

21	130	580	150,000	5.65	4.5270	4.5465
22	100	360	240,000	5.51	5.1253	5.1061
23	115	470	195,000	5.58	5.1139	5.1161
24	130	470	195,000	5.58	5.5782	5.5235
25	130	580	240,000	5.65	5.9883	5.9808
26	115	470	150,000	5.58	4.4618	4.4590
27	115	470	195,000	5.58	5.1139	5.1161
28	130	360	240,000	5.51	6.2590	6.2809
29	130	580	240,000	5.51	6.2377	6.2294
30	115	470	195,000	5.58	5.1139	5.1161
31	115	470	195,000	5.65	5.0077	5.0085

Table 4 shows the p-values that determine whether the effects are significant or insignificant.

Table 4: Estimated Regression Coefficient for CPR (mm/year)

Term	Effect	Coef	SE Coef	p-Value	
Constant		5.11609	0.00721	0.000	Significant
Temperature (ºF)	0.79277	0.39639	0.00573	0.000	Significant
Pressure (psig)	0.04859	0.0243	0.00573	0.001	Significant
Flow Rate (bbl/day)	1.19657	0.59829	0.00573	0.000	Significant
pH	-0.20439	-0.10219	0.00573	0.000	Significant
Temperature (ºF)*Temperature (ºF)	0.022	0.011	0.0151	0.476	Insignificant
Pressure (psig)*Pressure (psig)	-0.1042	-0.0521	0.0151	0.003	Significant
Flow Rate (bbl/day)*Flow Rate (bbl/day)	-0.1176	-0.0588	0.0151	0.001	Significant
pH*pH	-0.0109	-0.0054	0.0151	0.724	Insignificant
Temperature (ºF) *Pressure (psig)	-0.13484	-0.06742	0.00608	0.000	Significant
Temperature (ºF) *Flow Rate	0.25436	0.12718	0.00608	0.000	Significant
Temperature (ºF) *pH	0.00721	0.00361	0.00608	0.561	Insignificant
Pressure (psig)*Flow Rate (bbl/day)	0.0312	0.0156	0.00608	0.021	Significant
Pressure (psig)*pH	-0.00353	-0.00177	0.00608	0.775	Insignificant
Flow Rate (bbl/day)*pH	-0.04789	-0.02395	0.00608	0.001	Significant

The equation from table of estimated regression coefficients for corrosion penetration rate (mm/year) of the first – second order is given as *equation 1:*

$$CPR = -32.7 - 0.0215\,T + 0.00963\,P + 0.000044\,FR + 12.1\,pH + 0.000049\,T*T - 0.000004\,P*P - 0.000000\,FR*FR - 1.11\,pH*pH - 0.000041\,T*P + 0.000000\,T*FR + 0.00344\,T*pH + 0.000000\,P*FR - 0.000230\,P*pH - 0.000008\,FR*pH \qquad (1)$$

where:

CPR: Corrosion Penetration Rate (mm/year)

T: Temperature (ºF)

P: Pressure (psig)

FR: Flow Rate (bbl/day)

pH: -

Table 4 shows that all p-values associated with each individual model term. The terms are significant when alpha value is < 0.05.

b) Model Validation

To validate the developed model, the mean absolute percentage error (MAPE) was used to estimate the variation between the actual and predicted CPR. The value of the MAPE is 0.02%, compared with the actual values of Corrosion Penetration Rate, as plotted in Figure 2. The Nash-Sutcliffe Efficiency (NSE) was calculated for the model by Eq.2. The value of the NSE is 0.999, which indicates that the model is very good.

$$\mathrm{NSE} = 1 - \frac{\sum(A-P)^2}{\sum\left(A-\hat{A}\right)^2} \quad (2)$$

Where:

A: Actual value for CPR.

Â: Average actual value for CPR.

P: Predicted value for CPR.

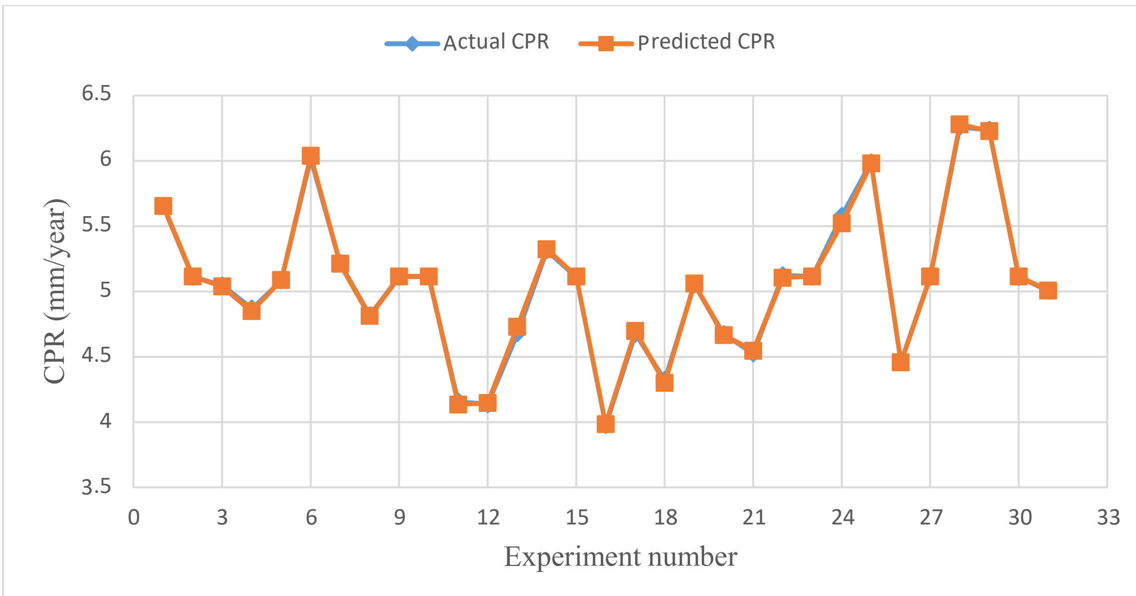

Fig. 2: The Actual and the Predicted Corrosion Penetration Rate

In addition, a probability plot is also used to identify the appropriate distribution. The Normal probability plot has some points that do not lie along the line in the upper and lower region. This may indicate potential outliers in data. Various fits, histograms, and order distributions are shown in Figure 3. It can be seen from the probability plots, that the data are from a normal distribution is the best one since all data fall within the 95% confidence interval.

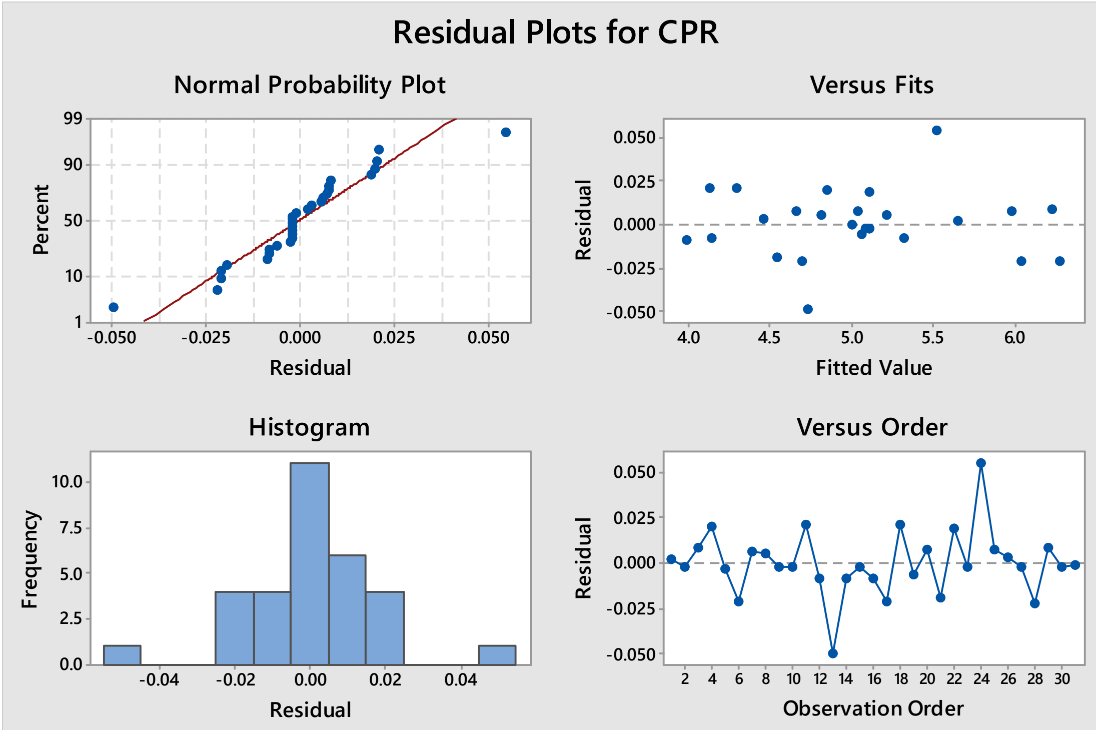

Fig. 3: Probability Plots for Corrosion Penetration Rate

c) Optimization of Corrosion Penetration Rate

As can be indicated from Figure 4, for a simulation model of one year, the minimum corrosion penetration rate conditions were determined as, temperature (100 °F), pressure (360 psig), flow rate (150,000 bbl/day), and pH (5.65). Accordingly, the minimum corrosion penetration rate is 3.98 mm/year.

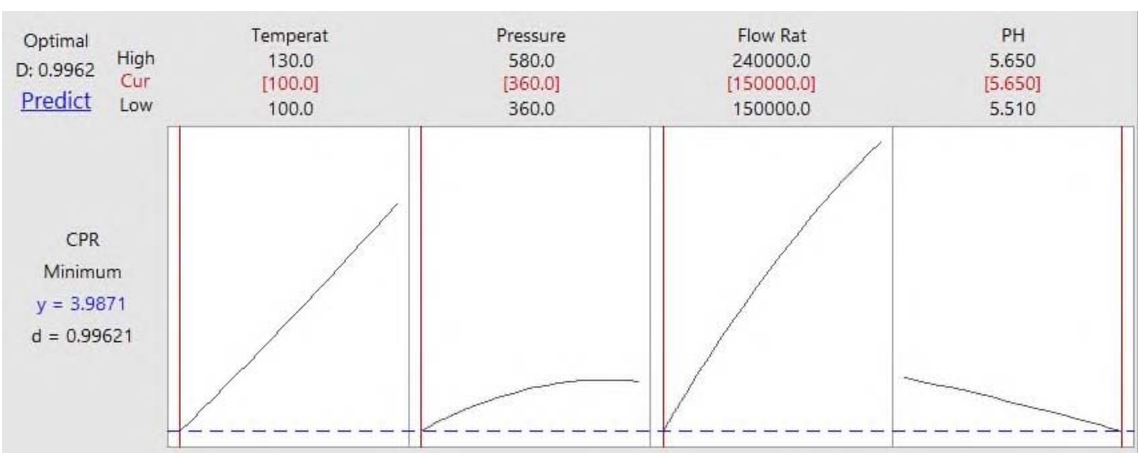

Fig. 4: Main Effect Plots of Crude Oil CPR Processes Parameters Temperature, Pressure, Flow Rate and pH

Figure 5 illustrates the contour plots that represent the simultaneous effect of two variables on response, with the other variables fixed to the mean value in the range of factors. As the stronger the effect, the color in the drawing is green, and the weaker the effect, the color is blue. As an illustration, this figure shows a contour plot that represents the simultaneous effect of flow rate and temperature at pressure=480 and pH=5.58 on CPR, the larger values of the factors (flow rate 240,000 bbl/day and temperature 130 °F) giving the greater value of the corrosion penetration rate, and the smaller values of the factors (flow rate 150,000 bbl/day and temperature 100 °F) giving the lower value of the corrosion penetration rate.

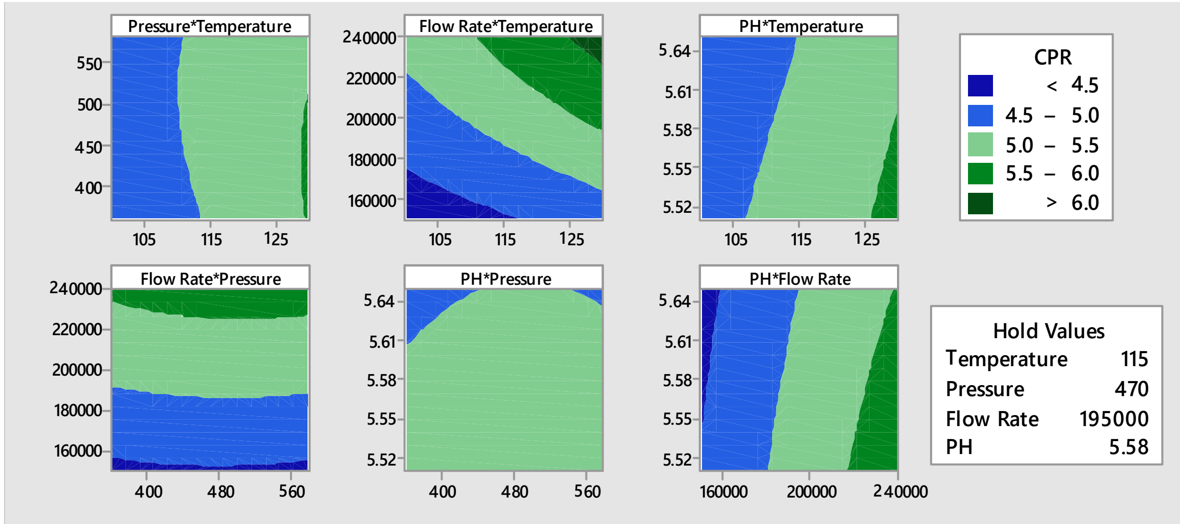

Fig. 5: Contour Plots

V. Conclusions

In this study, attempts were made to predict the corrosion penetration rate of the pipelines that are used for transporting crude oil between Sarir-Tobruk stations. The corrosion penetration rate values were determined by using Aspen HYSYS V10 software.

The following points summarize the conclusions of the study:

1. Based on ANOVA analysis, the four factors considered had significant effects on the corrosion penetration rate, as well as the quadratic effect for pressure and flow rate were significant, while temperature and pH were insignificant. However, the interaction between (temperature and pH), and (pressure and pH) had no significant effect on corrosion penetration rate. Also the interaction between (temperature and pressure), (temperature and flow rate), (pressure and flow rate), and (flow rate and pH) had significant effects.
2. Based on the comparison between the actual values of corrosion penetration rate calculated by using Aspen HYSYS software and the predicted values of corrosion penetration rate by using the RSM technique, it can be concluded that the RSM model could be used to predict the values of corrosion penetration rate, under the specified parameters ranges, with a mean absolute percentage error of 0.02%.
3. The optimal value for the numerically calculated corrosion penetration rate using the RSM model, was found to be 3.98 mm/year, with operating parameters values of temperature (100 °F), pressure (360 psig), flow rate (150,000 bbl/day), and pH (5.65).

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Optimizing Energy Consumption in Warehouse & Logistics Facilities: Measures for Existing and Future Facilities

By Qassim A. Abahussaien

Abstract- This paper offers a holistic approach in reducing energy consumption in industrial facilities, specifically warehouse & logistics facilities by exploring various ways or methods companies can adopt to reduce their warehouse & logistics facilities energy consumption, environmental impact, and operational expenses. It highlights the importance of why companies should invest in these green initiatives, as it will assist companies in complying with increasing regulations and mandates regarding greenhouse gas emissions (GHG), fulfilling their social responsibility to increasingly environmentally conscious consumers, rising utilization of e-commerce, and rising populations. The demand for these facilities will increase, and companies must be ready to meet this demand carefully, to balance their social responsibilities by reducing their GHGs, and their commitments to their shareholders by maintaining or improving their profit margins. Throughout this paper, measures for existing or in operation warehouse & logistics facilities will be highlighted, and then the paper will propose measures for future warehouse & logistics facilities to be considered to minimize their environmental impact.

Keywords: *energy efficiency, costs, ESG (Environment, Social, and Governance).*

GJRE-G Classification: *LCC: TJ163.3*

OPTIMIZINGENERGYCONSUMPTIONINWAREHOUSEANDLOGISTICSFACILITIESMEASURESFOREXISTINGANDFUTUREFACILITIES

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Keywords: energy efficiency, costs, ESG (Environment, Social, and Governance).

I. Introduction

Warehouse facilities faces a multitude of challenges in the future, from multiple perspectives. From the regulatory perspective, there are several regulations and agreements to reduce companies GHGs that many countries signed or committed to, such the Paris Climate Agreement, and the UN Sustainable Development Goals (SDG) 2050 agreement to substantially reduce GHGs, to name a few [1]. From a societal perspective, population numbers are rising, as well as the environmental awareness of consumers. A US study revealed in many categories, there is a clear and material link between consumer spending and products making ESG (Environmental, social, and governance)-related claims. In addition, the study stated that products making ESG-related claims accounted for nearly half of all retail sales in the categories examined in Figure 1, as well outperforming products that do not make ESG-related claims in the majority of the categories, in terms of growth.[2].

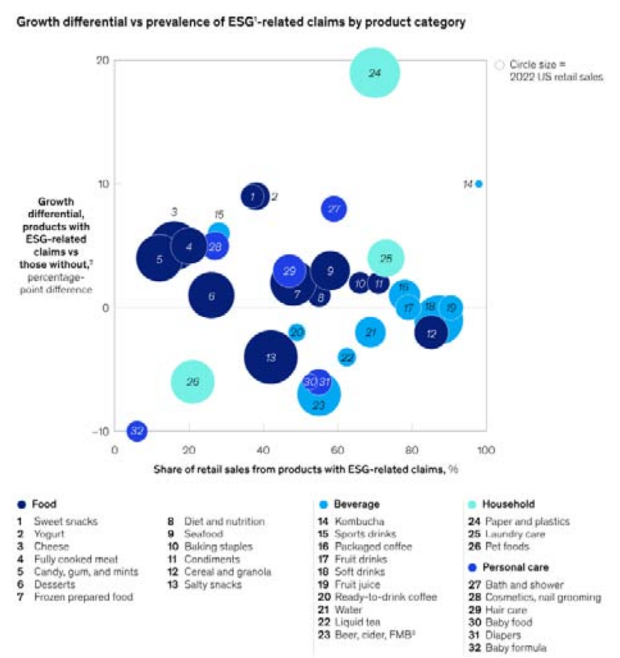

Figure 1: Comparison between products making ESG-related claims and products that do not make ESG-related claims in growth rates and share of US 2022 retail sales. (Mckinsey, 2023)

Consumers are not only environmentally conscious, they are utilizing e-commerce more and more, which will increase demands for warehouse & logistics facilities. The below figure illustrates the ongoing rise of e-commerce (figures are in billion U.S dollars):

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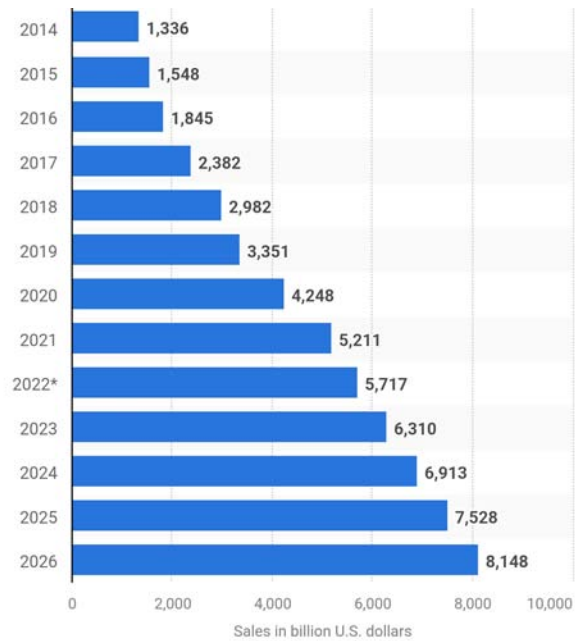

Figure 2: Worldwide retail sales of e-commerce from 2014 to 2026 (Statista, 2022) [3]

Moreover, the world's population is expected to increase from 8 billion to 9.7 in the upcoming 30 years, approximately a 2 billion increase, and could reach as high as 10.4 billion by the mid-2080s [4].

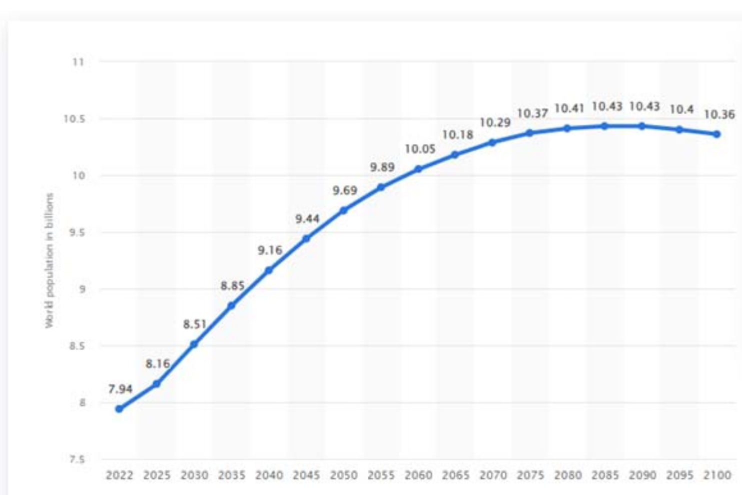

Figure 3: Development of the world's population from 2022 to 2100. (Statista, 2022) [5]

30% of produced GHGs is stemming from industrial buildings alone, which includes indirect emissions from increased energy consumption and other factors. In addition, warehouses account for a large portion of industrial buildings [6]. In 2021, the warehousing and storage industry consumed nearly a quarter of total electricity consumption in the US, when combining direct and indirect emissions [7]. The implication here is that the warehouse sector is the largest GHG emitter in the US economy, comprising 29.6% of total emissions [8]. The demand for them will go up due to increased population numbers and utilization of e-commerce, as mentioned before. It is imperative for companies to address these increasing demands, while fulfilling their ESG responsibilities.

In the upcoming section, the paper will compare the currently implemented measures in an oil and gas company with the proposed solutions, with a suggested path forward for the company to take to address any identified gaps.

II. Measures to Reduce Energy Consumption in an Existing Warehouse & Logistics Facilities

In this section, the paper will illustrate a number of measures to be taken to reduce energy consumption in warehouses, specifically warehouses already in operation. Note that the following is not inclusive of all possible ways to reduce energy consumption, as advancements in technologies may offer more or better ways to be adopted in the future. However, this does not mean that these measures should be ignored.

a) *Adjusting the Lighting System*

i. *Adopting an LED Lighting System*

Warehouse & logistics facilities need a lot of artificial lighting to function, as lighting is of the main energy-using systems in non-refrigerated warehouses [9]. So, the choice of which type of lighting to utilize to operate warehouse & logistics facilities is a crucial one in terms of energy consumption and GHG emissions. The best choice for these facilities is to adopt an LED lighting system, as it is the most efficient in terms of energy efficiency and light control, as LED lights have shorter switching times, more efficient dimming techniques, and higher light intensity when compared to traditional lighting systems (e.g. incandescent bulbs and fluorescent lamps). Moreover, they emit less heat than traditional lighting systems [10]. In fact, in warehouse & logistics facilities, studies have found that we can reduce their electricity costs by 75% by switching to LED lights and taking measures to control heat [9]. The following figures highlight a number of differences between LED light bulbs and traditional light bulbs [11]:

LED	CFL	Incandescent
Avg Life: 25,000 Hrs	Avg Life: 8,000 Hrs	Avg Life: 1,200 Hrs
No Mercury	Mercury	No Mercury
6-8 Watts	13-15 Watts	60 Watts
Uses 84% less energy	Uses 75% less energy	90% energy lost to heat

Figure 4: A comparison between LED lights and traditional light bulbs (Washington University in St. Louis, 2020)

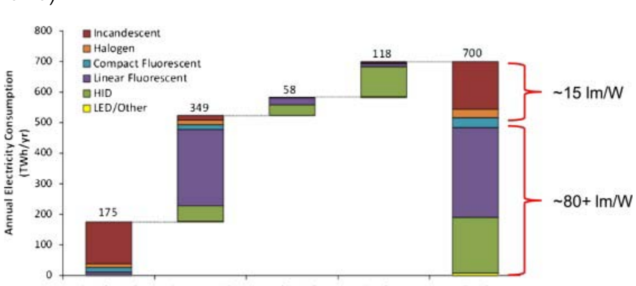

Figure 5: Light sources used in different sectors and their distribution of total energy consumption. (Marc Fontoynont, 2018) [12]

ii. *Installing a Photovoltaic System with Light Sensors*

If the geographical location is rich with natural light, an organization can enhance their lighting system by installing light sensors bundled with a photovoltaic system, where during natural light abundant times of the day, the system turns off the light source since it is already covered by natural light [13].

b) *Temperature Control*

As mentioned in section 2.1, heat is also a huge contributor in high electricity costs in warehouse & logistics facilities. Due to the nature of warehousing activities (such as receiving and issuing), temperature in a warehouse is volatile, with the constant flow materials going in and out, plus personnel going in and out of the warehouse, especially in high temperature or humidity areas [14].

i. *Partition between Areas Inside Warehouses with Different Temperatures*

To control the temperature and make it more consistent, install in warehouses doors that open and close quickly[15], and to achieve higher effectiveness, the doors should be automated with no human interaction needed to achieve higher degrees of temperature control [16].

ii. *Insulation*

Even if the temperature is mitigated with isolation efforts suggested in 2.2.1, the insulation of a warehouse plays a huge role in temperature control, so it is not enough to invest in isolation measures to control the temperature. Companies should install heavy and thick insulation to enhance temperature control inside a warehouse & logistics facility [17]. This will also reduce the energy required for constantly adjusting the temperature [14].

iii. *Installing Smart Sensors for HVAC Systems*

To improve temperature control efficiency, installing a smart temperature control system in a facility, instead of the traditional thermostat On/Off control model will further stabilize the temperature in the warehouse & logistics facility, and in turn will reduce energy consumption.

A study has simulated the traditional heating control method energy with three thermal control algorithms to compare each method's EUI (Energy Use Intensity). Due to its clarity and intuitiveness, Energy analysts compare building energy performances using the EUI indicator, as it is intuitive and clear. Fig 6 and Fig 7 illustrate the study's findings [9]:

No.	Model	Component
1	Thermostat On/Off (On/Off)	On/Off controller, PMV signal modifier
2	Fuzzy Inference System (FIS)	Damper angle controller, resistance coil, PMV signal modifier
3	Artificial Neural Network (ANN)	Damper angle controller, resistance coil, PMV signal modifier
4	Artificial Neural Network with 2 steps PMV signal modifier (ANNd)	Damper angle controller, resistance coil, 2 steps PMV signal modifier

Figure 5: Each model and its components (Park et al. 2018)

No.	Controller	Annual Energy Use (GJ)			EUI
		Cooling	Heating	Total	(kWh/m^2·yr)
1	On/Off	339.2	482.3	821.5	115.4
2	FIS	372.5	810.7	1183.2	166.2
3	ANN	331.2	479.7	810.9	113.9
4	ANNd	321.7	447.1	768.9	108.0

Figure 6: Each model and its EUI (Park et al. 2018)

As showcased in, the fourth model has the least EUI, with 6.7% less than the ON/Off model [9]. While this 6.7% might seem insignificant, pairing this effort with the other proposes measures will yield great results, especially when you scale up your operations.

c) Energy Efficient Handling and Storage Equipment

In warehouse & logistic facilities, various equipment is needed to perform its main functions, which depends on the type of material stored in these facilities. These MHEs (material handling equipment) range from forklifts and its types, among other MHEs. Historically, these MHEs are powered through gasoline or other similar fuel, both which emit of GHGs.

To offset this, companies need to invest in LIB (Lithium-ion battery) MHEs to reduce their environmental impact [18]. In doing so, their operations will resume as normal, while they save on energy costs since the batteries will be charged instead of fueling the MHEs with gas or any other type of fuel.

d) Utilizing Renewable Energy

Depending on the areas' location, renewable energy sources (such as solar, wind or kinetic energy) can be leveraged to decrease electricity costs and lessen GHGs for existing warehouse & logistics facilities,

For areas rich with natural sunlight, installing solar panels or solar cell generators is a sound investment to reduce energy costs.

A study has found that solar energy can be used to power the warehouse utilities in the case of solar panels, which can be installed on the roof of a warehouse. The study projected that 60% of the total energy consumption of a facility can be generated by from installing solar cells.

Kinetic energy can also be used in conjunction with automation, but it is very expensive [19], so it will be proposed in the next section.

III. Considerations for Future Warehouse & Logistics Facilities

a) Automation

As mentioned in 2.4, pair kinetic energy with automation for better results. Automatic solution require less heating and lighting, which are two of the biggest energy consumers in warehouse as previously mentioned section 2.1.

According to Lewczuk et al., 2021, the breakdown of actual energy consumption in warehouse & logistics facilities is as follows, with the highest being heating and cooling, and lighting:

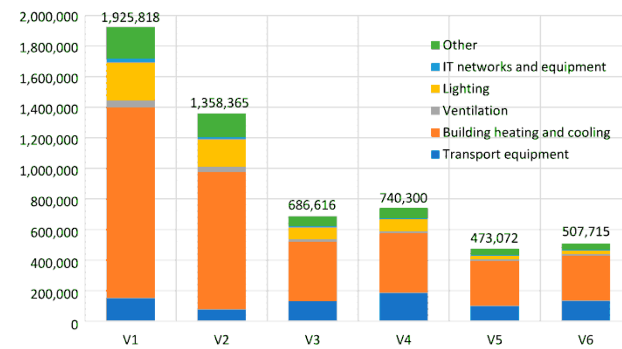

Figure 7: Warehouses end use categories and their energy consumption under different technologies (Variants of warehouses)

If you raise the level of automation, you decrease your dependence on labor, safeguard yourself from crises such pandemics social changes, military conflicts, and so forth, and ensure business continuity.

b) Mini Containers

Temperature controlled food transport are equipped with vapor compression refrigeration (VCR), and they emit huge amounts of GHGs. Alternative refrigeration technologies can be used to minimize or reduce emissions.

For example, Bagheri et al (2017) [20] recommends replacing fuel (engine) driven refrigerated transport with battery-powered transport, similar to what is discussed in 2.3. With battery-powered transport, weight will be reduced and emissions too.

A newer approach is to use MCs (mini containers), as illustrated in fig 8:

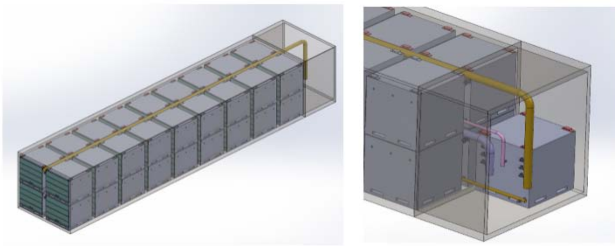

Figure 8: Conceptual design of MCs in a truck, with central driving unit (CDU) shown in (b)

The modular design of the MCs is designed to fit into various types of pick-up vehicles or equipment. In addition, the CDU maintains the required temperature and humidity, which enables companies to mix material or food in the same load, reducing the number of truckloads required to transport items. Overall, there are reductions in the cost, energy consumption, and GHGs emission when compared to using traditional loading methods [19].

c) Centralized Warehousing

The location of industrial facilities is a significant determinant of their sizes, construction time, and proximity to local markets, seaports, and intermodal terminals. The reason is that the location increases the potential industrial impact on the population. Also, the size of warehouse and logistics facilities indicate their environmental impact, as discussed by Mashudet al. (2022) [21]

When developing warehouse & logistics facilities, a large portion of the surrounding natural environment is consumed usually (by Ulucak et al. (2019) [22] and Clayton et al. (2021) [23]. These facilities require a lot of power to operate due to their various machineries and equipment, and this power is extracted from local services and local infrastructure, which they are highly dependent on [19].

The implication here is that the location of a warehouse & logistics facility is strategic, with numerous ESG considerations to take into account, as well as profitability.

IV. Discussion

The discussion in this paper intends to go in depth in the challenges and factors that existing and future warehouse & logistics facilities will face, from ESG-related concerns and their compliance, and to their organization's bottom line. This section will serve as a platform for further analysis and discussion on the aforementioned factors and more.

a) Developing Technologies (IoT, Industrial Revolution 4.0 and others)

Smart systems will undoubtably significantly benefit from advancements in technologies, with better power savings and energy efficiency. Advancements and higher adoption of Internet of Things, A.I. and machine learning (as part of the Industrial Revolution 4.0) will provide organizations for more opportunities to automate temperature and humidity control, among other benefits.

b) Investment Opportunities

There are many measures to go about reducing a warehouse & logistics facility's energy consumption or emitted GHGs. From adjusting the lighting system, temperature control, or using renewable energy, organizations might be discouraged or hesitant to invest in these measures.

Depending on the organization's size, investing in these measures might be costly. However, investing in them will net a positive Return on Investment on their operation costs, environmental impact, and consumer goodwill. A holistic investment in all the facilities' factors will generate the most returns. However, as a good starting point, companies should invest in their lighting systems and try to control the temperature of their facilities.

c) The Role of Automation

Automation will shape the future warehouse & logistics facilities in a major way. Automation will affect operations costs, energy consumption and emitted GHGs. However, the labor force will be disrupted significantly, as we increase the level of automation, the need of some job positions might be diminished or be eliminated entirely. While increasing levels of automation is inevitable, the changes in the labor force is a material issue that needs to approached carefully, as organizations have commitments all relevant shareholders, which include the labor force.

d) ESG Commitments

The case of reducing energy consumption in warehouse & logistics facilities is clear. Organizations have environmental, social, and government compliance commitments, as well as commitments to their bottom line. Organization who invest in these measures in their future facilities will have lower environmental impact by reducing their emissions, which in turn will satisfy and ever increasing environmentally conscious consumers. Moreover, they have higher probability of converting consumers into loyal or life-long consumers.

With increasing scrutiny and regulations from multiple governments, organizations can protect themselves from increased regulation or litigation, which will decrease their costs. On the operational side, reducing energy consumption will also decrease their operational costs.

Organizations have the opportunity to march into the next transformative period while balancing more than their bottom line, so the balancing act of fulfilling all these commitments will decide the future market leaders.

e) Centralization or Warehouse Hubs

A lot of natural land and power is required to host warehouse and logistics facilities. Organization have two methods when laying out their facilities' network, having decentralized or centralized facilities. Both methods have their benefits and disadvantages, as with decentralized you have more of a safety net in cases of failure, as opposed in a centralized warehouse, and in some cases have facilities closer to certain customers. Regardless, selecting a strategic location to construct a new centralized facility will have lower energy consumption and emissions, less facilities to operate, and if it is within proximity to an organization's major costumers, it will also reduce transportation costs. When constructing new facilities, it is of high priority to consider having centralized facilities to serve customers and lower organizations emissions. Centralized facilities may also present opportunities to form strategic partnerships within an organization's supply chain.

V. Conclusion

In conclusion, the paper explores some of the available methods and future concepts that aims to reduce energy consumption in warehouse & logistics facilities, whether they are in operation to be constructed. By investing in green initiatives and planning and designing for lower energy consuming facilities, organizations will ensure they are compliant with regulations, enhance their customers relationship, lower their environmental impact, and improve their profits by lower their operating costs. This paper may be used as preliminary guidelines for organizations to follow in tackling the multitude of challenges facing their facilities from multiple areas, in order to have greener existing or future warehouse & logistics facilities that maximize value for all stakeholders.

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The following is the official style and template developed for publication of a research paper. Authors are not required to follow this style during the submission of the paper. It is just for reference purposes.

Manuscript Style Instruction (Optional)

- Microsoft Word Document Setting Instructions.
- Font type of all text should be Swis721 Lt BT.
- Page size: 8.27" x 11'", left margin: 0.65, right margin: 0.65, bottom margin: 0.75.
- Paper title should be in one column of font size 24.
- Author name in font size of 11 in one column.
- Abstract: font size 9 with the word "Abstract" in bold italics.
- Main text: font size 10 with two justified columns.
- Two columns with equal column width of 3.38 and spacing of 0.2.
- First character must be three lines drop-capped.
- The paragraph before spacing of 1 pt and after of 0 pt.
- Line spacing of 1 pt.
- Large images must be in one column.
- The names of first main headings (Heading 1) must be in Roman font, capital letters, and font size of 10.
- The names of second main headings (Heading 2) must not include numbers and must be in italics with a font size of 10.

Structure and Format of Manuscript

The recommended size of an original research paper is under 15,000 words and review papers under 7,000 words. Research articles should be less than 10,000 words. Research papers are usually longer than review papers. Review papers are reports of significant research (typically less than 7,000 words, including tables, figures, and references)

A research paper must include:

a) A title which should be relevant to the theme of the paper.
b) A summary, known as an abstract (less than 150 words), containing the major results and conclusions.
c) Up to 10 keywords that precisely identify the paper's subject, purpose, and focus.
d) An introduction, giving fundamental background objectives.
e) Resources and techniques with sufficient complete experimental details (wherever possible by reference) to permit repetition, sources of information must be given, and numerical methods must be specified by reference.
f) Results which should be presented concisely by well-designed tables and figures.
g) Suitable statistical data should also be given.
h) All data must have been gathered with attention to numerical detail in the planning stage.

Design has been recognized to be essential to experiments for a considerable time, and the editor has decided that any paper that appears not to have adequate numerical treatments of the data will be returned unrefereed.

i) Discussion should cover implications and consequences and not just recapitulate the results; conclusions should also be summarized.
j) There should be brief acknowledgments.
k) There ought to be references in the conventional format. Global Journals recommends APA format.

Authors should carefully consider the preparation of papers to ensure that they communicate effectively. Papers are much more likely to be accepted if they are carefully designed and laid out, contain few or no errors, are summarizing, and follow instructions. They will also be published with much fewer delays than those that require much technical and editorial correction.

The Editorial Board reserves the right to make literary corrections and suggestions to improve brevity.

Format Structure

It is necessary that authors take care in submitting a manuscript that is written in simple language and adheres to published guidelines.

All manuscripts submitted to Global Journals should include:

Title

The title page must carry an informative title that reflects the content, a running title (less than 45 characters together with spaces), names of the authors and co-authors, and the place(s) where the work was carried out.

Author details

The full postal address of any related author(s) must be specified.

Abstract

The abstract is the foundation of the research paper. It should be clear and concise and must contain the objective of the paper and inferences drawn. It is advised to not include big mathematical equations or complicated jargon.

Many researchers searching for information online will use search engines such as Google, Yahoo or others. By optimizing your paper for search engines, you will amplify the chance of someone finding it. In turn, this will make it more likely to be viewed and cited in further works. Global Journals has compiled these guidelines to facilitate you to maximize the web-friendliness of the most public part of your paper.

Keywords

A major lynchpin of research work for the writing of research papers is the keyword search, which one will employ to find both library and internet resources. Up to eleven keywords or very brief phrases have to be given to help data retrieval, mining, and indexing.

One must be persistent and creative in using keywords. An effective keyword search requires a strategy: planning of a list of possible keywords and phrases to try.

Choice of the main keywords is the first tool of writing a research paper. Research paper writing is an art. Keyword search should be as strategic as possible.

One should start brainstorming lists of potential keywords before even beginning searching. Think about the most important concepts related to research work. Ask, "What words would a source have to include to be truly valuable in a research paper?" Then consider synonyms for the important words.

It may take the discovery of only one important paper to steer in the right keyword direction because, in most databases, the keywords under which a research paper is abstracted are listed with the paper.

Numerical Methods

Numerical methods used should be transparent and, where appropriate, supported by references.

Abbreviations

Authors must list all the abbreviations used in the paper at the end of the paper or in a separate table before using them.

Formulas and equations

Authors are advised to submit any mathematical equation using either MathJax, KaTeX, or LaTeX, or in a very high-quality image.

Tables, Figures, and Figure Legends

Tables: Tables should be cautiously designed, uncrowned, and include only essential data. Each must have an Arabic number, e.g., Table 4, a self-explanatory caption, and be on a separate sheet. Authors must submit tables in an editable format and not as images. References to these tables (if any) must be mentioned accurately.

Figures

Figures are supposed to be submitted as separate files. Always include a citation in the text for each figure using Arabic numbers, e.g., Fig. 4. Artwork must be submitted online in vector electronic form or by emailing it.

Preparation of Eletronic Figures for Publication

Although low-quality images are sufficient for review purposes, print publication requires high-quality images to prevent the final product being blurred or fuzzy. Submit (possibly by e-mail) EPS (line art) or TIFF (halftone/ photographs) files only. MS PowerPoint and Word Graphics are unsuitable for printed pictures. Avoid using pixel-oriented software. Scans (TIFF only) should have a resolution of at least 350 dpi (halftone) or 700 to 1100 dpi (line drawings). Please give the data for figures in black and white or submit a Color Work Agreement form. EPS files must be saved with fonts embedded (and with a TIFF preview, if possible).

For scanned images, the scanning resolution at final image size ought to be as follows to ensure good reproduction: line art: >650 dpi; halftones (including gel photographs): >350 dpi; figures containing both halftone and line images: >650 dpi.

Color charges: Authors are advised to pay the full cost for the reproduction of their color artwork. Hence, please note that if there is color artwork in your manuscript when it is accepted for publication, we would require you to complete and return a Color Work Agreement form before your paper can be published. Also, you can email your editor to remove the color fee after acceptance of the paper.

Tips for Writing a Good Quality Engineering Research Paper

Techniques for writing a good quality engineering research paper:

1. Choosing the topic: In most cases, the topic is selected by the interests of the author, but it can also be suggested by the guides. You can have several topics, and then judge which you are most comfortable with. This may be done by asking several questions of yourself, like "Will I be able to carry out a search in this area? Will I find all necessary resources to accomplish the search? Will I be able to find all information in this field area?" If the answer to this type of question is "yes," then you ought to choose that topic. In most cases, you may have to conduct surveys and visit several places. Also, you might have to do a lot of work to find all the rises and falls of the various data on that subject. Sometimes, detailed information plays a vital role, instead of short information. Evaluators are human: The first thing to remember is that evaluators are also human beings. They are not only meant for rejecting a paper. They are here to evaluate your paper. So present your best aspect.

2. Think like evaluators: If you are in confusion or getting demotivated because your paper may not be accepted by the evaluators, then think, and try to evaluate your paper like an evaluator. Try to understand what an evaluator wants in your research paper, and you will automatically have your answer. Make blueprints of paper: The outline is the plan or framework that will help you to arrange your thoughts. It will make your paper logical. But remember that all points of your outline must be related to the topic you have chosen.

3. Ask your guides: If you are having any difficulty with your research, then do not hesitate to share your difficulty with your guide (if you have one). They will surely help you out and resolve your doubts. If you can't clarify what exactly you require for your work, then ask your supervisor to help you with an alternative. He or she might also provide you with a list of essential readings.

4. Use of computer is recommended: As you are doing research in the field of research engineering then this point is quite obvious. Use right software: Always use good quality software packages. If you are not capable of judging good software, then you can lose the quality of your paper unknowingly. There are various programs available to help you which you can get through the internet.

5. Use the internet for help: An excellent start for your paper is using Google. It is a wondrous search engine, where you can have your doubts resolved. You may also read some answers for the frequent question of how to write your research paper or find a model research paper. You can download books from the internet. If you have all the required books, place importance on reading, selecting, and analyzing the specified information. Then sketch out your research paper. Use big pictures: You may use encyclopedias like Wikipedia to get pictures with the best resolution. At Global Journals, you should strictly follow here.

6. Bookmarks are useful: When you read any book or magazine, you generally use bookmarks, right? It is a good habit which helps to not lose your continuity. You should always use bookmarks while searching on the internet also, which will make your search easier.

7. Revise what you wrote: When you write anything, always read it, summarize it, and then finalize it.

8. Make every effort: Make every effort to mention what you are going to write in your paper. That means always have a good start. Try to mention everything in the introduction—what is the need for a particular research paper. Polish your work with good writing skills and always give an evaluator what he wants. Make backups: When you are going to do any important thing like making a research paper, you should always have backup copies of it either on your computer or on paper. This protects you from losing any portion of your important data.

9. Produce good diagrams of your own: Always try to include good charts or diagrams in your paper to improve quality. Using several unnecessary diagrams will degrade the quality of your paper by creating a hodgepodge. So always try to include diagrams which were made by you to improve the readability of your paper. Use of direct quotes: When you do research relevant to literature, history, or current affairs, then use of quotes becomes essential, but if the study is relevant to science, use of quotes is not preferable.

10. Use proper verb tense: Use proper verb tenses in your paper. Use past tense to present those events that have happened. Use present tense to indicate events that are going on. Use future tense to indicate events that will happen in the future. Use of wrong tenses will confuse the evaluator. Avoid sentences that are incomplete.

11. Pick a good study spot: Always try to pick a spot for your research which is quiet. Not every spot is good for studying.

12. Know what you know: Always try to know what you know by making objectives, otherwise you will be confused and unable to achieve your target.

13. Use good grammar: Always use good grammar and words that will have a positive impact on the evaluator; use of good vocabulary does not mean using tough words which the evaluator has to find in a dictionary. Do not fragment sentences. Eliminate one-word sentences. Do not ever use a big word when a smaller one would suffice.

Verbs have to be in agreement with their subjects. In a research paper, do not start sentences with conjunctions or finish them with prepositions. When writing formally, it is advisable to never split an infinitive because someone will (wrongly) complain. Avoid clichés like a disease. Always shun irritating alliteration. Use language which is simple and straightforward. Put together a neat summary.

14. Arrangement of information: Each section of the main body should start with an opening sentence, and there should be a changeover at the end of the section. Give only valid and powerful arguments for your topic. You may also maintain your arguments with records.

15. Never start at the last minute: Always allow enough time for research work. Leaving everything to the last minute will degrade your paper and spoil your work.

16. Multitasking in research is not good: Doing several things at the same time is a bad habit in the case of research activity. Research is an area where everything has a particular time slot. Divide your research work into parts, and do a particular part in a particular time slot.

17. Never copy others' work: Never copy others' work and give it your name because if the evaluator has seen it anywhere, you will be in trouble. Take proper rest and food: No matter how many hours you spend on your research activity, if you are not taking care of your health, then all your efforts will have been in vain. For quality research, take proper rest and food.

18. Go to seminars: Attend seminars if the topic is relevant to your research area. Utilize all your resources.

19. Refresh your mind after intervals: Try to give your mind a rest by listening to soft music or sleeping in intervals. This will also improve your memory. Acquire colleagues: Always try to acquire colleagues. No matter how sharp you are, if you acquire colleagues, they can give you ideas which will be helpful to your research.

20. Think technically: Always think technically. If anything happens, search for its reasons, benefits, and demerits. Think and then print: When you go to print your paper, check that tables are not split, headings are not detached from their descriptions, and page sequence is maintained.

21. Adding unnecessary information: Do not add unnecessary information like "I have used MS Excel to draw graphs." Irrelevant and inappropriate material is superfluous. Foreign terminology and phrases are not apropos. One should never take a broad view. Analogy is like feathers on a snake. Use words properly, regardless of how others use them. Remove quotations. Puns are for kids, not grunt readers. Never oversimplify: When adding material to your research paper, never go for oversimplification; this will definitely irritate the evaluator. Be specific. Never use rhythmic redundancies. Contractions shouldn't be used in a research paper. Comparisons are as terrible as clichés. Give up ampersands, abbreviations, and so on. Remove commas that are not necessary. Parenthetical words should be between brackets or commas. Understatement is always the best way to put forward earth-shaking thoughts. Give a detailed literary review.
22. Report concluded results: Use concluded results. From raw data, filter the results, and then conclude your studies based on measurements and observations taken. An appropriate number of decimal places should be used. Parenthetical remarks are prohibited here. Proofread carefully at the final stage. At the end, give an outline to your arguments. Spot perspectives of further study of the subject. Justify your conclusion at the bottom sufficiently, which will probably include examples.
23. Upon conclusion: Once you have concluded your research, the next most important step is to present your findings. Presentation is extremely important as it is the definite medium though which your research is going to be in print for the rest of the crowd. Care should be taken to categorize your thoughts well and present them in a logical and neat manner. A good quality research paper format is essential because it serves to highlight your research paper and bring to light all necessary aspects of your research.

Informal Guidelines of Research Paper Writing

Key points to remember:

- Submit all work in its final form.
- Write your paper in the form which is presented in the guidelines using the template.
- Please note the criteria peer reviewers will use for grading the final paper.

Final points:

One purpose of organizing a research paper is to let people interpret your efforts selectively. The journal requires the following sections, submitted in the order listed, with each section starting on a new page:

The introduction: This will be compiled from reference matter and reflect the design processes or outline of basis that directed you to make a study. As you carry out the process of study, the method and process section will be constructed like that. The results segment will show related statistics in nearly sequential order and direct reviewers to similar intellectual paths throughout the data that you gathered to carry out your study.

The discussion section:

This will provide understanding of the data and projections as to the implications of the results. The use of good quality references throughout the paper will give the effort trustworthiness by representing an alertness to prior workings.

Writing a research paper is not an easy job, no matter how trouble-free the actual research or concept. Practice, excellent preparation, and controlled record-keeping are the only means to make straightforward progression.

General style:

Specific editorial column necessities for compliance of a manuscript will always take over from directions in these general guidelines.

To make a paper clear: Adhere to recommended page limits.

Mistakes to avoid:

- Insertion of a title at the foot of a page with subsequent text on the next page.
- Separating a table, chart, or figure—confine each to a single page.
- Submitting a manuscript with pages out of sequence.
- In every section of your document, use standard writing style, including articles ("a" and "the").
- Keep paying attention to the topic of the paper.

- Use paragraphs to split each significant point (excluding the abstract).
- Align the primary line of each section.
- Present your points in sound order.
- Use present tense to report well-accepted matters.
- Use past tense to describe specific results.
- Do not use familiar wording; don't address the reviewer directly. Don't use slang or superlatives.
- Avoid use of extra pictures—include only those figures essential to presenting results.

Title page:

Choose a revealing title. It should be short and include the name(s) and address(es) of all authors. It should not have acronyms or abbreviations or exceed two printed lines.

Abstract: This summary should be two hundred words or less. It should clearly and briefly explain the key findings reported in the manuscript and must have precise statistics. It should not have acronyms or abbreviations. It should be logical in itself. Do not cite references at this point.

An abstract is a brief, distinct paragraph summary of finished work or work in development. In a minute or less, a reviewer can be taught the foundation behind the study, common approaches to the problem, relevant results, and significant conclusions or new questions.

Write your summary when your paper is completed because how can you write the summary of anything which is not yet written? Wealth of terminology is very essential in abstract. Use comprehensive sentences, and do not sacrifice readability for brevity; you can maintain it succinctly by phrasing sentences so that they provide more than a lone rationale. The author can at this moment go straight to shortening the outcome. Sum up the study with the subsequent elements in any summary. Try to limit the initial two items to no more than one line each.

Reason for writing the article—theory, overall issue, purpose.

- Fundamental goal.
- To-the-point depiction of the research.
- Consequences, including definite statistics—if the consequences are quantitative in nature, account for this; results of any numerical analysis should be reported. Significant conclusions or questions that emerge from the research.

Approach:

- o Single section and succinct.
- o An outline of the job done is always written in past tense.
- o Concentrate on shortening results—limit background information to a verdict or two.
- o Exact spelling, clarity of sentences and phrases, and appropriate reporting of quantities (proper units, important statistics) are just as significant in an abstract as they are anywhere else.

Introduction:

The introduction should "introduce" the manuscript. The reviewer should be presented with sufficient background information to be capable of comprehending and calculating the purpose of your study without having to refer to other works. The basis for the study should be offered. Give the most important references, but avoid making a comprehensive appraisal of the topic. Describe the problem visibly. If the problem is not acknowledged in a logical, reasonable way, the reviewer will give no attention to your results. Speak in common terms about techniques used to explain the problem, if needed, but do not present any particulars about the protocols here.

The following approach can create a valuable beginning:

- o Explain the value (significance) of the study.
- o Defend the model—why did you employ this particular system or method? What is its compensation? Remark upon its appropriateness from an abstract point of view as well as pointing out sensible reasons for using it.
- o Present a justification. State your particular theory(-ies) or aim(s), and describe the logic that led you to choose them.
- o Briefly explain the study's tentative purpose and how it meets the declared objectives.

Approach:

Use past tense except for when referring to recognized facts. After all, the manuscript will be submitted after the entire job is done. Sort out your thoughts; manufacture one key point for every section. If you make the four points listed above, you will need at least four paragraphs. Present surrounding information only when it is necessary to support a situation. The reviewer does not desire to read everything you know about a topic. Shape the theory specifically—do not take a broad view.

As always, give awareness to spelling, simplicity, and correctness of sentences and phrases.

Procedures (methods and materials):

This part is supposed to be the easiest to carve if you have good skills. A soundly written procedures segment allows a capable scientist to replicate your results. Present precise information about your supplies. The suppliers and clarity of reagents can be helpful bits of information. Present methods in sequential order, but linked methodologies can be grouped as a segment. Be concise when relating the protocols. Attempt to give the least amount of information that would permit another capable scientist to replicate your outcome, but be cautious that vital information is integrated. The use of subheadings is suggested and ought to be synchronized with the results section.

When a technique is used that has been well-described in another section, mention the specific item describing the way, but draw the basic principle while stating the situation. The purpose is to show all particular resources and broad procedures so that another person may use some or all of the methods in one more study or referee the scientific value of your work. It is not to be a step-by-step report of the whole thing you did, nor is a methods section a set of orders.

Materials:

Materials may be reported in part of a section or else they may be recognized along with your measures.

Methods:

- Report the method and not the particulars of each process that engaged the same methodology.
- Describe the method entirely.
- To be succinct, present methods under headings dedicated to specific dealings or groups of measures.
- Simplify—detail how procedures were completed, not how they were performed on a particular day.
- If well-known procedures were used, account for the procedure by name, possibly with a reference, and that's all.

Approach:

It is embarrassing to use vigorous voice when documenting methods without using first person, which would focus the reviewer's interest on the researcher rather than the job. As a result, when writing up the methods, most authors use third person passive voice.

Use standard style in this and every other part of the paper—avoid familiar lists, and use full sentences.

What to keep away from:

- Resources and methods are not a set of information.
- Skip all descriptive information and surroundings—save it for the argument.
- Leave out information that is immaterial to a third party.

Results:

The principle of a results segment is to present and demonstrate your conclusion. Create this part as entirely objective details of the outcome, and save all understanding for the discussion.

The page length of this segment is set by the sum and types of data to be reported. Use statistics and tables, if suitable, to present consequences most efficiently.

You must clearly differentiate material which would usually be incorporated in a study editorial from any unprocessed data or additional appendix matter that would not be available. In fact, such matters should not be submitted at all except if requested by the instructor.

Content:

- Sum up your conclusions in text and demonstrate them, if suitable, with figures and tables.
- In the manuscript, explain each of your consequences, and point the reader to remarks that are most appropriate.
- Present a background, such as by describing the question that was addressed by creation of an exacting study.
- Explain results of control experiments and give remarks that are not accessible in a prescribed figure or table, if appropriate.
- Examine your data, then prepare the analyzed (transformed) data in the form of a figure (graph), table, or manuscript.

What to stay away from:

- Do not discuss or infer your outcome, report surrounding information, or try to explain anything.
- Do not include raw data or intermediate calculations in a research manuscript.
- Do not present similar data more than once.
- A manuscript should complement any figures or tables, not duplicate information.
- Never confuse figures with tables—there is a difference.

Approach:

As always, use past tense when you submit your results, and put the whole thing in a reasonable order.

Put figures and tables, appropriately numbered, in order at the end of the report.

If you desire, you may place your figures and tables properly within the text of your results section.

Figures and tables:

If you put figures and tables at the end of some details, make certain that they are visibly distinguished from any attached appendix materials, such as raw facts. Whatever the position, each table must be titled, numbered one after the other, and include a heading. All figures and tables must be divided from the text.

Discussion:

The discussion is expected to be the trickiest segment to write. A lot of papers submitted to the journal are discarded based on problems with the discussion. There is no rule for how long an argument should be.

Position your understanding of the outcome visibly to lead the reviewer through your conclusions, and then finish the paper with a summing up of the implications of the study. The purpose here is to offer an understanding of your results and support all of your conclusions, using facts from your research and generally accepted information, if suitable. The implication of results should be fully described.

Infer your data in the conversation in suitable depth. This means that when you clarify an observable fact, you must explain mechanisms that may account for the observation. If your results vary from your prospect, make clear why that may have happened. If your results agree, then explain the theory that the proof supported. It is never suitable to just state that the data approved the prospect, and let it drop at that. Make a decision as to whether each premise is supported or discarded or if you cannot make a conclusion with assurance. Do not just dismiss a study or part of a study as "uncertain."

Research papers are not acknowledged if the work is imperfect. Draw what conclusions you can based upon the results that you have, and take care of the study as a finished work.

- You may propose future guidelines, such as how an experiment might be personalized to accomplish a new idea.
- Give details of all of your remarks as much as possible, focusing on mechanisms.
- Make a decision as to whether the tentative design sufficiently addressed the theory and whether or not it was correctly restricted. Try to present substitute explanations if they are sensible alternatives.
- One piece of research will not counter an overall question, so maintain the large picture in mind. Where do you go next? The best studies unlock new avenues of study. What questions remain?
- Recommendations for detailed papers will offer supplementary suggestions.

Approach:

When you refer to information, differentiate data generated by your own studies from other available information. Present work done by specific persons (including you) in past tense.

Describe generally acknowledged facts and main beliefs in present tense.

The Administration Rules

Administration Rules to Be Strictly Followed before Submitting Your Research Paper to Global Journals Inc.

Please read the following rules and regulations carefully before submitting your research paper to Global Journals Inc. to avoid rejection.

Segment draft and final research paper: You have to strictly follow the template of a research paper, failing which your paper may get rejected. You are expected to write each part of the paper wholly on your own. The peer reviewers need to identify your own perspective of the concepts in your own terms. Please do not extract straight from any other source, and do not rephrase someone else's analysis. Do not allow anyone else to proofread your manuscript.

Written material: You may discuss this with your guides and key sources. Do not copy anyone else's paper, even if this is only imitation, otherwise it will be rejected on the grounds of plagiarism, which is illegal. Various methods to avoid plagiarism are strictly applied by us to every paper, and, if found guilty, you may be blacklisted, which could affect your career adversely. To guard yourself and others from possible illegal use, please do not permit anyone to use or even read your paper and file.

CRITERION FOR GRADING A RESEARCH PAPER (COMPILATION) BY GLOBAL JOURNALS

Please note that following table is only a Grading of "Paper Compilation" and not on "Performed/Stated Research" whose grading solely depends on Individual Assigned Peer Reviewer and Editorial Board Member. These can be available only on request and after decision of Paper. This report will be the property of Global Journals.

Topics	Grades		
	A-B	**C-D**	**E-F**
Abstract	Clear and concise with appropriate content, Correct format. 200 words or below	Unclear summary and no specific data, Incorrect form Above 200 words	No specific data with ambiguous information Above 250 words
Introduction	Containing all background details with clear goal and appropriate details, flow specification, no grammar and spelling mistake, well organized sentence and paragraph, reference cited	Unclear and confusing data, appropriate format, grammar and spelling errors with unorganized matter	Out of place depth and content, hazy format
Methods and Procedures	Clear and to the point with well arranged paragraph, precision and accuracy of facts and figures, well organized subheads	Difficult to comprehend with embarrassed text, too much explanation but completed	Incorrect and unorganized structure with hazy meaning
Result	Well organized, Clear and specific, Correct units with precision, correct data, well structuring of paragraph, no grammar and spelling mistake	Complete and embarrassed text, difficult to comprehend	Irregular format with wrong facts and figures
Discussion	Well organized, meaningful specification, sound conclusion, logical and concise explanation, highly structured paragraph reference cited	Wordy, unclear conclusion, spurious	Conclusion is not cited, unorganized, difficult to comprehend
References	Complete and correct format, well organized	Beside the point, Incomplete	Wrong format and structuring

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