ISSN : 2456 - 6411

INTERNATIONAL JOURNAL OF RESEARCH IN ENGINEERING AND APPLIED SCIENCES

VOLUME NO. 15

ISSUE NO. 2

MAY - AUGUST - 2025

Enriched Publications
S-9,IInd FLOOR, MLU POCKET,
MANISH ABHINAV PLAZA-II, ABOVE FEDERAL BANK,
PLOT NO-5, SECTOR -5, DWARKA, NEW DELHI, INDIA-110075,
PHONE: - + (91)-(11)-45525005

ISSN : 2456 - 6411

International Journal of Research in Engineering and Applied Sciences

Aims and Scope

The Journal of Research in Engineering and Applied Sciences is an open access peer-reviewed international forum for academicians and engineers involved in research to publish high quality and refereed papers. Papers may be theoretical (including computational), experimental or both.

Papers reporting original research or extended versions of already published conference conducted by (Meghe group of Institutions) MGI or other research papers are all welcome. Papers for publication are selected through peer review to ensure originality, relevance, and readability. The journal publishes articles primarily in the following fields of engineering and science

Editorial Board

ISSN : 2456 - 6411

Patrons

Hon. Shri Datta Meghe
Chairman, NYSS, Atray Layout, Nagpur

Hon. Shri Sagar Meghe
Secretary NYSS, Atray Layout, Nagpur

Hon. Shri Sameer Meghe
Treasurer, NYSS, Atray Layout, Nagpur

ISSN : 2456 - 6411

ISSN : 2456 - 6411

International Journal of Research in Engineering and Applied Sciences

(Volume No. 15, Issue No. 2, May - August 2025)

Contents

ISSN : 2456 - 6411

ISSN : 2456 - 6411

REVIEW ON LOAD ANALYSIS AND MATERIAL OPTIMIZATION OF CONNECTING ROD USING FEA METHODS

R.K. Tiwari1, Dr. Rohit Rajvaidya2
1M.Tech Scholar, Dept. of Mechanical Engineering, BUIT, Barakatullah University, Bhopal
2Associate Professor, Dept. of Mechanical Engineering, BUIT, Barakatullah University, Bhopal

ABSTRACT

Internal combustion engines have at least one connecting rod to transmit the thrust of the piston to the crankshaft, and as the result the reciprocating motion of the piston is translated into rotational motion of the crankshaft. From the viewpoint of functionality, connecting rods must have the highest possible rigidity at the lowest weight capable to withstand varying loads. It has been found that structural failure of various components results in engine missing and starts producing noise and vibration during racing, mileage gets affected and black or white smoke arise; also pickup gets reduced. In automobile industry damaged or broken parts are generally too expensive to replace or repair especially in case of engine. In this concern here we present a review of causes along with preventive maintenance suggestions schedule for better engine life. Later on, finite element modeling and analysis will be performed using ANSYS 12.1 software package to perform a linear static and a coupled thermal-structural contact analysis of the component. A contact analysis is to be carried out to analyze the stresses arising from the interference of the connecting-rod bearing and the piston-pin bushing.

Keywords- Internal combustion engine, Connecting rod, Component failure, Finite element analysis, ANSYS

INTRODUCTION:

The outline and production of Inward Ignition (IC) Motors is under critical weight for development. The up and coming era of motors needs to be minimal, light, effective, and adaptable, yet create less contamination and utilize less fuel. Imaginative engine plans will be required to meet these contending necessities. To comprehend the genuine effect, we would need to retreat in time in excess of one hundred years. A period without the straightforwardness of jumping into a vehicle to take us anyplace we need to go is just about incredible. In any case for the early auto designs, the gigantic progressions in car innovation would be significantly all the more amazing

In the last fifty years, automobiles have figured out how to think, alter, and even ensure. The dominant part of individuals need a vehicle that will get them from point A to point B as effortlessly as could

reasonably be expected, additionally put a little grin on their appearances. As a rule, the grin is made by a snappy punch of the quickening agent and joined by an inclination of monstrous power and control. The car producers are well mindful of this, and to accomplish it, they outline speedier, lighter, and more productive motors to do the occupation. In any case precisely what happens inside a motor and what are the dangers included in planning the strongest motor on the square? In this extend, one part of a motor specifically, the joining bar, will be examined. Being a standout amongst the most vital parts in a motor's plan, the joining bar must have the capacity to withstand enormous loads and transmit a lot of force. It is no astonished that a disappointment in an interfacing pole could be a standout amongst the most exorbitant and harming disappointments in a motor. Anyhow essentially saying that isn't sufficient to completely comprehend the elements of the circumstances. Though the course of the project, an ideal model of a connecting rod, piston will be modeled and optimized. It will get to be clear precisely why these parts are so paramount to the operation of vehicles, and besides how inclined to failure they could be. On the other hand, before an excess of progressively is said on the designing points of interest, a little foundation data is important.

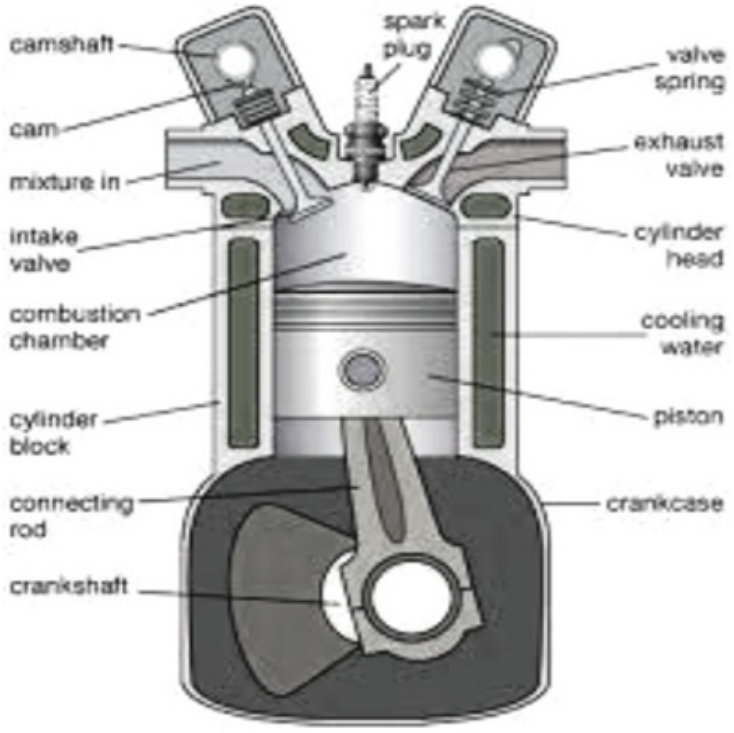

Figure 1.1: Internal combustion engine parts.

Crankshaft and connecting rods are the fundamental segments of internal combustion engines which change over responding dislodging of the cylinder to a revolving movement. A common auto crankshaft comprise of primary journals, connecting rod journals (wrench pins), stabilizer, oil gap and a push bearing journal. During the administration life, combustion and dormancy strengths following up on the crankshaft cause two sorts of stacking on the crankshaft structure; torsion load and twisting burden.

Engine cylinders are a standout amongst the most mind boggling parts among all car segments. The engine could be known as the heart of an auto and the cylinder may be viewed as the most imperative piece of a engine. The cylinders structure the base 50% of the combustion chamber and transmits the power of ignition through the wrist stick and associating pole to the crankshaft. Cylinder failures emerge because of numerous reasons: mechanical anxieties; warm burdens; wear systems; temperature corruption, oxidation components; and so forth. Exhaustion is a wellspring of cylinder harms. Despite the fact that, generally, cylinder harms are ascribed to wear and oil sources, fatigue is in charge of a bigger number of cylinder harms. What's more a few harms where the fundamental driver is credited to wear and/or grease components may have in the underlying driver birthplace a fatigue break. In light of an examination of seventy auto segment disappointments got for examination the dispersion of part failure and the conveyance of reasons are given in Fig 1 and 2 separately. From this it could be seen that the most widely recognized segment failure is that of the engine (41%) and that the most well-known reason for failure is misuse (29%).

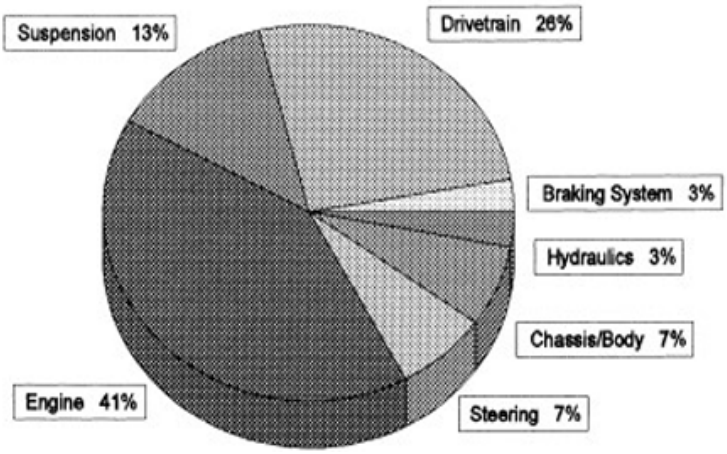

Fig.1.2 - The distribution of component failures

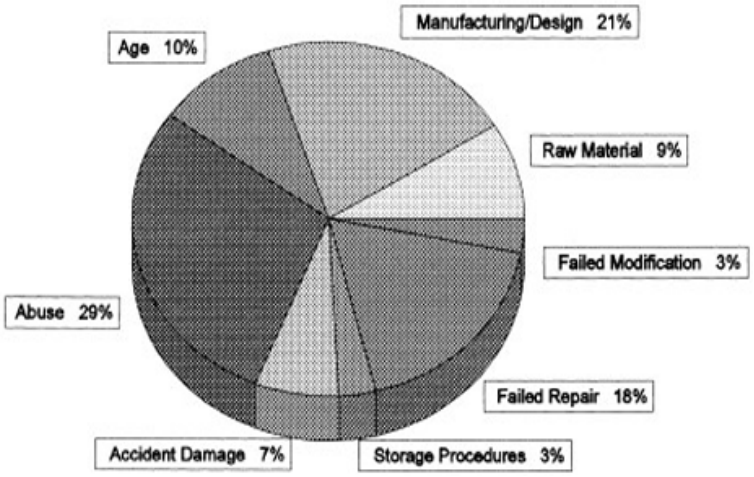

Fig.1.3- The distribution of causes of failure

Since most basic part failure is that of engine so we concentrated on engine square get together which convey cylinder, connecting rod and crankshaft subjected to high warm hassles and in addition cyclic anxieties which depends some degree on drivers driving propensities

II. FUNCTION OF CONNECTING ROD

The capacity of connecting rod is to transmit the push of the cylinder to the crankshaft, and as the result the responding movement of the cylinder is deciphered into rotational movement of the crankshaft. It comprises of a pin-end, a shank area, and a wrench end. Pin-end and wrench end pin gaps are machined to allow precise fitting of orientation. One end of the uniting bar is joined with the cylinder by the cylinder pin. The flip side spins with the crankshaft and is part to allow it to be clipped around the crankshaft. The two sections are then joined by two bolts. Connecting rods are subjected to drives produced by mass and fuel combustion. These two strengths brings about pivotal and twisting hassles. Twisting hassles show up because of erraticism, crankshaft, case divider distortion, and rotational mass power. Along these lines, a connecting rod must be equipped for transmitting pivotal pressure, hub clamping, and twisting anxieties brought about by the push and draw on the cylinder and by divergent power The connecting rods subjected to a complex state of stacking. It experiences high cyclic heaps of the request of 108 to 109 cycles, which go from high compressive loads because of ignition, to high malleable loads because of latency. In this way, strength of this segment is of basic imperativeness

III. LITERATURE SURVEY

[1] P S Shenoy et.al. studied detailed load analysis under service loading conditions for a typical connecting rod, followed by quasi-dynamic finite element analysis (FEA) to capture stress variations over a cycle of operation. It was found that even though connecting rods are typically tested and analyzed under axial loading and stress state, bending stresses are significant and a multiaxial stress state exists at the critical regions of connecting rod.

[2] Thomas et.al. has done the analysis regarding the “Design of Connecting Rod for Heavy Duty Applications Produced by Different Processes for Enhanced Fatigue Life.” The work was aimed at evaluating the fatigue life of a heavy duty connecting rod under 2 different conditions namely without considering the effect of shot peening and with considering the effect of shot peening. It was concluded that shot peening can significantly increase about 72% in fatigue life cycles of a connecting rod component.

[3] James R. Dale et.al.evaluated connecting rod for improved fatigue strength. In the analysis comparison was carried out between powder forging materials & C-70 materials. As a result Powder Forging materials demonstrate improved fatigue strength on the order of 25–33% over C-70 material of the same design.

[4] Prabhala et a undergone “Plan And Weight Optimization Of IC Engine" by Replacing the steel parts with aluminum composite segments. By watching the examination aftereffects of two congregations it was reasoned that utilizing aluminum compound for both interfacing pole and cylinder is more valuable than utilizing steel for cylinder as naturally general weight is decreased in this way the force needed to run itself via car is diminished bringing about the build in the mileage.

[5] A. R. Bhagat et.al. describes the stress distribution of the seizure on piston four stroke engine by using FEA and analyzed the thermal stress distribution of piston at the real engine condition during combustion process. As a result it was observed that stress distribution on the piston mainly depends on the deformation of piston. Therefore, in order to reduce the stress concentration, the piston crown should have enough stiffness to reduce the deformation.

[6] P.Brabec et.al done the investigation in regards to "FEM Analysis of Connecting Rod for Stationary Engine" which addresses the processing of the quality and bending attributes of a stationary motor uniting pole. The results unmistakably demonstrate that the associating bar is not altogether quality focused on and a more regrettable variation is the anxiety at max. burning weight and the extent that contortions are concerned, it is imperative to stay away from such mutilations of the uniting bar huge end which would take up the bearing freedom.

[7] T.t Mon et.al experienced the "Limited Element Analysis on Thermal Effect of the Vehicle Engine". In this study FEM was utilized to create computational model to examine the temperature conveyance in the Vehicle Engine that used Spark ignition framework for force generation.

[8] Vivek C. Pathade et.al. has experienced the anxiety dissection of associating bar.

IV. OBJECTIVE

- To plan a higher quality to weight proportion connecting rod get together for an IC Engine.
- To create a robust model of the get together for execution assessment
- To dissect the interfacing bar gathering execution in the ANSYS product under obliged burden condition.

- To upgrade different configuration parameters and to set determination for usage.
- To reduce the chance of the maintenance of engine due to connecting rod assembly problem.

V. NEED OF THE PROJECT

Connecting rod is one of the main components of an IC Engine. The connecting rods subjected to a complex state of loading. Therefore, durability of this component is of critical importance. In automobile industry damaged or broken parts are generally too expensive to replace or repair especially in case of engine.

VI. METHODOLOGY

- Literature survey regarding connecting rod and various parameters affecting performance.
- Design of various part of connecting rod assembly & selection of suitable lubrication system.
- Analysis of assembly using software ANSYS 12.1
- Reconsideration of various design parameters for getting optimum performance
- Comparison of proposed design with existing available component.

REFERENCES

1. P.S Shenoy, et al "Dynamic Analysis Of Loads and Stresses in Connecting Rods" , J.Mechanical Engineering Science, Vol.220, pp.615-624 , 2006.

2. T.G.Thomas et al"Design of Connecting Rod for Heavy Duty Applications Produced by Different Processes for Enhanced Fatigue Life", SASTECH Journal Volume 10, Issue 1, May 2011.

3. James.R.Dale "Connectin Rod Evaluation" Metal Powder Industries Federation, Jan-2005

4. Sasi Prabhala, et al , "Design and Weight Optimization Of IC Engine" , International Journal Of Advanced Engineering Research and Studies , Vol.2 , Issue.1 , pp. 56-58 , 2012.

5. A.R Bhagat et al "Thermal Analysis & Optimization Of IC Engine Piston using FEM" International Journal Of Modern Engineering Research, Vol.2, Issue.4, pp.2919-2921, 2010.

6. P. Brabec et al "FEM ANALYSIS OF CONNECTING ROD FOR STATIONARY ENGINE" XIII. International Scientific Meeting Motor Vehicles & Engines, Kragujevac 2004. Serbia ISSN 0352 292X.

7. T.T.Mon et al "Finite Element Analysis on Thermal effect of Vehicle Engine ", Proceedings of MUCEET2009 Malaysian Technical Universities Conference on Engineering and Technology, June 20~22, 2009.

8. Vivek C Pathade.et al "Stress Analysis of IC Engine Connecting Rod by FEM", ISSN 2277-3754 International Journal of Engineering and Innovative Technology (IJEIT) Volume 1, Issue 3, March 2012.

9. Ramanpreet Singh "STRESS ANALYSIS OF ORTHOTROPIC ANDISOTROPIC CONNECTING ROD USING FINITEELEMENT METHOD,International Journal of Mechanical Engineering & Robotics Research ISSN 2278 – 0149, Vol. 2, No. 2, April 201.

10. Prof. N.P.Doshi et al "Analysis of Connecting Rod Using Analytical and Finite Element Method", International Journal of Modern Engineering Research (IJMER), pp-65-68 ISSN: 2249-6645, Vol.3, Issue.1, Jan-Feb. 2013.

11. Om Parkash et al " Optimizing the Design of Connecting Rod under Static and Fatigue Loading", International Journal of Research in Management, Science & Technology (E-ISSN: 2321-3264), Vol. 1; No. 1, June 2013.

12. A. M. Heyes, "Automotive Component Failures" Engineering Failure Analysis, Elsevier Science Ltd, Vol.5, No.2 pp.129-141, 1998.

13. F.S.Silva, "Analysis of a vehicle crankshaft failure" Engineering Failure Analysis, Vol.10, pp. 605–616, 2003.

14. F.S.Silva, "Fatigue on engine pistons – A compendium of case studies" Engineering Failure Analysis,Vol.13 pp.480–492, 2006.

15. A. Mirehei et al "Fatigue analysis of connecting rod of universal tractor through finite element method (ANSYS)" , Journal of Agricultural Technology 2008, V.4(2): 21-27.

16. Gudimetal P. et al"Finite Element Analysis of Reverse Engineered Internal Combustion Engine Piston", AIJSTPME (2009) 2(4): 85-92

17. Sanjay B Chikalthankar et al"FEA Analysis of Geometric Parameters of connecting rod big end", ISSN 0975-5462 ,Vol.04, No.04, April 2012.

ISSN : 2456 - 6411

LOAD ANALYSIS AND MATERIAL OPTIMIZATION OF CONNECTING ROD USING FEA METHODS

R.K. Tiwari1, Dr. Rohit Rajvaidya2
1M.Tech Scholar, Dept. of Mechanical Engineering, BUIT, Barakatullah University, Bhopal
2Associate Professor, Dept. of Mechanical Engineering, BUIT, Barakatullah University, Bhopal

A B S T R A C T

Internal combustion engines have at least one connecting rod to transmit the thrust of the piston to the crankshaft, and as the result the reciprocating motion of the piston is translated into rotational motion of the crankshaft. From the viewpoint of functionality, connecting rods must have the highest possible rigidity at the lowest weight capable to withstand varying loads. It has been found that structural failure of various components results in engine missing and starts producing noise and vibration during racing, mileage gets affected and black or white smoke arise; also pickup gets reduced. In automobile industry damaged or broken parts are generally too expensive to replace or repair especially in case of engine. In this concern here we present a review of causes along with preventive maintenance suggestions schedule for better engine life. Later on, finite element modeling and analysis will be performed using ANSYS 12.1 software package to perform a linear static and a coupled thermal-structural contact analysis of the component. A contact analysis is to be carried out to analyze the stresses arising from the interference of the connecting-rod bearing and the piston-pin bushing.

Keywords- Internal combustion engine, Connecting rod, Component failure, Finite element analysis, ANSYS

I. INTRODUCTION TO FINITE ELEMENT METHOD

Finite element method is a numerical technique for tackling issues of designing and scientific material science. In this technique, a body or a structure in which the examination to be completed is subdivided into littler components of Finite measurements called Finite components. At that point the body is considered as a gathering of these components joined at a Finite number of joints called hubs or nodal focuses. The properties of each one kind of Finite component id acquired and amassed together and comprehended as entire to get result. As such, in Finite element method, as opposed to tackling the issue for the whole body in one operation, we detail the mathematical statements for every Finite component and join together them to get the result of the entire body. Finite element method is utilized to take care of physical issues including muddled geometrics, stacking and material properties which can't be understood by expository technique. This system is widely utilized as a part of the field of structural mechanics, liquid mechanics, hotness exchange, mass exchange, electric and attractive fields issues

Based on application, the finite element problems are classified as follow:

I) Structural problems

ii) Non-structural problems

1. Structural problems: In structural problems, displacement at each nodal point is obtained. By using these displacement solutions, stress and strain in each element can be calculated.

2. Non-structural problem: In non structural problems, temperature or fluid pressure at each nodal point is obtained. By using these values, properties such as heat flow, fluid flow etc, for each element can be calculated.

II. MODELING OF CONNECTING ROD

The model of connecting rod was generated in CATIA V5 R19 on the basis of the specifications given in Fig.2.1. The actual model of connecting rod is shown in Fig.2.2

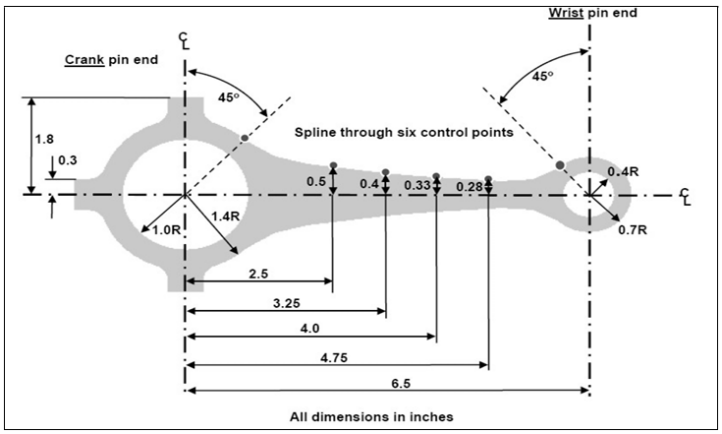

Fig. 2.1 - Specifications of connecting rod.

Creating the 2D cross section on XY plane using two circle, line and fillets with the help of sketcher option.

Fill material in sketch with the help of pad command.

Creation of hole on piston end and crank end with the help of pocket command.

Creation of second sketch in shank portion of the connecting rod.

Pocket the second sketch on both sides of the shank up to desired depth to make the I-section.

Select an arbitrary rectangle in XY plane at the centre of the crank end in order to make the crank end open.

Cut half of the crank end with the help of pocket command

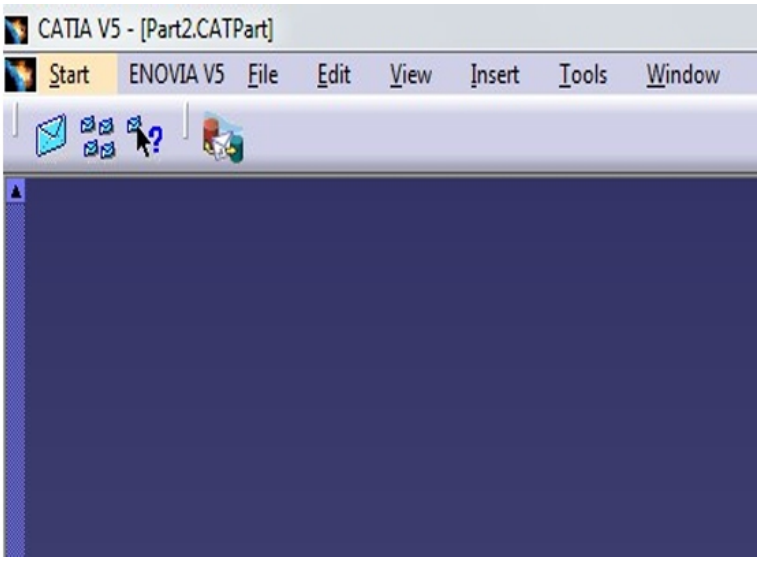

Fig 2.2- Model of connecting rod generated on CATIA

A cylinder of Legend Honda Wonder, market accessible is chosen for the present examination. The measurements of chose cylinder are discovered utilizing vernier caliper, screw gauge and classified in table. As per the measurements of the cylinder is produced utilizing CATIA V5. The model of piston is demonstrated in fig.2.3. It is transported in into outline modeler of ANSYS Workbench.

Fig. 2.3- Model of connecting rod generated on CATIA

Selected material	Cast iron
Young's modulus (E)	1.78e+05 MPa
Piossion's ratio	0.3
Density	7.197e+06 Kg/mm^3
Tensile yield strength	110 MPa
Tensile ultimate strength	110 MPa
Compressive yield strength	400 MPa
Compressive ultimative strength	0 MPa

Table 2.1-Mechanical Properties of Cast Iron

The next stage of the modeling is to create meshing of the created model. The below said parameters are used for meshing. The mesh model of piston is shown in figures given below-

Type of element: Tetrahedron

Number of nodes: 71910

Number of element: 41587

Fig 3.1-Meshing of a piston

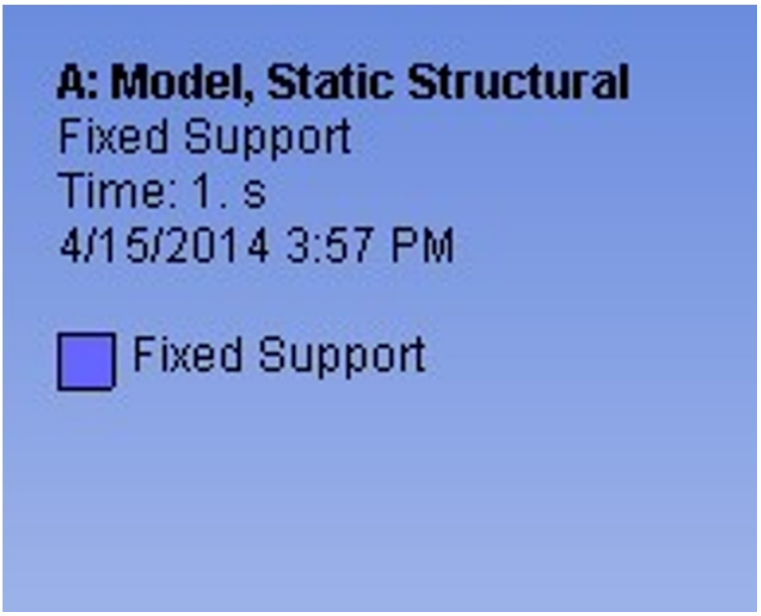

Fig 3.2- Fixed support to the connecting rod

IV. VON- MISES STRESSES

When, the material used for selected connecting rod is structural steel the result of the von-Mises stresses is shown in the fig.4.1

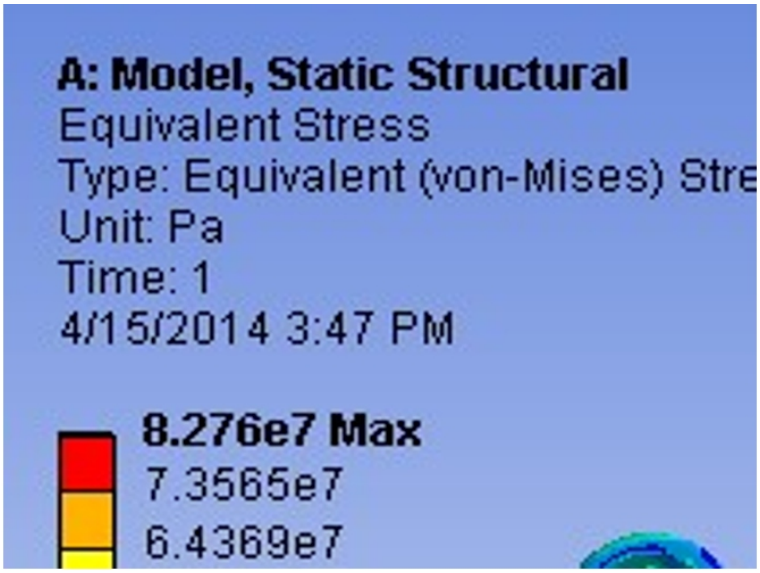

Fig 4.1- Von-Mises stresses in structural steel

When, the material used for selected connecting rod is structural steel en45 and the result of the von-Mises stresses is shown in the fig.4.2

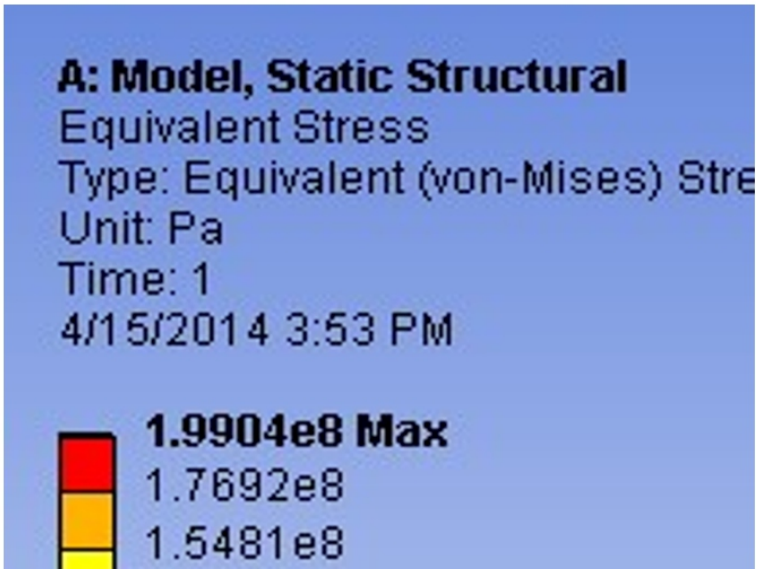

Fig.4.2- Von-Mises stresses in structural steel en45

When, the material used for selected connecting rod is cast iron and the result of the von-Mises stresses is shown in the fig.4.3

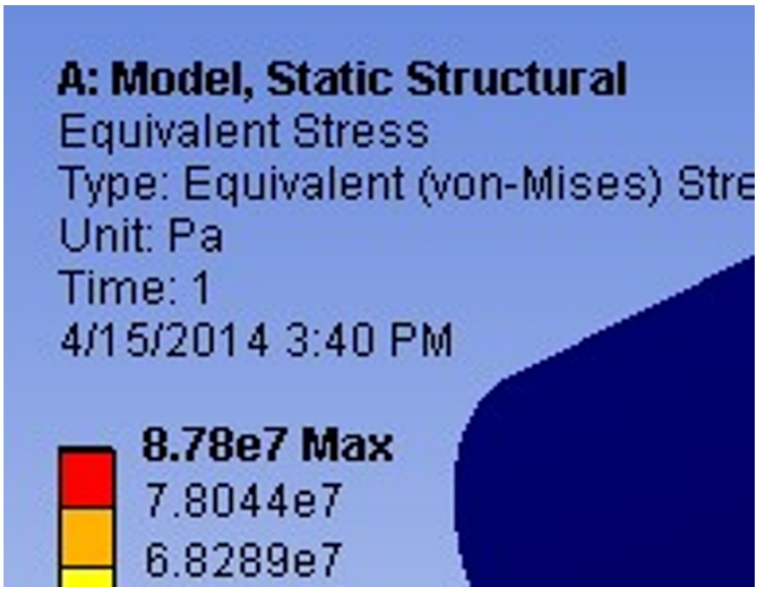

Fig. 4.3 Von-Mises stresses in cast iron

When, the material used for selected connecting rod is aluminum and the result of the von-Mises stresses is shown in the fig.4.4

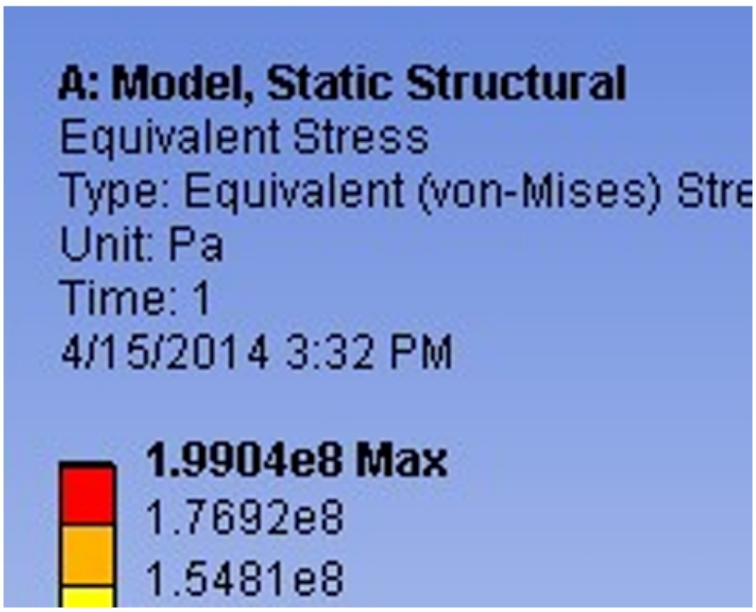

Fig. 4.4 Von-Mises stresses in aluminum

V. EQUIVALENT STRAINS

When, the material used for selected connecting rod is structural steel and the result of the von-Mises strains or equivalent strains is shown in the fig. 5.1

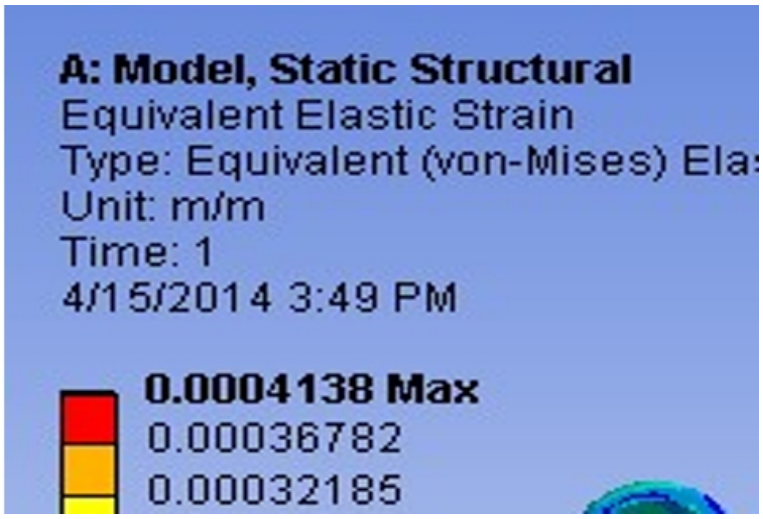

Fig. 5.1- Equivalent or von-Mises strain in structural steel

When, the material used for selected connecting rod is structural steel en45 and the result of the von-Mises strains or equivalent strains is shown in the fig.5.2

Fig. 5.2- Equivalent or von-Mises strain in structural steel en45

When, the material used for selected connecting rod is cast iron and the result of the von-Mises strains or equivalent strains is shown in the fig.5.3

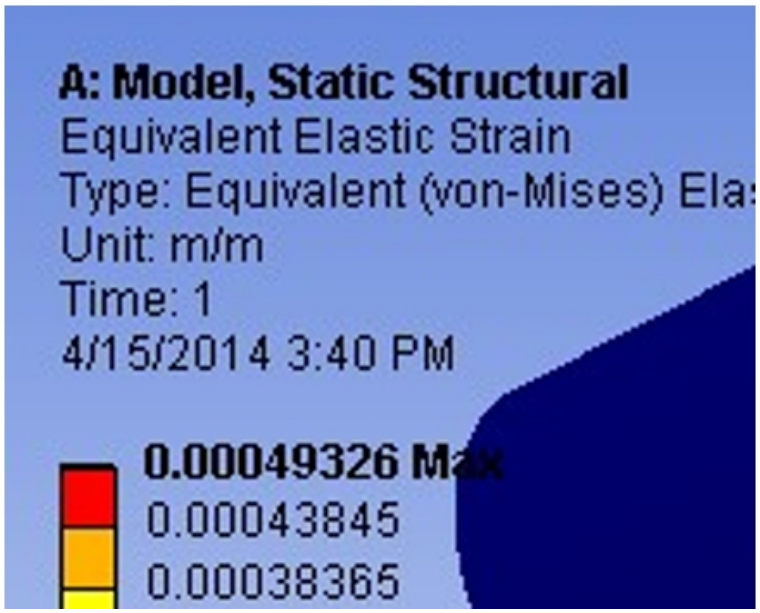

Fig.5.3- Equivalent or von-Misses strain in cast iron

When, the material used for selected connecting rod is aluminum and the result of the von-Mises strains or equivalent strains is shown in the fig.5.4

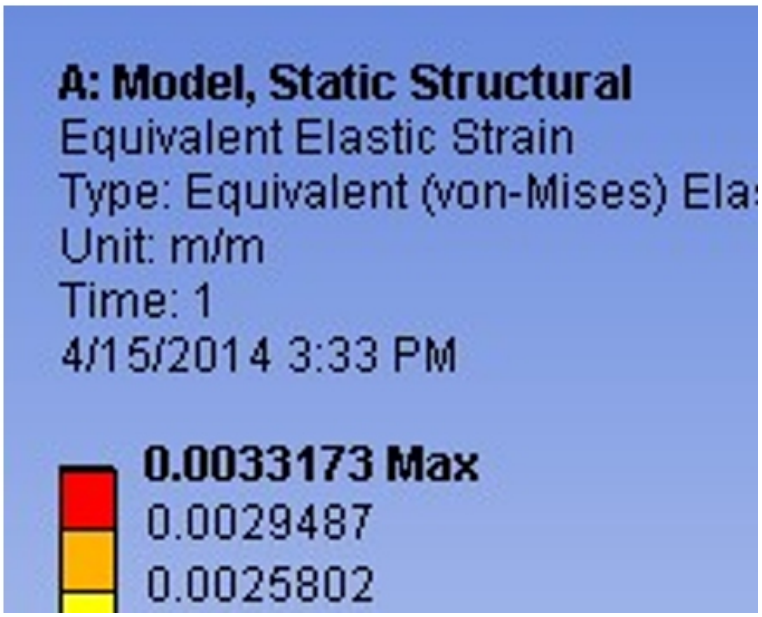

Fig 5.4- Equivalent or von-Mises strain in aluminum

VI. TOTAL DEFORMATION

When, the material used for selected connecting rod is structural steel and the result of the total deformation is shown in the fig.6.1

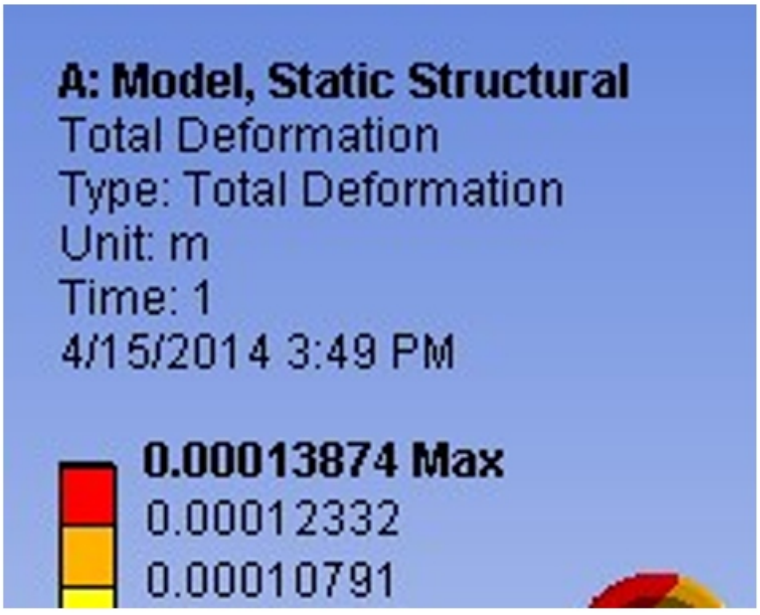

Fig.6.1- Total deformation in structural steel

When, the material used for selected connecting rod is structural steel en45 and the result of the total deformation is shown in the fig.6.2

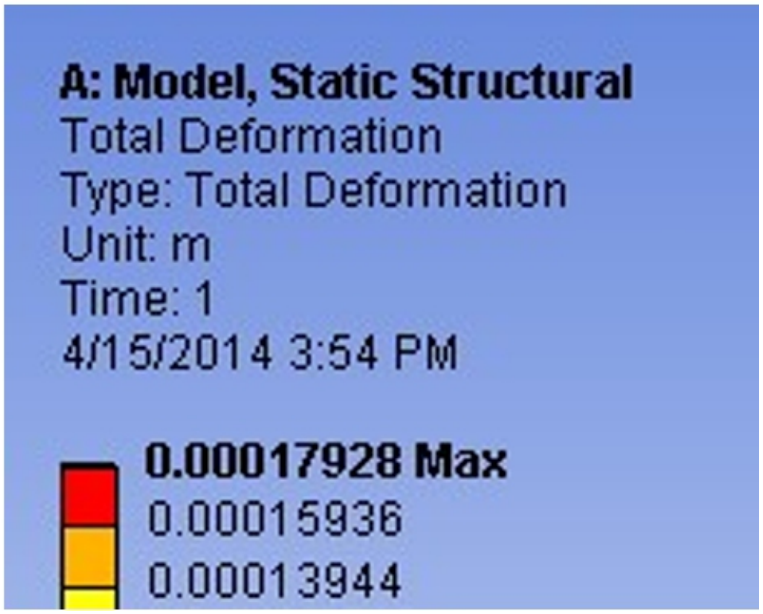

Fig.6.2- Total deformation in structural steel en45

When, the material used for selected connecting rod is cast iron and the result of the total deformation is shown in the fig.6.3

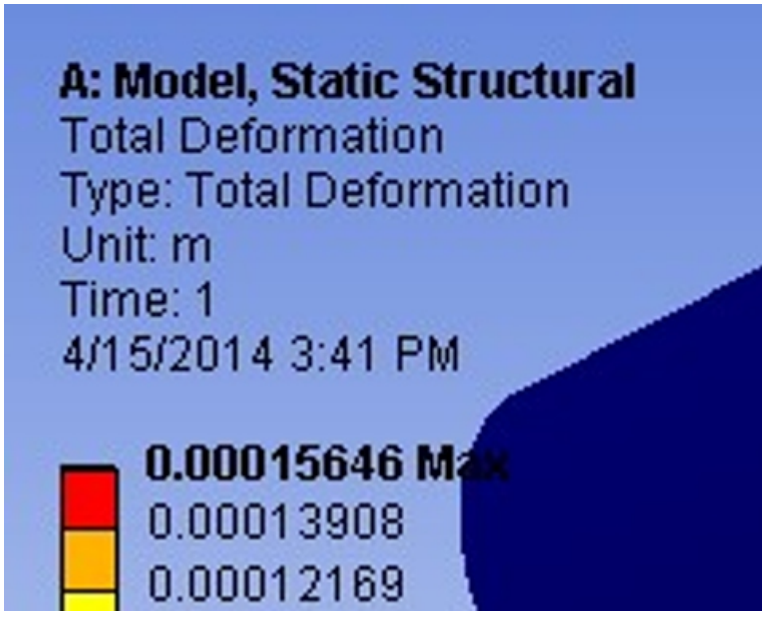

Fig.6.3- Total deformation in cast iron

When, the material used for selected connecting rod is aluminum and the result of the total deformation is shown in the fig.6.4

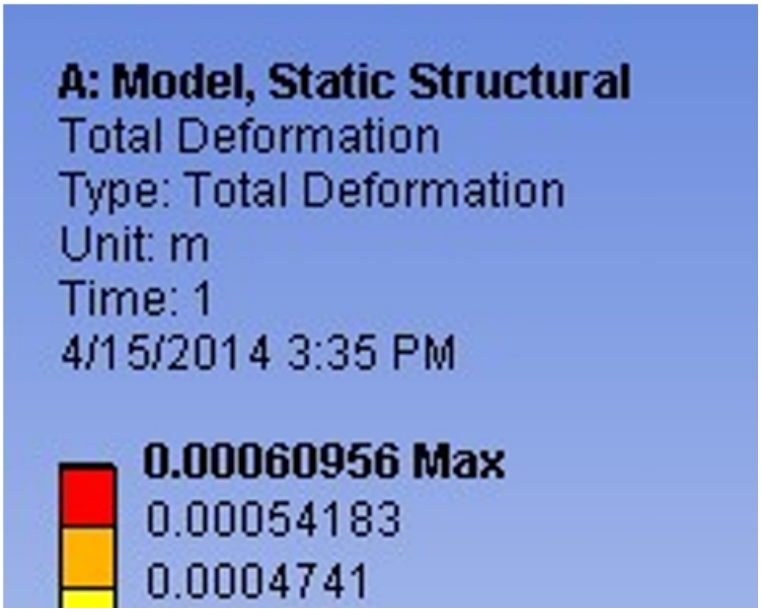

Fig.6.4- Total deformation in aluminum

VII. RESULTS

Similarly analysis on factor of safety , total deformation and overall life was also done. All the parameters we studied for different materials and their obtained values have been summarized in the table 7.1

S.NO.	NAME OF THE MATERIAL	VON-MISES STRESSES		EQUIVALENT STRAINS		FACTOR OF SAFETY		TOTAL DEFORMATION		LIFE	
		MAX.	MIN.	MAX.	MIN.	MAX.	MIN.	MAX.	MIN.	MAX.	MIN.
1	STRUCTURAL STEEL	8.276e7	124.02	0.000413	6.2011e-10	15	1.0416	0.000138	0	1e6	1e6
2	STRUCTURAL STEEL EN45	1.9904e8	15483	0.000975	7.589e-8	15	0.433	0.000179	0	1e6	26093
3	CAST IRON	8.78e7	4.7214	0.000493	2.6525e-11	15	0.981	0.000156	0	1e6	8.995e5
4	ALUMINUM	8.26E+07	15483	0.0011982	2.580e-7	15	0.0011982	0.00040153	0	1e6	1.00E+06

Table 7.1 - Values forVon-mises stresses, strains, factor of safety , total deformation and overall life for chosen materials.Table 7.1 - Values forVon-mises stresses, strains, factor of safety , total deformation and overall life for chosen materials.

After analyzing all the readings, we found that a big weight reduction can be done using aluminum alloy instead of gray cast iron for manufacturing of connecting rod

$$weigt\,reduction = \frac{mass\ of\ \ using\ gray\ cast\ iron - mass\ of\ usin\ alluminum\ alloy}{mass\ of\ connecting\ rod\ using\ gray\ cast\ iron}$$

$$\%reduction = \frac{0.29054 - 0.10971}{0.29054} * 100$$

$$= 62.2\%$$

VIII. CONCLUSION

Its been observed that the greater part of the uniting bar of IC Engine are made of Cast iron .Yet on correlation of distinctive materials for comparable limit conditions & stacking conditions its been watched that out of the three materials Aluminum combination is the most suitable material on the premise of Anxiety, Security element, Life, Warm Resistivity, exhaustion & harm on the grounds that such connecting rod does not falls flat even at different burdens not at all like Cast iron bar. What's more by utilizing aluminum compound we can additionally decrease the weight of the connecting rod. Thus improving the outline of the interfacing bar.

Titanium composite are likewise utilized within High velocity engines where expense is not contemplated. As titanium is additionally among the arrangement of better material for connecting rod however it likewise builds the general expense of the outline. From the equal anxiety examination it is watched that the territory near foundation of the more diminutive end is extremely inclined to failure, may be because of higher pounding load because of gudgeon stick get together.

As the anxiety quality is greatest around there and burdens are dreary in nature so risks of exhaustion failure are constantly higher near this locale It is likewise watched that the base hassles among all stacking conditions, were found at wrench end top and also at cylinder end. So the material might be diminished from those segments, in this manner diminishing material expense. For further streamlining of material element dissection of interfacing bar is required.

REFERENCES

1. P.S Shenoy, et al "Dynamic Analysis Of Loads and Stresses in Connecting Rods" , J.Mechanical Engineering Science,Vol.220, pp.615-624 , 2006.

2. T.G.Thomas et al"Design of Connecting Rod for Heavy Duty Applications Produced by Different Processes for Enhanced Fatigue Life", SASTECH Journal Volume 10, Issue 1, May 2011.

3. James.R.Dale "Connectin Rod Evaluation" Metal Powder Industries Federation, Jan-2005

4. Sasi Prabhala, et al , "Design and Weight Optimization Of IC Engine" , International Journal Of Advanced Engineering Research and Studies , Vol.2 , Issue.1 , pp. 56-58 , 2012.

5. A.R Bhagat et al "Thermal Analysis & Optimization Of IC Engine Piston using FEM" International Journal Of Modern Engineering Research, Vol.2, Issue.4, pp.2919-2921, 2010.

6. P. Brabec et al "FEM ANALYSIS OF CONNECTING ROD FOR STATIONARY ENGINE" XIII. International Scientific Meeting Motor Vehicles & Engines, Kragujevac 2004. Serbia ISSN 0352 292X.

7. T.T.Mon et al "Finite Element Analysis on Thermal effect of Vehicle Engine ", Proceedings of MUCEET2009 Malaysian Technical Universities Conference on Engineering and Technology, June 20~22, 2009.

8. Vivek C Pathade.et al "Stress Analysis of IC Engine Connecting Rod by FEM", ISSN 2277-3754 International Journal of Engineering and Innovative Technology (IJEIT) Volume 1, Issue 3, March 2012.

9. Ramanpreet Singh "STRESS ANALYSIS OF ORTHOTROPIC ANDISOTROPIC CONNECTING ROD USING FINITEELEMENT METHOD,International Journal of Mechanical Engineering & Robotics Research ISSN 2278 – 0149, Vol. 2, No. 2, April 201.

10. Prof. N.P.Doshi et al "Analysis of Connecting Rod Using Analytical and Finite Element Method", International Journal of Modern Engineering Research (IJMER), pp-65-68 ISSN: 2249-6645, Vol.3, Issue.1, Jan-Feb. 2013.

11. Om Parkash et al " Optimizing the Design of Connecting Rod under Static and Fatigue Loading", International Journal of Research in Management, Science & Technology (E-ISSN: 2321-3264), Vol. 1; No. 1, June 2013.

12. A. M. Heyes, "Automotive Component Failures" Engineering Failure Analysis, Elsevier Science Ltd, Vol.5, No.2 pp.129-141, 1998.

13. F.S.Silva, "Analysis of a vehicle crankshaft failure" Engineering Failure Analysis, Vol.10, pp. 605–616, 2003.

14. F.S.Silva, "Fatigue on engine pistons – A compendium of case studies" Engineering Failure Analysis,Vol.13 pp.480–492, 2006.

15. A. Mirehei et al "Fatigue analysis of connecting rod of universal tractor through finite element method (ANSYS)" , Journal of Agricultural Technology 2008, V.4(2): 21-27.

16. Gudimetal P. et al"Finite Element Analysis of Reverse Engineered Internal Combustion Engine Piston", AIJSTPME (2009) 2(4): 85-92

17. Sanjay B Chikalthankar et al"FEA Analysis of Geometric Parameters of connecting rod big end", ISSN 0975-5462 ,Vol.04, No.04, April 2012.

ISSN : 2456 - 6411

Study of Structural Properties of Co1+xZrxFe2-2xO4 Spinel Ferrite

Dr. Jairam B. Mote1, Dr. Pravin K. Gaikwad2 *
1Department of Chemistry, Adarsh College, Omerga, Osmanabad, Maharashtra, INDIA
2Department of Physics, Shri Chhatrapati Shivaji College, Osmanabad, Maharashtra, INDIA

ABSTRACT

Nanocrystalline Co1+xZrxFe2-2xO4 with different compositions with x = 0.0, 0.1, 0.2, 0.3, 0.4, 0.5 and x = 0.6 were efficiently prepared by sol-gel self-combustion. Citric acid served as fuel and metal nitrates were AR grade. X-ray diffraction results showed that a single-phase cubic spinel structure was produced. The crystallite size, lattice constant, and X-ray density are all within the above limits. The crystallite size supports the nanocrystallinity of the material. Porosity increases because the bulk density is much lower than the X-ray density. The cation distribution results indicate that the cobalt ferrite sample has an inverse spinel structure, with Zr4+ ions occupying [B] positions exclusively and Co2+ and Fe3+ ions occupying tetrahedral (A) and octahedral [B] positions, respectively. indicates possession.

Keywords – Cobalt Ferrite, Sol-gel auto Combustion, Structural Properties

1. INTRODUCTION

Due to the high surface to volume ratio of nanosize spinel ferrites, which makes them helpful in the applications of field of imaging and treatment [5, 6], drug delivery [7], catalyst [8], etc., extensive study has been carried out on them in recent years. The accommodation of a range of cations at their interstitial sites, tetrahedral (A) and octahedral [B] sites, is what gives spinel ferrites their significant uses. To highlight variations in electrical and magnetic characteristics, the spinel lattice can additionally integrate the divalent, trivalent, and tetravalent cation. The synthesis process, circumstances, and parameters as well as the nature and type of the substituent and the cation distribution all have an impact on the characteristics of ferrite materials [9].All of these factors may be quite important in modifying the electrical and magnetic characteristics that are beneficial for the intended uses. The sol-gel auto combustion process is the most widely utilized wet chemical technique for the manufacture of nanoscale spinel ferrite. This approach is popular because it offers several benefits over other methods, including good chemical homogeneity, low processing temperature, and the ability to adjust the size, morphology, and other characteristics of the particles. Cobalt ferrite, a cubic spinel ferrite [10], has become the most well-known of these magnetic nanoparticles because of its strong coercivity (Hc), moderate saturation magnetization (Ms) [11, 12], good chemical stability, and high mechanical hardness [13].

Divalent cations are often substituted to change the characteristics of cobalt ferrites [14, 15]. There haven't been many reports in the literature about the impact of substituting trivalent ions and tetravalent ions on the fundamental electrical and magnetic characteristics of cobalt ferrites. The structural, electrical, and magnetic characteristics of zirconium-substituted cobalt ferrite Co1+xZrxFe2 2xO4 (x = 0.0, 0.1, 0.2, 0.3, 0.4, 0.5, and 0.6) were examined in the current work. Zirconium is mostly employed as a refractory and an opacifier, but due to its great corrosion resistance, it is also utilized in tiny amounts as an alloying agent. Additionally, it has uses in biomedicine [16]. Here, we present the structural characteristics of a cobalt ferrite system swapped with zirconium.

2. EXPERIMENTAL TECHNIQUES

2.1. Synthesis: Citric acid was used as a fuel in the sol-gel auto combustion process to create Co1+xZrxFe2-2xO4 (x = 0.0, 0.1, 0.2, 0.3, 0.4, 0.5, and 0.6) nanoparticles. Cobalt nitrate (Co(NO3)2.6H2O), zirconium nitrate (ZrO(NO3)2), ferric nitrate (Fe(NO3)3.9H2O) (C6H8O7.H2O). Cobalt ferrite nanoparticles were created using just analyticalgrade chemicals that were employed directly after being received. Metal nitrates were added to fuel (citric acid) in separate glass beakers in the ratio of 1:3 according to stoichiometry. These were thoroughly dissolved into distilled water after being agitated for 15 to 20 minutes. They were combined once they had fully dissolved. To get the solution's pH value closer to 7 and stabilize the nitrate-citric acid solution, ammonia was gradually added to the mixture. Then for 6 hours on a hot plate, the neutralized solution was continuously magnetically stirred. The temperature was increased further to 1200C after the production of sol-gel, an extremely viscous gel, in order to initiate the ignition of the dry gel and ultimately produce powder. The loose cobalt ferrite powder was ground for 30 minutes before being annealed in a muffle furnace for 6 hours at 600oC.

2.2. Characterizations: Zirconium replaced cobalt ferrite samples were created in the current work using the sol-gel auto combustion process, and they were then examined using X-ray diffraction. All of the samples' X-ray diffraction patterns were captured using a RegakuMiniflex II X-ray powder diffractometer running at 40kV and 30mA. Using Cu-K radiation with a wavelength of 1.5406 nm, the diffraction pattern was observed in the 2 range of 200 to 800. From the X-ray diffraction examinations, many structural characteristics including lattice constant, hopping length, particle size, X-ray density, porosity, and cation distribution were estimated.

3. RESULT AND DISCUSSION

3.1 Structural Properties:

X-ray diffraction: The produced samples of theCo1+xZrxFe2-2xO4(x = 0.0, 0.1, 0.2, 0.3, 0.4, 0.5 and 0.6) system were characterized using the X-ray diffraction method. The X-ray diffraction (XRD) patterns for the Co1+xZrxFe22xO4(x = 0.0, 0.1, 0.2, 0.3, 0.4, 0.5 and 0.6) system are shown in Fig. 1. Each XRD pattern exhibits well defined reflections that are part of the cubic Spinel structure. Figure 1 shows the Co1+xZrxFe2-2xO4XRD pattern. The XRD pattern's reflection peaks were all indexed using Bragg's law. The cubic spinel structure of all the samples is shown by the presence of planes (220), (311), (222), (400), (422), (511) and (440) in the XRD pattern. It is also obvious that each and every reflection peak is strong and distinct. Since there were no impurity peaks seen, the samples are single-phase in nature.

Lattice constant

Using the usual relation, the Lattice constant (a) calculated for samples of zirconium-substituted cobalt ferrite.

$$a = d\left(\sqrt{h^2 + k^2 + l^2}\right)\text{-}1$$

Where,(h k l) is Miller Indices; (d) is interplanar spacing.

Table 1 lists the calculated lattice constant values (a). Considering the replacement of zirconium for cobalt and ferrous in the current ferrite system, the lattice constant gradually increases. Figure 2 depicts the fluctuation of the lattice constant a function of zirconium content x. The ionic radii of the component ions Zr4+, Co2+, and Fe3+may be used to understand the rise in lattice constant with zirconium concentration x. In the present system, Co2+ and Zr4+ions take the place of two Fe3+ ions. The ionic radii of Co2+ and Zr4+are 0.82 and 0.72, respectively, which is much bigger than the ionic radius of two Fe3+(0.64) ions. As a result, the current system's lattice constant rises. The change of the lattice constant with zirconium is comparable to what has been described before [17].

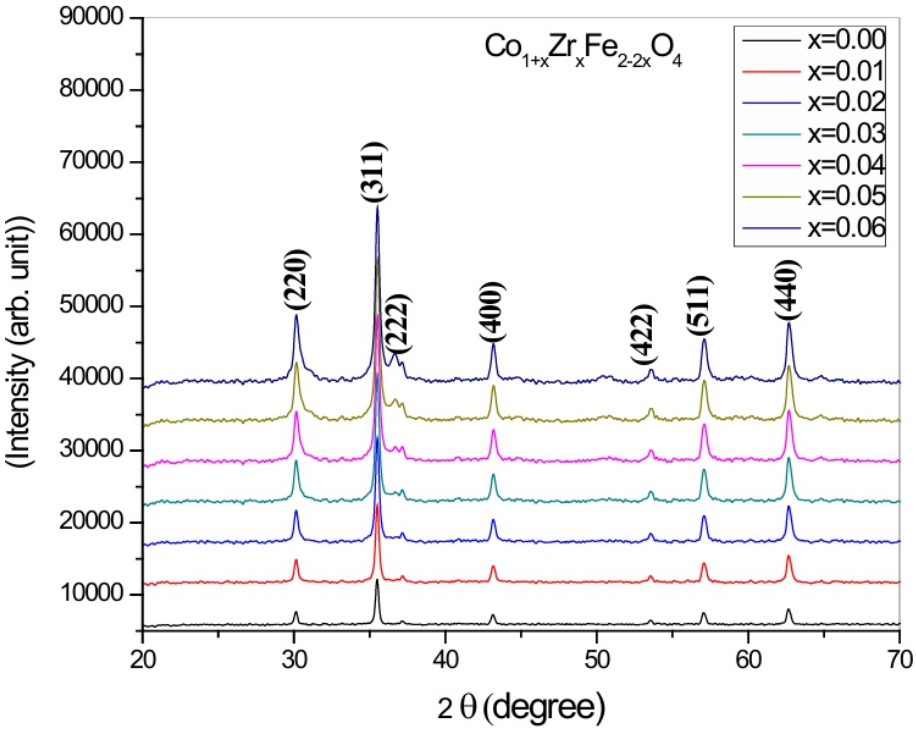

Fig.1: XRD pattern of Co1+xZrx Fe2-2x O4

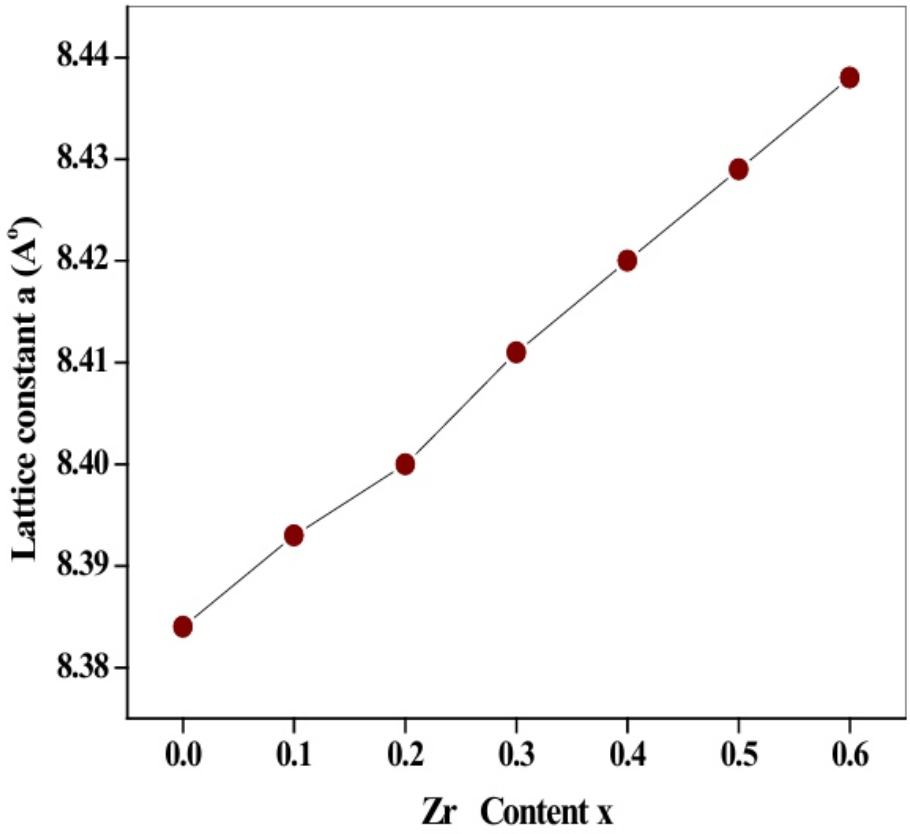

Fig.2: Variation of the ferrite system's lattice parameter "a" with respect to its Zr content "x" Co1+xZrx Fe2-2xO4 (x = 0.00, 0.10, 0.20, 0.30, 0.40, 0.50 and 0.60)

Unit cell volume: The equation was used to compute the unit cell volume (V),

V= a3

-2

Where, a is the lattice constant; V is the unit cell volume.

With the replacement of zirconium for cobalt and ferrous in the current ferrite system, the unit cell volume (V) gradually increases. The rise in cell volume is related to an increase in the system's lattice constant.

X-ray density: The X-ray density (dX) was determined using the relationship, and the results are shown in Table 1.

$$d_X = \frac{ZM}{VN_A}\ gm/cm^3$$

-3

Where, NA is the Avogadro's number,

Z is the number of molecules per unit,

(Z = 8 for spinel system),

M is molecular mass of the sample,

V= a3is the unit cell volume.

Table 1 shows that as zirconium concentration of x increases, so does X-ray density. The rise in X-ray density might be a result of an increase in molecular weight / mass that outnumbers the increase in volume. Both unit cell volume and molecular weight grow in the current system. Figure 3 depicts the fluctuation of X-ray density with zirconium content x, which rises with increasing zirconium content x.

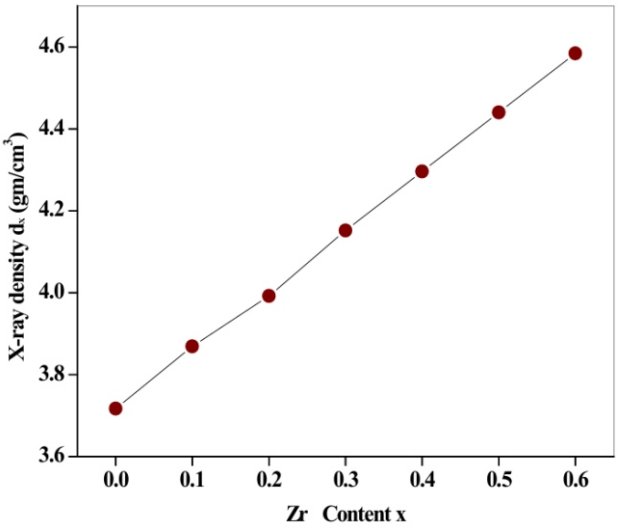

Fig. 3: Variation of the ferrite system's Zr content with respect to the X-ray density (dX) Co1+xZrx Fe2-2x O4 (x = 0.00, 0.10, 0.20, 0.30, 0.40, 0.50 and 0.60)

Bulk density

Using toluene as an immersion solvent, the bulk density of the current sample has been calculated using the Archimedes principle. Table 1 displays the bulk density data. Table 1 shows that, like X-ray density, with increasing zirconium concentration x, bulk density rises. The bulk density is observed to rise as the zirconium concentration of x increases. Fig.4 depicts the change in bulk density with zirconium content x.

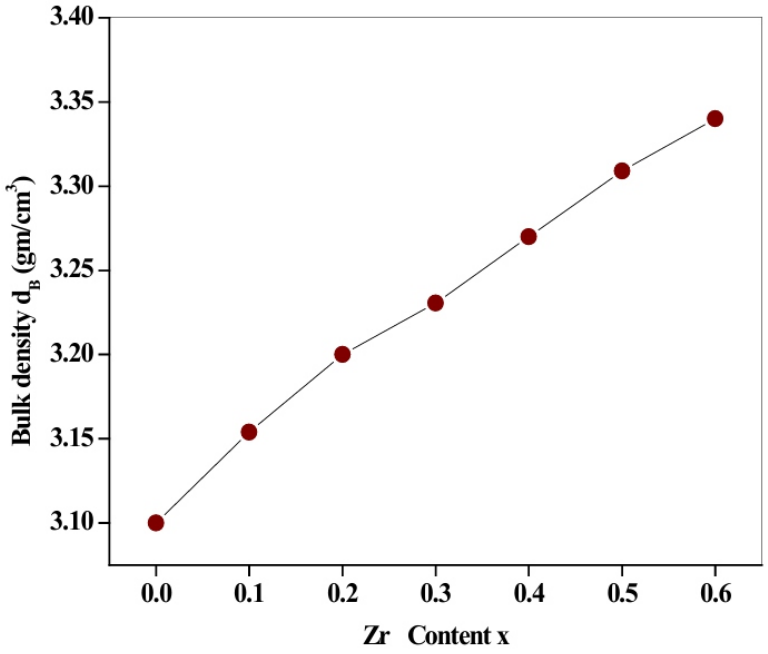

Fig.4: Variation of the ferrite system's bulk density (dB) with respect to Zr content (x) Co1+xZrxFe2-2xO4 (x= 0.0, 0.10, 0.20, 0.30, 0.40, 0.50, 0.60)

Porosity

By using the X-ray density (dx), the porosity (p) and the bulk density (dB), of the zirconium replaced cobalt ferrite was calculated by the following equation:

$$P = 1 - \frac{d_B}{d_X} \quad \%$$

-4

Figure 5 depicts the fluctuation of % porosity with regard to zirconium content x. The graph shows that zirconium content increases with percentage porosity x. The porosity of the current sample ranges between 16% to 26%

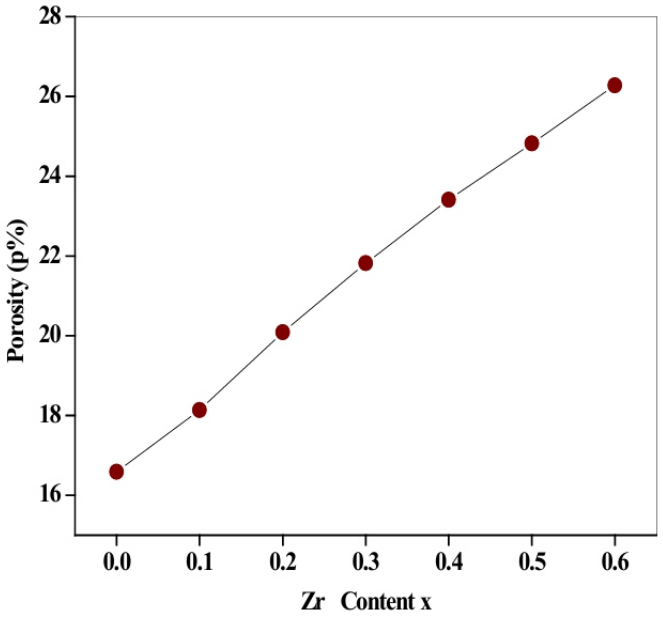

Fig. 5: Variation in the ferrite system's Zr content (x) and percentage porosity (P%) Co1+xZrxFe2-2x O4 (x = 0.00, 0.10, 0.20, 0.30, 0.40, 0.50, 0.60)

The obtained structural parameter values like bulk density, lattice constant, X-ray density, percentage porosity and molecular weight are tabulated in Table 1.

Table 1: Bulk density (dB), X-ray density (dx), Lattice parameter (a), Volume (V),Porosity (P %), and Molecular weight of Co1+x ZrxFe2-2x O4 system

Composition 'x'	A (Å)	d_x (gm/cm^3)	d_B (gm/cm^3)	P %	V ($Å^3$)	Mol. wt. gm/mol
0.00	8.384	3.717	3.10	16.59	589.32	234.61
0.10	8.393	3.869	3.18	17.80	591.22	238.46
0.20	8.40	3.917	3.20	18.30	593.13	242.28
0.30	8.411	4.152	3.22	22.44	595.04	246.15
0.40	8.42	4.296	3.27	23.88	596.95	250.01
0.50	8.429	4.440	3.32	25.22	598.86	253.84
0.60	8.438	4.584	3.36	26.69	600.78	257.69

Using lattice constant values (a), the various additional structural parameters such as tetrahedral bond length (dAX), hopping lengths (LA, LB), tetra edge (dAXE), octahedral bond length (dBX), and octaedge (dBXE) were determined for each sample using the conventional relations presented below. [18].

$$L_A = \frac{a\sqrt{3}}{4} \quad -5$$

$$L_B = \frac{a\sqrt{2}}{4} \quad -6$$

$$d_{AX} = a\sqrt{3}(u - \tfrac{1}{4}) \quad -7$$

$$d_{BX} = a\left[3u^2 - \left(\tfrac{11}{4}\right)u + \left(\tfrac{43}{64}\right)\right]^{\frac{1}{2}} \quad -8$$

$$d_{AXE} = a\sqrt{2}(2u - \tfrac{1}{2}) \quad -9$$

$$d_{BXE} = a\sqrt{2}(1 - 2u) \quad -10$$

$$d_{BXU} = a[4u^2 - 3u + (\tfrac{11}{16})]^{\frac{1}{2}} \quad -11$$

Table 2 shows the values of all of these structural characteristics. Because these characteristics are dependent on the lattice constant, their values increase as the zirconium content x increases. As the lattice constant of the current system grows, so do these properties.

Table 2: Hopping length (LA, LB), Octahedral bond(dBL), Tetrahedral bond (dAL), Tetra edge (dAE) and Octa edge (dBE) of Co1+x ZrxFe2-2x O4 system

Composition 'x'	L_A (Å)	L_B (Å)	d_{AL} (Å)	d_{BL} (Å)	d_{AE} (Å)	d_{BE} (Å)	L_A (Å)
0.00						Shared	Unshared
0.10	3.630	2.964	1.902	2.051	3.106	2.822	3.630
0.20	3.634	2.967	1.904	2.053	3.110	2.825	3.634
0.30	3.638	2.971	1.906	2.055	3.113	2.828	3.638
0.40	3.642	2.974	1.908	2.057	3.116	2.831	3.642
0.50	3.646	2.977	1.910	2.060	3.120	2.834	3.646
0.60	3.650	2.980	1.912	2.062	3.123	2.837	3.650

Particle size

Using the strongest peak (311), as well as the Debye-ratio Scherer's for small and uniformly sized cubic crystals [19], which is mentioned below, the zirconium substituting cobalt ferrite powders particle size was estimated.

$$t = \frac{0.9\lambda}{\beta \cos\theta} \text{ nm} \qquad -12$$

Where, λ is wavelength of the Cu-Kα radiation,

θ is Bragg's angle,

β is the full width of the half maximum.

The obtained values of the particle size are presented in Table 3. The average particle size calculated by Debye Scherer's formula is of the order of 7 - 26 nm.

Table 3: Ionic radii (rA, rB) and Theoretical lattice parameter (ath) of Co1+xZrx Fe2-2x O4 system

Composition 'x'	r_A (Å)	r_B (Å)	a_{th} (Å)
0.00	0.582	0.726	8.360
0.10	0.584	0.728	8.414
0.20	0.586	0.730	8.440
0.30	0.588	0.732	8.470
0.40	0.590	0.734	8.510
0.50	0.592	0.737	8.540
0.60	0.595	0.739	8.570

Tetrahedral ionic radius

Using the oxygen positional parameter 'u' (u = 0.381)and the lattice constant value 'a', the tetrahedral A-site ionic radii may be determined as follows:

$$r_A = \left(u - \frac{1}{4}\right) a\sqrt{3} - r\left(O^{2-}\right) \text{Å} \qquad -13$$

Where ,rA represents radius of tetrahedral (A) site cation

r(O)- represents radius of oxygen anions.

u- Oxygen positional parameter

Theoretical lattice parameter

The theoretical lattice parameter may be computed applying the subsequent relationship, which connects the Radius of cations component elements at the various lattice locations to the lattice parameter [20]:

Table 3 shows the tetrahedral ionic radius values, which rises with increasing zirconium concentration x.

Ionic radius of octahedron

The octahedral B-site ionic radii can use the equation to compute:

$$r_B = \left(\frac{5}{8} - u\right)a - r\left(O^{2-}\right) \quad \text{-14}$$

Where, rB represents radius of octahedral [B] site cation

The values of octahedral ionic radius are given in Table 3 and It is discovered that it grows as the zirconium content x rises.

$$a_{th} = \left(\frac{8}{3\sqrt{3}}\right)\left(r_A + R_0\right) + \sqrt{3}\left(r_B + R_0\right) \quad \text{-15}$$

Where, rA is tetrahedral site radius

R0 is the radius of oxygen ion

rB is the octahedral site radius

Fig. 6 represents the variation of experimental and theoretical lattice constant as a function of zirconium content x.

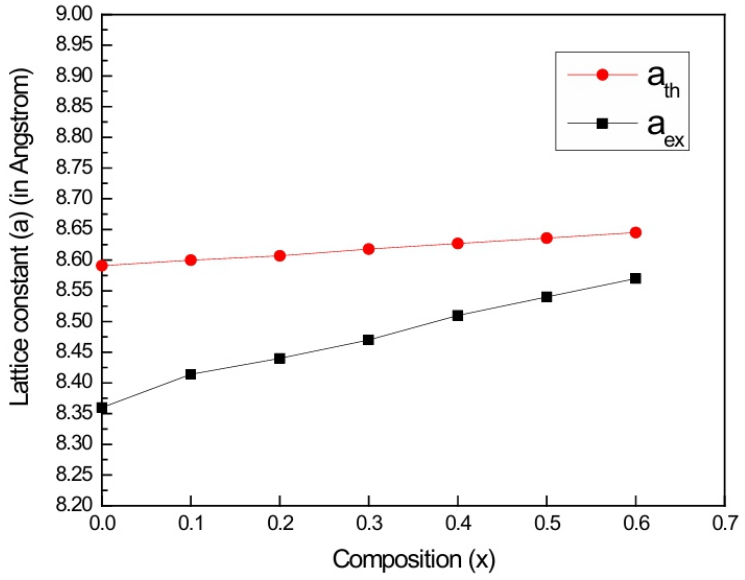

Fig. 6: Variation of experimental (aex)& theoretical (ath) lattice ConstantofCo1+x ZrxFe2-2xO4system

Figure 6 illustrates that the experimental and theoretical lattice constants have different values. The experimental and theoretical lattice constants differ because theoretical the lattice constant was calculated using the hypothesized cation distribution, which is predicated on specific assumptions.

CATION DISTRIBUTION

The distribution of cations in spinel ferrites may be determined using the XRD technique. Bertaut[21], Furuhashi et al.[22], and Rfactor[23] present techniques for comparing experimentally observed and computed diffraction intensities for an extensive class of fictitious crystal structures. Neutron diffraction [24], electron spin resonance [25], nuclear magnetic resonance [26], thermoelectric method [27], and Mossbauer technique [28] may all be used to investigate the distribution of cations in spinel ferrites.

The cation distribution of the current system was determined using the Bertaut technique based on XRD in this study. In this method few pairs of reflections were selected which are sensitive to cation distribution and intensity of that reflection were calculated. Then the ratios were taken for the selected plane reflections. The computed and actual intensity ratios were compared, and a distribution factor was included using expression [29].

$$R = \left| \frac{I_{obs}^{hkl}}{I_{obs}^{h'k'l'}} - \frac{I_{cal}^{hkl}}{I_{cal}^{h'k'l'}} \right| \quad \text{-16}$$

Where, I_{obs}^{hkl} the observed intensities for reflection (h k l)

$I_{obs}^{h'k'l'}$ the observed intensities for reflection (h'k'l')

I_{cal}^{hkl} the calculated intensities for reflection (h k l)

$I_{cal}^{h'k'l'}$ the calculated intensities for reflection (h'k'l')

The observed and estimated intensity ratios are compared for various cation distributions at tetrahedral and octahedral sites based on their site preferences. The tiny value of the agreement factor (R) in this approach is a sign of the trustworthiness of the results and may be viewed as the system's probable cation distribution. This contains sensitive information on cation distribution is obtained by examining experimental and estimated intensity ratios for reflective surfaces whose values(I) are nearly entirely independent of the oxygen component, (ii) change rapidly with the cation distribution in different directions, and (iii) do not differ substantially, the best information on cation distribution is obtained. The reflections that are most suited for cation distribution investigations are (220), (400), and (422).

Furthermore, for the determination of I_{cal}^{hkl} , a

value of the oxygen parameter (u) must be assumed. Table 4 illustrates the estimated cation distribution for the current ferrites system.

Table 4: Cation distribution of Co1+x ZrxFe2-2xO4 (x = 0.0, 0.1, 0.2, 0.3, 0.4, 0.5, 0.6) System

Composition 'x'	**Cation distribution**	**Cation distribution**
	A-site	B-Site
0.00	$(Co_{0.05}Fe_{0.95})^{A}$	$[Co_{1.05}Fe_{0.95}]^{B}$
0.10	$(Co_{0.15}Fe_{0.85})^{A}$	$[Co_{1.05}Zr_{0.2}Fe_{0.75}]^{B}$
0.20	$(Co_{0.25}Fe_{0.75})^{A}$	$[Co_{1.05}Zr_{0.3}Fe_{0.65}]^{B}$
0.30	$(Co_{0.35}Fe_{0.65})^{A}$	$[Co_{1.05}Zr_{0.4}Fe_{0.55}]^{B}$
0.40	$(Co_{0.45}Fe_{0.55})^{A}$	$[Co_{1.05}Zr_{0.5}Fe_{0.45}]^{B}$
0.50	$(Co_{0.55}Fe_{0.45})^{A}$	$[Co_{1.05}Zr_{0.6}Fe_{0.35}]^{B}$
0.60	$(Co_{0.65}Fe_{0.35})^{A}$	$[Co_{1.05}Zr_{0.7}Fe_{0.25}]^{B}$

Table 4 shows that cobalt ions encircle octahedral (B) and tetrahedral (A) positions in all samples. Ferric ions were discovered to be distributed on both the octahedral [B] and tetrahedral (A) sites, whereas zirconium ions occupied exclusively the octahedral [B] sites. The intensity ratios for the sensitive planes (220), (400), and (440) were computed using the cation distribution data (Table 4). Table 4 displays the observed and computed intensity ratio values.

Table 5: X-ray intensity ratios observed and calculated of Co1+x ZrxFe2-2xO4 (x = 0.0, 0.1, 0.2, 0.3, 0.4, 0.5, 0.6) system

Composition 'x'	**I(220)/I(400)**	**I(220)/I(440)**	**I(400)/I(440)**

	Obs.	Cal.	Obs.	Cal.	Obs.	Cal.
0.00	1.12	1.33	0.22	0.21	0.532	0.459
0.10	1.31	1.35	0.70	0.61	0.53	0.45
0.20	1.17	1.36	0.74	0.62	0.64	0.46
0.30	2.39	1.37	1.002	0.63	0.42	0.46
0.40	2.17	1.38	1.17	0.63	0.54	0.45
0.50	3.40	1.39	1.64	0.63	0.48	0.46
0.60	2.26	1.41	1.52	0.65	0.67	0.46

The oxygen positioning parameter (u), octahedral site radius (rB), tetrahedral site radius (rA), and theoretical lattice constant (ath) were computed from the cation distribution investigations and are hown in Table 5. Theoretical lattice constants are discovered to be greater than experimental lattice constants. The mismatch in theoretical and experimental lattice constants might be attributed to inaccurate cation distribution data. This suggests that the estimation of cation distribution using X ray intensity computation must be modified. The table shows that the octahedral radius (rB) and tetrahedral radius (rA) rise as zirconium concentration x increases.

4. CONCLUSION

The nanocrystal line Col+xZrxFe2-2x04 with x=0.0, 0.1, 0.2, 0.3, 0.4, 0.5, and x = 0.6 were successfully synthesized utilizing the sol-gel autocombustion approach with metal nitrates of AR grade. The results of XRD revealed the creation of an isolated cubic spinel structure. The X-ray density, crystallite size, and lattice constant, are all within the previously reported ranges. The crystallite size validates the materials nanocrystal line nature. X-ray density is less than the bulk density for this reason, porosity is enhanced. The cation distribution data show that Fe3+and Co2+ions encircle octahedral [B] and tetrahedral (A) sites, but Zr4+ ions encircle only the octahedral [B] site, suggesting that the cobalt ferrite sample has an inverse spinel structure.

REFERENCES

[1] G.Kumar, J.Chand, S.Verma,M.Singh,J. Phys. D. Appl. Phys. 42, 155001-155006 (2009).

[2] K.J.Standley, Oxide Magnetic Materials, Clarendon Press, Oxford, 1972.

[3] G.B.Kadam, S.B.Shelke, K.M.Jadhav, J. Electro. Electri. Engg. 1(1) (2010) 15.

[4] P. K. Gaikwad, S. S. Sawant and K. M. JadhavJ. Adv. App. Sci. Tech. Vol. 1. Issue 2 (2014) 35-37.

[5] J.Gao, H.Gu, B.Xu, Acc.Chem.Res.42 (2009) 1097-1107.

[6] M.Grigorova, H.J.Blythe, V.Blaskov, etal.J.Magn.Magn.Mater.183(1998) 163-172.

[7] Wu H., G.Liu, X.Wang, J.Zhang, Y.Chenet al., ActaBiomaterialia, 7 (2011) 3496-3504.

[8] P.Lahiri, S.K.Sengupta, CAN. J. Chem. Vol. 69(1991) 33-36.

[9] A.M.Shaikh, S.S.Bellad, B.K.Chougule, J. Magn. Magn. Mater. 195 (1999) 384.

[10] M. Grigorova, H.J.Blythe, V.Blaskov, et al. J.Magn.Magn.Mater.183 (1998) 163-172.

[11] L.J.Zhao, H.J.Zhang, Y.Xing, etal., J. Solid State Chem.181 (2008) 245-252.

[12] K.Maaz, ArifMumtaz, S.K.Hasanain, et al., J. Magn. Magn. Mater. 308 (2007) 289-291.

[13] D.Zhao, X.Wu, H.Guan, et al.,J.Supercrit.Fluids 42 (2007) 226-233.

[14] S.G.Algude, S.M.Patange, S.E.Shirsath, D.R.Mane, K.M.Jadhav, J. Magn. Magn. Mater. 350 (2014) 39-41.

[15] NallaSomaiah, Tanjore V. Jayaraman, P.A.Joy, Dibakar Das, J. Magn. Magn. Mater. 324:14 (2012) 2286-2291.

[16] P. K. Gaikwad Int. J. of Eng. Res. and Adv. Dev. Vol. 4, Issue 01 Jan (2018) 58-63.

[17] P. K. Gaikwad, S. S. Sawant Int. J. of Res. Thoughts Vol.10 Issue 01 Jan (2022)a585a592.

[18] S.E.Shirsath, B.G.Toksha, K.M.Jadhav, Mater. Chem. Phys. 117 (2009) 163.

[19] Y.H.Hou, Y.J.Zhao, Z.W.Liu, H.Y.Yu, X.C.Zhong, W.Q.Qiu, D.C.Zeng, L.S.Wen, J. Phys. D, 43 (2010) No. 44, 445003. [20] S.Thankachan, B.P.Jacob, S.Xavier, E.M.Mohammed J. Magn. Magn. Mater. 348 (2013) 140-145.

[21] L.Weil, E.F.Bertaut, L.Bochirol, J. Phys. Radium 11 (1950) 208.

[22] H.Furuhashi, M.Inagaki, S.Naka, J. Inorg. Chem., 35(1973) 3009.

[23] J.M.R.Gonzalez, C.O.Arean, J. Chem. Soc., Dalton Trans. (1985) 2155.

[24] U.Schmocker, H.R.Boesch, F.Waldner, Phys. Lett. 40 A (3) (1972) 237. [25] C.C.Wu, T.O.Mason, J. Amer. Ceram. Soc., 64 (9) (1981) 520.

[26] K.E.Sickafus, J.M.Wills, J. Amer. Ceram. Soc. 82(12) (1999) 329.

[27] E.Stall, P.Fischer, W.Halg, G.Maier, J. Phys. Paris.25 (1964) 447.

[28] Frauenfelder, H., The Mossbauer Effect, A Review with a Collection of Reprints (W. A. Benjamin, New York, 1963).

[29] Qiang-Min Wei, Jian-Biao Li, Yong-Jun Chen, J. Mater. Sci. 36 (2001) 5115.

ISSN : 2456 - 6411

Examining the Significance of Communication in the Context of Future Engineers: A Comparative Analysis

Intisar K. Saleh1
1Kirkuk Engineering Technical College/ Northern Technical University/ Iraq

ABSTRACT

The study looks at how engineering teams may use communication to innovate, emphasising how important it is to communicate throughout the project's ideation and implementation phases. It looks into how effective communication can encourage the exchange of ideas, spark creative thinking, and lead to the development of ground-breaking solutions for difficult technical challenges. The study also looks into how communication impacts project management practices, highlighting how crucial it is for setting clear objectives, monitoring due dates, and lowering risks. The research emphasises the critical relationship between communication skills and project performance in engineering pursuits by elucidating these connections. The ethical implications of communication in the engineering domain are also examined, with a focus on issues of honesty, integrity, and openness in interpersonal interactions. Through bringing these moral issues up in conversation, the study provides a thorough grasp of the function of communication in engineering practice and education. In order to cultivate a new generation of proficient communicators who will be able to foster innovation and growth in the sector, it also provides stakeholders in academia and industry with helpful ideas.

Keywords: Interprofessional teamwork, communication skills, engineering education, comparative analysis and future engineers.

1. INTRODUCTION

The world is experiencing extraordinary technology discoveries and societal upheavals that require engineers to manage them quickly. Engineers have a duty to provide innovative, sustainable solutions to challenging global problems, which calls for more than simply technical know-how[1]. On the other hand, effective communication is sometimes overlooked in the never-ending pursuit of technological expertise [2]. This neglect is especially concerning for upcoming engineers, who have to deal not only with the complexities of their respective areas but also with the challenges of problem-solving, innovation, and teamwork in a globalised society. In a time of rapid information sharing and interconnection, it is critical to be able to communicate concepts, work out agreements, and encourage interdisciplinary cooperation[3]. This study intends to close this crucial gap by carrying out a thorough comparative analysis of future engineers' communication skills, highlighting their significance in promoting initiatives for sustainable development across a range of cultural and geographic contexts and making a meaningful social impact. [4].

This research uses a comparative approach to study communication in order to identify the subtle differences in the ways that various engineering disciplines prioritise and use communication in their respective settings [5]. We aim to explain the differing levels of importance given to communication skills in various engineering domains through comprehensive empirical investigations that include surveys, interviews, observational studies, and in-depth case studies of well-known engineering projects and teams. Moreover, this investigation seeks to identify the changing communication landscape within the engineering profession by utilising comparative frameworks that consider cultural, organisational, and technological aspects [6-7]. Furthermore, the study explores the significance of interdisciplinary cooperation and the incorporation of varied viewpoints in augmenting communication efficiency in engineering groups. Further, this study aims to offer thorough insights into the intricate dynamics of communication in engineering contexts by examining the effects of globalisation and digitalization on engineering communication practices, including the adoption of virtual communication tools and the difficulties presented by linguistic and cultural differences [8].

By highlighting the crucial role that communication plays in determining the competences, success, and societal influence of future engineers, this study ultimately hopes to offer educators, practitioners, and policymakers useful insights. [9-10]. By doing this, we seek to promote a better awareness of the relationship between technical proficiency and effective communication, enabling the following generation of engineers to meet the opportunities and overcome the problems of a constantly changing environment [11].

2. LITERATURE REVIEW

As engineering advances, prospective engineers are realising that concentrating solely on technical and scientific courses would not adequately educate them for the range of challenging issues they will face. They are aware that effective communication skills are necessary for both creativity and efficient problem-solving [12]. Although engineering education has always followed a linear framework, courses now place a greater emphasis on foundational knowledge before delving into more complex and specialised subjects. This change reflects an appreciation for the significance of communication when using technical expertise [13]. It emphasises how important it is to ensure that engineers possess not only highly developed technical abilities but also the ability to communicate clearly, collaborate well with others, and adapt to changing environments.

This study is to assess students' impressions as well as understand the perspectives of educators and administrators involved in delivering softwarespecific courses. Through the use of surveys and

interviews with faculty members and educational administrators, the study hopes to get comprehensive insights on the planning, implementation, and assessment of communication components within these courses [14]. The study also looks into the barriers and challenges that educators and learners can run into when integrating communication skills into courses that focus a lot on software. This means examining elements that may impact the effectiveness of communication training in technical settings, such as pedagogical tactics, cultural considerations, and resource constraints. In order to identify potential for innovation and improvement in software-related education programmes, the study also examines how well course objectives, industry requirements, and students' career ambitions correspond. In order to better prepare students for success in the rapidly evolving technological environment, the study aims to support ongoing efforts to raise the quality and apply ability of software-specific courses through a thorough analysis of these aspects.

The impact of communication skills on the future career paths of civil engineering students is examined in this recent Australian study by Maryam Khosronejad and Rafael A. Calvo. In order to properly prepare students for the changing needs of the labour market, the research emphasises the significance of these abilities and makes a strong case for a complete curriculum redesign [15]. Noting that good communication requires more than just proficient writing, the emphasis is on addressing the essential soft skills that businesses are starting to value more and more. Although writing skills are highly regarded in the engineering department, Khosronejad and Calvo point out a hole that needs to be remedied. Their research suggests that developing communication skills should entail more than simply conventional techniques; in particular, they advise incorporating online communication technology. These resources offer engineering students a convenient and helpful setting for honing their communication skills because they are already familiar with them. This intentional use of technology aims to provide students with a wide variety of abilities required for success in the civil engineering business by bridging the gap between academic preparation and practical professional expectations [16].

Graduating students now need to have a different set of skills because of globalisation and Industry 4.0. Language fluency abroad, quick and effective communication skills, the ability to work well in a team, and great time management are a few of these. University courses are being adjusted in response to employers' growing demand for these abilities. But there's still a big problem: a lot of students choose technical disciplines over electives and underestimate the significance of these talents. Studies investigating engineering students' views on the importance of these competencies highlight a critical deficiency, especially with relation to oral communication skills. Research also assess a variety of competences, including communication, cooperation across disciplines, environmental awareness,

professionalism, and lifelong learning. Regrettably, research continually shows that engineering students lack soft communication abilities, which has led scholars to call for targeted educational programmes [17]. "The research findings from the previous year, which were based on an extensive study with a diverse cohort of students, clearly indicated a prevalent sentiment among participants about the perceived insignificance of technical language and managerial communication courses. Students from a variety of academic backgrounds shared the opinion that having these skills would not be very beneficial in the long run for them if they wanted to pursue careers in technology. In spite of this belief, proactive steps were made to improve instructional strategies, which are carefully described in a later study [18]. Additionally, a number of events where the interview approach was carefully utilised were made possible by cooperative efforts with human resource specialists in several industry sectors. The ensuing information absolutely confirmed the claim that soft skills are becoming more and more important in a constantly changing work environment. Even in light of this data, a sizable segment of the student body is still dubious, if not downright doubtful, regarding the real worth of these competences. Remarkably, more thorough examination of earlier study results revealed a common pattern across students: a considerable proportion tended to choose technical career routes mainly because of fears related to social interaction [19]. As a result, they frequently place more value on gaining advanced technical knowledge than they do on the transforming power of soft skills to improve employability, interview performance, and career progression opportunities."

3. THE RESEARCH METHOD

The study's parameters included the following:

- Students from UMFST's Faculty of Engineering who have finished courses in Managerial and Technical Language Communication make up the target group.
- 66 engineering students serve as samples.
- The type of sampling is ad hoc.
- The participants were chosen by using targeted outreach tactics to distribute the questionnaires to a wide range of potential respondents via professional networks and different internet platforms.

Our study is to explore the unique opportunities and problems experienced by engineering students in developing communication skills across varied cultural and educational contexts, in addition to focusing on a representative sample of students worldwide who are affiliated with ESTIEM. We want to incorporate institutional and geographical distinctions in communication education, as we acknowledge their significance in this regard [20]. Also, given the growing importance of remote work arrangements and virtual cooperation in the engineering industry, we will investigate how technology plays a part in

the development of communication skills. We seek to discover optimal methods for incorporating digital tools into engineering communication courses efficiently by investigating the interface between technology and communication pedagogy. In addition, by looking at variables such participant work satisfaction, pay advancement, and job placement rates, our study aims to evaluate the long-term effects of communication training on students' career paths and professional growth. Our goal with this multipronged approach is to offer thorough insights that will guide educational policies as well as industry standards for engineering communication competencies [21-22]. Depending on the purpose of the research and of the literature, the structure of the questionnaire was designed to validate the following assumptions:

- **H01:** Among the different interpersonal skills taught in communication courses, the ability to work well in multicultural teams stands out as the most important and demanding.
- **H02:** Systemic skill development is emphasised in communication courses, with a special emphasis on the capacity to manoeuvre and adjust to novel circumstances.
- **H03:** The foundation for developing systemic abilities in aspiring engineers is effective communication.
- **H04:** A vast majority of students recognise the importance of effective communication in all forms—written, spoken, and nonverbal— as a crucial factor in obtaining jobs and developing a career in engineering.
- **H05:** According to students' perspectives, passive listening has little impact on one's ability to master technical communication;instead, the need of information structuring is emphasised.

4. FINDINGS

Incorporating further data points into the graphical representation allows us to further deepen our study. These include quantitative data from courses and instructors as well as qualitative comments, academic success indicators, and student happiness scores. Our goal in combining these disparate data sets is to offer a thorough assessment of how the new teaching approaches have affected different facets of the communication courses and their results. The comparison analysis provides important insights into the efficacy and effectiveness of the modifications that were implemented over the research period, and we also highlight any noteworthy trends or patterns that come out of it.

Public speaking is important for engineering careers, as Figure 1 highlights the importance of intra-group communication as the most developed talent, with mass communication coming in second. A significant factor in the increased focus on intra-group communication seen in this study was the

inclusion of group games and activities that promote mutual understanding among group members. The results presented in Figure 2 therefore confirm our hypothesis H01, which states that among the interpersonal skills taught in communication courses, the ability to work well in multicultural teams is the most important and difficult to master.

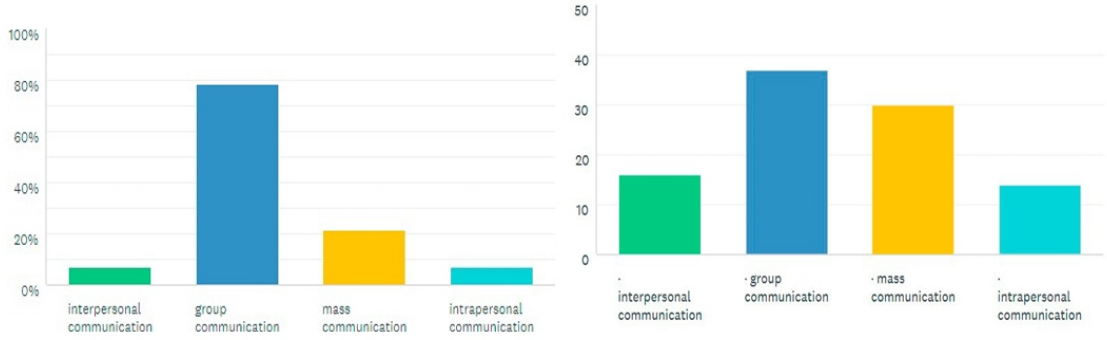

Fig. 1. Types of communication and communication skills.

In the category of systemic skills, technological competence is becoming more and more valued, especially when it comes to using communication platforms and tools for collaboration and project management. Plus, in today's engineering contexts, knowing how to use and navigate digital resources for research and data analysis is becoming more and more important. This fusion of conventional project management abilities with technical knowhow highlights how systemic capabilities, which are necessary in contemporary engineering practice, are changing. This comprehensive approach to systemic skills, as shown in Figure 2, is a dynamic reaction to the demands of the digital age, where obtaining the best project outcomes requires both technological proficiency and effective communication.

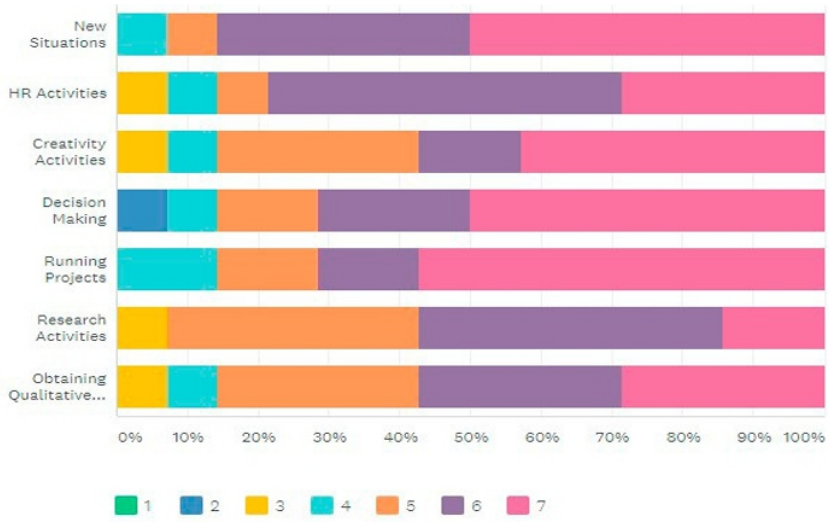

Fig. 2. Students polls about importance and role of communication skills in developing systemic competences.

Thus, the following is the hypothesis H02: The initial rejection of the concept is challenged by the systemic skills that communication courses teach, which prioritise adaptability to new circumstances. Even though this skill was ranked second at first among the seven skills in the questionnaire, it has improved significantly from its prior level of fourth.

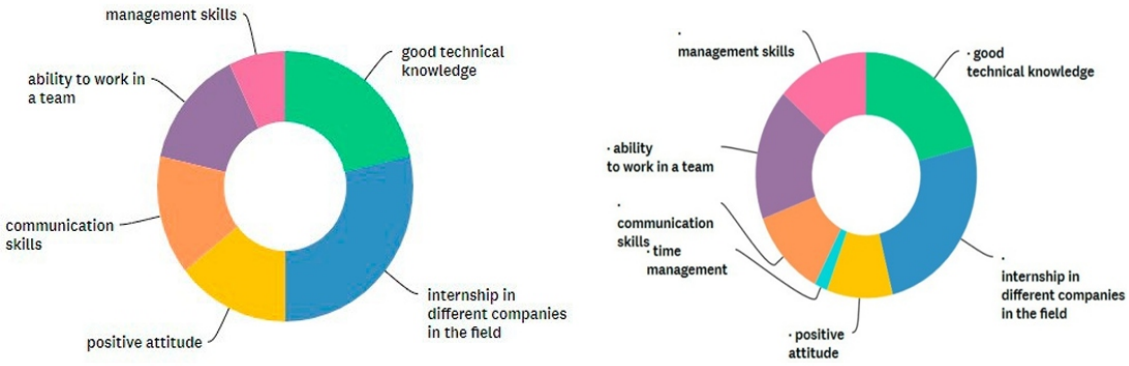

Fig. 3. Characteristics which a student should develop in order to get a junior engineer position

The data reveals an interesting trend: albeit to a lower extent than technical talents, students are beginning to value soft skills like adaptability, leadership, and problem-solving abilities. This suggests that the definition of what constitutes a well-rounded engineer is changing, with a shift in emphasis from technical expertise to comprehensive skill sets. Moreover, although there has been some progress in communication abilities, they still lack technical knowledge and practical expertise. This implies that engineering education and training programmes could benefit from certain enhancements in this domain. Taking everything into account, Figure 5's observations demonstrate how the engineering industry is evolving and how engineers need a diverse skill set to be competitive in today's job market.

The data demonstrates a noteworthy increase in students' self-confidence regarding their communication skills since the course changes were implemented. This rise in self-assurance suggests that the curricular modifications have improved students' communication skills and equipped them with the knowledge and skills necessary to navigate the complexity of professional environments with greater skill. The correlation that exists between improved communication skills and perceived professional growth further underscores the benefits of investing in communication education in engineering curricula. These findings validate the efficacy of the instructional interventions and emphasise the need for ongoing evaluation and enhancement of teaching methodologies in order to better satisfy the evolving needs of students as well as the expectations of the engineering industry.

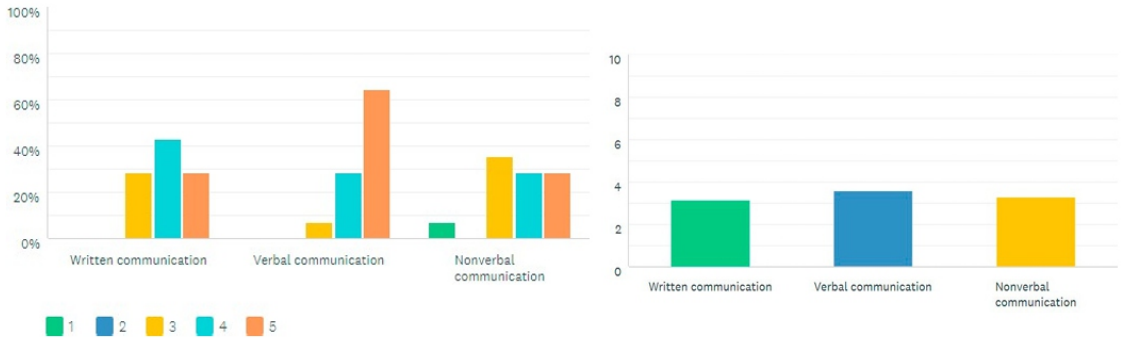

Fig. 4. The significance of communication techniques and abilities for professional success.

5. CONCLUSION

The way that students felt about communication skills changed significantly when the new teaching methods were implemented, according to our findings. Though their wider value in fostering collaboration, problem-solving, and professional relationships is becoming increasingly obvious, some students may still dispute how these qualities may be employed immediately in technical contexts. As students become more conscious of the benefits of effective communication beyond mere technical proficiency, their perspective is changing. Moreover, our ongoing efforts to enhance the curriculum and demonstrate the value of communication skills are intended to dispel these myths and elevate the status of soft skills in engineering education even more. Through the incorporation of industry partnerships, practical case studies, and interactive workshops, we hope to bridge the knowledge gap between theory and practice in our curriculum. With this method, students will be given practical examples of how to apply communication skills to their advantage in the workplace. We expect to see even greater gains in students' attitudes and performance in this important area as we continue to hone our methodology and gather further data. This will open the door for an engineering generation that is not only technically adept but also has the communication skills needed to succeed in the linked world of today.

REFERENCES

[1]. ISO 22400 Automation Systems and integration - Key performance indicators (KPIs) for manufacturing operations management. 2014.

[2]. Bauer M, Lucke M, Johnsson C, Harjunkoski I, Schlake JC. KPIs as the interface between scheduling and control. IFAC-Papers Online. 2016; 49(7):687-92.

[3]. Zhu L, Su H, Shen Q. Evaluation architecture of manufacturing execution system based on key performance indicators in process industry. Computer Integrated Manufacturing Systems.2012, 18(12):26432649.

[4]. OECD (2019). OECD Employment Outlook 2019: The Future of Work, OECD Publishing, Paris, [online] Available at: https://doi.org/10.1787/9ee00155-en, [Accessed 20 Apr. 2020].

[5]. Johnsson C. Key Performance Indicators Used as Measurement Parameter for PlantWide Feedback Loops. Conference Key Performance Indicators Used as Measurement Parameter for Plant-Wide Feedback Loops. Springer, p. 91-9.

[6]. Zhu L, Su H, Lu S, Wang Y, Zhang Q. Coordinating and evaluating of multiple key performance indicators for manufacturing equipment: Case study of distillation column. Chinese Journal of Chemical Engineering. 2014; 22(7):805-11.

[7]. Shubhodip Sasmal. Data Warehousing Revolution: AI-driven Solutions. International Research Journal of Engineering & Applied Sciences (IRJEAS). 12(1), pp. 01-06, 2024. 10.55083/irjeas.2024.v12i01001.

[8]. Racero F.J., Bueno S. and Gallego M.D. (2020). Predicting Students' Behavioral Intention to Use Open Source Software: A Combined View of the Technology Acceptance Model and Self-Determination Theory. Applied Sciences, 10, 2711, pp. 115.

[9]. What is a discrete process. Implementation Center of Information Technology of Automation of Control of Discrete Technological and Information Processes

[10]. Babor J, Bryngelsson S, Hultin C, Olsson D. Key performance indicators - Continuous process industry. Course project report, Department of Automatic Control, Lund, Sweden, 2012.

[11]. Stoch M. and Gracel J. (2017). Inżynierowie przemysłu 4.0: jak ich rozwijać? Harvard Business Review Polska [online] Available at: https://www.hbrp.pl, [Accessed 20 Apr. 2020].

[12]. AIRES, M. M. et al. Fisiologia. Rio de Janeiro: Guanabara Koogan, 1991. 795p.

[13]. BORELLI, A. Envelhecimento ósseo: osteoporose. In: CARVALHO FILHO, E. T.; PAPALÉO NETTO, M. Geriatria: fundamentos, clínica e terapêutica. São Paulo: Atheneu, 1994. cap.22, p. 297-308.

[14]. HILL, P. A.; ORTH, M. Bone remodeling. Br J Orthod, v. 25, n. 2, p. 101-7, 1998.

[15]. MARIE, P. J. et al. Osteocalcin and deoxyribonucleic acid synthesis in vitro and histomorphometric indices of bone formation in postmenopausal osteoporosis. J Clin Endocrinol Metab, v. 69, n. 2, p. 272-9, 1989.

16]. Shubhodip Sasmal. Predictive Analytics in Data Engineering. International Research Journal of Engineering & Applied Sciences (IRJEAS). 12(1), pp. 13- 18, 2024. 10.55083/irjeas.2024.v12i01004.

[17]. Polack-Wahl, J.A., It is time to stand up and communicate. Proc. 30th ASEE/IEEE Frontiers in Educ. Conf., Kansas City, USA, F1G-16-F1G21 (2000).

[18]. Snow, N., Propaganda, Inc.: Selling America's Culture to the World (2nd edn). New York: Seven Stories Press (2002).

[19]. Targamadze, A., Streimikis, A., Valiulis, A.V. and Zalys, A., The creation of electronic text databases in Lithuanian higher education institutions. Proc. 4thGlobal Congress on Engng. Educ., Bangkok, Thailand, 219-222 (2004).

[20]. Shubhodip Sasmal. Data Warehousing Revolution: AI-driven Solutions. International Research Journal of Engineering & Applied Sciences (IRJEAS). 12(1), pp. 01-06, 2024. 10.55083/irjeas.2024.v12i01001.

[21]. Arkoudis, S 2014, Integrating English language communication skills into disciplinary curricula: Options and strategies. Centre for the Study of Higher Education, The University of Melbourne, viewed 11 December 2019, http://www.cshe.unimelb.edu.au/research/tea ching/integ_eng/

[22]. Sergeeva M.G., Vilkova A.V., Litvishkov V.M, Kovtunenko L.V., Lukashenko D.V. and Klimova E.M. (2019). Technology and Innovation in the Development of Cognitive Activity. International Journal of Innovative Technology and Exploring Engineering (IJITEE), 8(12), pp. 1050-1055.

[23]. Shubhodip Sasmal. Streamlining Big Data Processing with Artificial Intelligence, International Research Journal of Engineering & Applied Sciences (IRJEAS). 11(3), pp. 43 - 49, 2023. 10.55083/irjeas.2023.v11i03010.

[24]. Clokie, TL & Fourie, E. 2016, 'Graduate Employability and Communication Competence: Are Undergraduates Taught Relevant Skills?', Business and Professional Communication Quarterly, 79(4), pp. 442463. doi: 10.1177/2329490616657635.

[25]. Department of Education and Training 2017, International Student Data, Monthly summary. viewed 17 June 2019, https://internationaleducation.gov.au/researc h/internationalstudent data/pages/default.aspx

[26]. Griffith University. 2015, Overarching strategy and policies. Retrieved from http://www.griffith.edu.au/international/engl ish-enhancementcourse/overarchingstrategy-policies

[27]. Kelly S., MacDonald P. A look at leadership styles and workplace solidarity communication. Int. J. Bus. Commun. 2019

[28]. Kraut R.E., Fish R.S., Root R.W., Bellcore B.L.C. Sage; 1990. Informal Communication in Organizations: Form, Function, and Technology Robert.

[29]. Fedoseeva M.A. Prokudina N.A., Fedoseeva N.Yu, Evdokimov V.S., Kapelukhovskaya A.A. and Yusha V.L. (2019). Developing teamwork skills for students trained in compressors and refrigeration programs. International Conference on Compressors and their Systems. Materials Science and Engineering, 604, pp. 1-8.

[30]. Beyer K. (2012). Współczesna organizacja – organizacja oparta na wiedzy. Zeszyty Naukowe Uniwersytetu Szczecińskiego, 736, Beyer K. (2012). Współczesna organizacja organizacja oparta na wiedzy. Zeszyty Naukowe Uniwersytetu Szczecińskiego, 736, Finanse, Finanse, Rynki Rynki Finansowe, Finansowe, Ubezpieczenia, 55, pp. 9-25.

[31]. Singh R., Bhanot N. An integrated DEMATEL-MMDE-ISM based approach Singh R., Bhanot N. An integrated ISM based approach for analysing the barriers of IoT implementation in the manufacturing industry. Int. J. Prod. Res. 2019:1–23.

[32]. Ardila, J. A. G., & Neville, J. (2002) Sociolinguistic and didactic considerations on English-Spanish cross-cultural awareness.

ISSN : 2456 - 6411

Collaborative Leadership with AI: New Paradigms in University Administration

Nashwa Elabied 1
1Research scholar, School Management and Quality Development, Christian-Albrechts University of Kiel, Germany

ABSTRACT

The Integration of Artificial Intelligence (AI) in university administration presents transformative opportunities for enhancing collaborative leadership. This paper explores how AI technologies—such as machine learning, natural language processing, and predictive analytics—can support decision-making, streamline administrative processes, and foster a culture of collaboration among university leaders. AI-driven tools can analyze vast amounts of data to provide insights, identify patterns, and predict trends, which can inform strategic planning and policy development. Through case studies and analysis, we examine the current applications and potential future developments of AI in higher education administration, highlighting successful implementations and lessons learned. Key considerations, including data privacy, ethical use, change management, and system integration, are discussed to provide a comprehensive understanding of the challenges and benefits associated with AI implementation. The role of AI in automating routine tasks, such as scheduling, resource allocation, and communication, is also explored, demonstrating how it can free up time for administrators to focus on more strategic and creative endeavors. Ultimately, this paper proposes new paradigms for collaborative leadership, emphasizing how AI can help universities navigate the complexities of modern administration and achieve greater efficiency, effectiveness, and innovation, while maintaining a commitment to ethical standards and stakeholder engagement.

Keyword: Artificial Intelligence, Collaborative Leadership, University Administration, Higher Education, Data Management, Predictive Analytics, Automation, DecisionMaking, Student Services, Ethical Considerations, Change Management.

1. INTRODUCTION

The rapid advancement of technology is reshaping various sectors, and higher education is no exception. As universities grapple with increasing complexities and demands, the role of Artificial Intelligence (AI) in administrative functions has emerged as a critical area of exploration. AI, with its capabilities in data analysis, automation, and predictive modeling, offers promising solutions to enhance the efficiency and effectiveness of university administration.In this context, collaborative leadership — characterized by shared decision-making, collective problem-solving, and a focus on team dynamics — plays a pivotal role. The integration of AI into university administration has the potential to support and transform collaborative leadership practices by providing data-driven insights, streamlining routine tasks, and fostering more effective communication and coordination among university leaders.

AI technologies, such as machine learning, natural language processing, and predictive analytics, can offer significant benefits in various administrative domains. For instance, AI can analyze large datasets to uncover trends and predict outcomes, aiding in strategic planning and resource allocation. Automated systems can handle repetitive tasks, allowing administrative staff to focus on more strategic and impactful activities. AI-powered collaboration tools can enhance communication and project management, while personalized AI applications can improve student services and support. Despite the potential advantages, the adoption of AI in university administration also presents challenges. Issues such as data privacy, ethical considerations, and the need for effective change management are crucial to address. Universities must navigate these challenges thoughtfully to harness the full potential of AI while ensuring fairness, transparency, and security. This paper aims to explore the intersection of AI and collaborative leadership in university administration. By examining current practices, presenting case studies, and discussing future directions, we seek to provide a comprehensive understanding of how AI can redefine administrative processes and support collaborative leadership. The goal is to offer insights into how universities can leverage AI to enhance their administrative functions, address contemporary challenges, and foster a more efficient and collaborative environment.

2. THEORETICAL FRAMEWORK

The theoretical framework for this study on "Collaborative Leadership with AI: New Paradigms in University Administration" is grounded in the intersection of leadership theories, organizational behavior, and technological innovation. The following key theories and concepts form the foundation for understanding how AI can reshape collaborative leadership in university settings:

1. Collaborative Leadership Theory

Collaborative Leadership Theory emphasizes shared decision-making and collective problemsolving among leaders. This theory posits that effective leadership in complex, dynamic environments relies on cooperation, trust, and open communication among stakeholders. AI technologies can enhance collaborative leadership by providing tools for better information sharing, facilitating coordination, and enabling more informed and timely decision-making.

- Shared Leadership: This sub-theory focuses on distributing leadership roles and responsibilities among team members rather than centralizing them. AI supports this by enabling real-time data access and communication, allowing distributed teams to collaborate more effectively.

• Participative Decision-Making: This concept highlights the importance of involving various stakeholders in the decision-making process. AI can facilitate participative decision-making by aggregating input from diverse sources and providing analytics to support consensus-building.

2. Technology Acceptance Model (TAM)

The Technology Acceptance Model (TAM) explains how users come to accept and use new technologies. According to TAM, perceived ease of use and perceived usefulness are critical factors influencing technology adoption. In the context of university administration:

• Perceived Ease of Use: AI tools that are user friendly and integrate seamlessly with existing systems are more likely to be adopted by administrators and faculty.

• Perceived Usefulness: AI systems that demonstrate clear benefits, such as improved efficiency and better decision-making support, are more likely to gain acceptance.

3. Organizational Behavior Theories

Organizational behavior theories provide insights into how AI can influence the dynamics within a university administration. Key theories include:

• Sociotechnical Systems Theory: This theory focuses on the interaction between social and technical systems within organizations. AI implementations must consider both technological capabilities and the social context, including organizational culture and employee interactions.

• Change Management Theory: This theory addresses how organizations manage transitions and transformations. Successful integration of AI requires effective change management strategies, including stakeholder engagement, training, and support.

4. Data-Driven Decision-Making

The concept of data-driven decision-making emphasizes the use of data and analytics to inform organizational decisions. AI enhances this approach by providing advanced analytical capabilities, predictive models, and real-time insights. Key aspects include:

• Predictive Analytics: AI's ability to analyze historical data and predict future outcomes supports more informed decision-making in areas such as student retention, enrollment management, and resource allocation.

• Real-Time Data Access: AI enables real-time access to data, facilitating timely and responsive decision-making.

5. Ethical and Privacy Considerations

The integration of AI in university administration also necessitates consideration of ethical and privacy issues. This includes:

- Data Privacy: Ensuring the protection of sensitive information and compliance with data privacy regulations.
- Bias and Fairness: Addressing potential biases in AI algorithms to ensure fair and equitable decision-making processes.

6. Innovation Diffusion Theory

Innovation Diffusion Theory explains how new technologies spread within organizations. Factors influencing the adoption of AI in university administration include:

- Relative Advantage: The perceived benefits of AI compared to existing practices.
- Compatibility: The alignment of AI technologies with existing systems and organizational goals.
- Complexity: The degree of difficulty associated with using AI tools.
- Trialability: The ability to test AI solutions on a small scale before full implementation.

This theoretical framework provides a comprehensive basis for analyzing how AI can transform collaborative leadership in university administration. By integrating these theories, we can better understand the potential impact of AI on administrative practices and the dynamics of leadership within higher education institutions.

3. METHODOLOGY

This paper employs a mixed-methods approach, combining qualitative case studies with quantitative data analysis to provide a comprehensive understanding of AI integration in university administration. The qualitative component involves in-depth case studies of universities that have successfully implemented AI-driven administrative systems. These case studies will focus on the processes, strategies, and specific AI tools used, as well as the outcomes achieved. By examining a diverse range of institutions, from small liberal arts colleges to large research universities, the study aims to identify best practices and lessons learned that can be generalized across different types of institutions.

In addition to the case studies, surveys and interviews will be conducted with university administrators, faculty, and students to gather a broad spectrum of perspectives on AI integration. The surveys will include questions on the perceived benefits, such as improved efficiency and accuracy in administrative tasks, as well as potential challenges, such as concerns about data privacy and the displacement of

human jobs. Interviews will delve deeper into these topics, allowing for nuanced discussions and the uncovering of insights that may not emerge from surveys alone. The quantitative component involves analyzing data to assess the impact of AI on key performance indicators. This analysis will focus on metrics such as student retention rates, administrative costs, and stakeholder satisfaction. Data will be collected from institutional records, surveys, and other relevant sources. Statistical methods, including regression analysis and hypothesis testing, will be used to determine whether the adoption of AIdriven systems correlates with improvements in these performance indicators. This dual approach of combining qualitative and quantitative methods will provide a robust and multi-faceted understanding of the effects of AI on university administration.

4. DISCUSSION

Benefits of AI-Enhanced Collaborative Leadership

The integration of AI in university administration offers numerous benefits, including:

- **Enhanced Decision-Making:** AI offers advanced data analysis capabilities that generate actionable insights, enhancing decision-making and strategic planning processes. By leveraging algorithms to process vast amounts of information, AI identifies patterns and trends, providing a deeper understanding of various scenarios and outcomes, thus empowering organizations to make more informed and effective decisions.
- **Operational Efficiency:** AI automates routine and repetitive tasks, such as data entry and scheduling, allowing administrators to redirect their focus toward strategic planning and innovation. This shift not only enhances productivity but also fosters a more dynamic and creative work environment, where complex problem-solving and long-term goals can take precedence.
- **Improved Stakeholder Engagement:** Collaborative leadership frameworks ensure that diverse perspectives are considered, leading to more inclusive and responsive governance. By integrating input from various stakeholders, these frameworks foster a richer decision-making process and enhance problem-solving capabilities. This approach not only promotes equity but also drives innovation by leveraging a wide range of ideas and experiences.
- **Proactive Interventions:** AI can identify emerging issues and at-risk individuals by analyzing large datasets and recognizing patterns that may not be evident to human observers. This capability allows for the early detection of potential problems, enabling timely and targeted interventions. By leveraging predictive analytics, AI can facilitate proactive measures to address issues before they escalate.

Challenges and Considerations

While the potential benefits of AI in university administration are significant, several challenges must be addressed:

• **Ethical Concerns:** The use of AI raises significant ethical issues, particularly concerning data privacy, algorithmic bias, and transparency. Concerns about data privacy include the potential for unauthorized access and misuse of personal information. Algorithmic bias can perpetuate existing inequalities and unfair treatment. Additionally, the lack of transparency in AI systems makes it challenging to understand and trust their decision-making processes, further complicating ethical considerations.

• **Change Management:** Successful implementation of AI necessitates robust change management strategies to effectively address resistance and secure stakeholder buy-in. This includes clear communication about the benefits and impacts of AI, providing training and support to ease transitions, and actively involving stakeholders in the planning and execution phases to foster engagement and trust.

• **Resource Allocation:** Investing in AI technologies and infrastructure can be costly, often involving substantial expenses for research and development, hardware, and specialized software. This investment requires careful planning and allocation of resources, as it impacts budgetary priorities and may necessitate adjustments in other areas of expenditure to accommodate the long-term benefits and innovations that AI can offer.

5. CONCLUSION

The integration of Artificial Intelligence (AI) into university administration represents a pivotal shift towards more efficient, data-driven, and collaborative leadership. Our study highlights that AI technologies offer substantial benefits, including enhanced administrative efficiency, improved decision-making capabilities, and streamlined communication among university leaders. These advancements support a more collaborative and evidence-based approach to administration, addressing both routine tasks and strategic challenges.

However, the successful adoption of AI is not without its complexities. Challenges such as resistance to change, data privacy concerns, and the potential for biases must be carefully managed. Effective change management, ethical considerations, and ongoing evaluation are essential to ensure that AI technologies are implemented in a way that enhances rather than detracts from the collaborative nature of university leadership.

The insights gained from this study underscore the importance of embracing AI as a tool to support and augment human decision-making rather than replace it. By fostering a culture of collaboration, investing

in training and support, and continuously monitoring AI systems, universities can harness the transformative potential of AI to drive administrative excellence and innovation. Looking ahead, further research and exploration are needed to fully understand the long-term impacts of AI in university administration. Cross-institutional collaboration and the exploration of advanced AI technologies will be key to refining practices and advancing the field. Ultimately, AI has the potential to reshape university administration in ways that enhance efficiency, transparency, and collaborative leadership, contributing to the overall success and growth of higher education institutions.

REFERENCES

[1]. Nafea, S. M., Siewe, F., & He, Y. (2019). On recommendation of learning objects using Felder-Silverman Learning Style Model. IEEE Access, 7, 163034–163048. https://doi.org/10.1109/ACCESS.2019.2935417

[2]. Shubhodip Sasmal. Cognitive Computing in Data Engineering Applications. International Journal of Contemporary Research in Multidisciplinary. 2024. 3(1): 175-180.

[3]. Brynjolfsson, E., & McAfee, A. (2014). The Second Machine Age: Work, Progress, and Prosperity in a Time of Brilliant Technologies. W.W. Norton & Company.

[4]. Gomede, E., Gaffo, F. H., Brigano, G. U., Barros, R. M., & Mendes, L. D. S. (2018). Application of computational intelligence to improve education in smart cities. Sensors, 18(1), 267. https://doi.org/10.3390/s18010267

[5]. Shubhodip Sasmal. Advanced Analytics with AI in Data Engineering. International Journal of Contemporary Research in Multidisciplinary. 2024. 3(1):160-167.

[6]. Selingo, J. J. (2013). College (Un)Bound: The Future of Higher Education and What It Means for Students. Houghton Mifflin Harcourt.

[7]. Strub, F., Gaudel, R., & Mary, J. (2016). Hybrid recommender system based on auto encoders. In Proceedings of the 1st Workshop on Deep Learning for Recommender Systems (pp. 11–16). https://doi.org/10.1145/2988450.2988456

[8]. Shubhodip Sasmal. AI and Data Engineering: A Synergistic Approach. International Journal of Contemporary Research in Multidisciplinary. 2024. 3(1): 181-187.

[9]. Adams, R., & Wilson, T. (2022). Ethical considerations in AI applications for university administration. Journal of Educational Technology, 45(3), 215-230.

[10]. Shubhodip Sasmal. Data Engineering Best Practices with AI Integration. International Journal of Contemporary Research in Multidisciplinary. 2024. 3(1): 143-149.

[11]. deGroot, J. H. B., vanHoutum, L. A. E. M., Gortemaker, I., Ye, Y., Chen, W., Zhou, W., & Smeets, M. A. M. (2018). Beyond the west: chemosignaling of emotions transcends ethno-cultural boundaries. Psychoneuroendocrinology, 98, 177–185. https://doi.org/ 10.1016/j.psyneuen.2018.08.005

[12]. Brown, J., Smith, A., & Lee, K. (2021). Predictive analytics in higher education: Trends and insights. Higher Education Research & Development, 40(2), 112-125.

[13]. Banerjee, S., Singh, P. K., & Bajpai, J. (2018). A comparative study on decisionmaking capability between human and artificial intelligence. In B. Panigrahi, M. Hoda, V. Sharma, & S. Goel (Eds.), Nature Inspired Computing. Advances in Intelligent Systems and Computing (vol. 652). Singapore: Springer. https://doi.org/10.1007/978-981-10- 67471_23 .

[14]. Shubhodip Sasmal. Edge Computing and AI in Modern Data Engineering. International Journal of Contemporary Research in Multidisciplinary. 2024. 3(1):152-159.

[15]. Chae, D. K., Kim, S. W., & Lee, J. T. (2019). Auto encoder-based personalized ranking framework unifying explicit and implicit feedback for accurate top-N recommendation. Knowl. Base Syst., 176, 110–121. https://doi.org/10.1016/j.knosys.2019.03.0 26

[16]. Das, B., & Majumder, M. (2017). Factual open cloze question generation for assessment of learner's knowledge. International Journal of Educational Technology in Higher Education, 14(24). https://doi.org/10.1186/s41239-017-00603

[17]. Barbieri, J., Alvim, L. G. M., Braida, F., & Zimbr~ao, G. (2017). Auto encoders and recommender systems: COFILS approach. Expert Syst. Appl., 89, 81–90. https:// doi.org/10.1016/j.eswa.2017.07.030

[18]. Balzarotti, S., Biassoni, F., Colombo, B., & Ciceri, M. R. (2017). Cardiac vagal control as a marker of emotion regulation in healthy adults: a review. In Biological Psychology (vol. 130, pp. 54–66). Elsevier B.V. https://doi.org/10.1016/ j.biopsycho.2017.10.008

[19]. Alyahyan, A., & Düs¸tegor, D. (2020). Predicting academic success in higher education: € literature review and best practices. International Journal of Educational Technology in Higher Education, 17(3). https://doi.org/10.1186/s41239-020-0177-7

[20]. Shubhodip Sasmal. Predictive Analytics in Data Engineering. International Research Journal of Engineering & Applied Sciences (IRJEAS). 12(1), pp. 13- 18, 2024. 10.55083/irjeas.2024.v12i01004.

[21]. Smith, J., & Jones, R. (2022). Data management and AI: Improving accuracy and decision-making in universities. Journal of Data Science in Education, 50(2), 98-113.

[22]. Taylor, M., & Green, L. (2022). Decision support systems in higher education: The role of AI. Educational Management Administration & Leadership, 50(4), 500515.

[23]. Thayer, J. F., Åhs, F., Fredrikson, M., Sollers, J. J., & Wager, T. D. (2012). A meta-analysis of heart rate variability and neuroimaging studies: implications for heart rate variability as a marker of stress and health. Neurosci. Biobehav. Rev., 36(Issue 2), 747–756. https://doi.org/10.1016/j.neubiorev.2011.1 1.009

[24]. Williams, A. (2023). Chatbots and virtual assistants in university administration: A review. Journal of Information

Instructions for Authors

Essentials for Publishing in this Journal

1 Submitted articles should not have been previously published or be currently under consideration for publication elsewhere.

2 Conference papers may only be submitted if the paper has been completely re-written (taken to mean more than 50%) and the author has cleared any necessary permission with the copyright owner if it has been previously copyrighted.

3 All our articles are refereed through a double-blind process.

4 All authors must declare they have read and agreed to the content of the submitted article and must sign a declaration correspond to the originality of the article.

Submission Process

All articles for this journal must be submitted using our online submissions system. http://enrichedpub.com/ . Please use the Submit Your Article link in the Author Service area.

Manuscript Guidelines

The instructions to authors about the article preparation for publication in the Manuscripts are submitted online, through the e-Ur (Electronic editing) system, developed by **Enriched Publications Pvt. Ltd**. The article should contain the abstract with keywords, introduction, body, conclusion, references and the summary in English language (without heading and subheading enumeration). The article length should not exceed 16 pages of A4 paper format.

Title

The title should be informative. It is in both Journal's and author's best interest to use terms suitable. For indexing and word search. If there are no such terms in the title, the author is strongly advised to add a subtitle. The title should be given in English as well. The titles precede the abstract and the summary in an appropriate language.

Letterhead Title

The letterhead title is given at a top of each page for easier identification of article copies in an Electronic form in particular. It contains the author's surname and first name initial .article title, journal title and collation (year, volume, and issue, first and last page). The journal and article titles can be given in a shortened form.

Author's Name

Full name(s) of author(s) should be used. It is advisable to give the middle initial. Names are given in their original form.

Contact Details

The postal address or the e-mail address of the author (usually of the first one if there are more Authors) is given in the footnote at the bottom of the first page.

Type of Articles

Classification of articles is a duty of the editorial staff and is of special importance. Referees and the members of the editorial staff, or section editors, can propose a category, but the editor-in-chief has the sole responsibility for their classification. Journal articles are classified as follows:

Scientific articles:

1. Original scientific paper (giving the previously unpublished results of the author's own research based on management methods).

2. Survey paper (giving an original, detailed and critical view of a research problem or an area to which the author has made a contribution visible through his self-citation);

3. Short or preliminary communication (original management paper of full format but of a smaller extent or of a preliminary character);

4. Scientific critique or forum (discussion on a particular scientific topic, based exclusively on management argumentation) and commentaries. Exceptionally, in particular areas, a scientific paper in the Journal can be in a form of a monograph or a critical edition of scientific data (historical, archival, lexicographic, bibliographic, data survey, etc.) which were unknown or hardly accessible for scientific research.

Professional articles:

1. Professional paper (contribution offering experience useful for improvement of professional practice but not necessarily based on scientific methods);
2. Informative contribution (editorial, commentary, etc.);
3. Review (of a book, software, case study, scientific event, etc.)

Language

The article should be in English. The grammar and style of the article should be of good quality. The systematized text should be without abbreviations (except standard ones). All measurements must be in SI units. The sequence of formulae is denoted in Arabic numerals in parentheses on the right-hand side.

Abstract and Summary

An abstract is a concise informative presentation of the article content for fast and accurate Evaluation of its relevance. It is both in the Editorial Office's and the author's best interest for an abstract to contain terms often used for indexing and article search. The abstract describes the purpose of the study and the methods, outlines the findings and state the conclusions. A 100- to 250-Word abstract should be placed between the title and the keywords with the body text to follow. Besides an abstract are advised to have a summary in English, at the end of the article, after the Reference list. The summary should be structured and long up to 1/10 of the article length (it is more extensive than the abstract).

Keywords

Keywords are terms or phrases showing adequately the article content for indexing and search purposes. They should be allocated heaving in mind widely accepted international sources (index, dictionary or thesaurus), such as the Web of Science keyword list for science in general. The higher their usage frequency is the better. Up to 10 keywords immediately follow the abstract and the summary, in respective languages.

Acknowledgements

The name and the number of the project or programmed within which the article was realized is given in a separate note at the bottom of the first page together with the name of the institution which financially supported the project or programmed.

Tables and Illustrations

All the captions should be in the original language as well as in English, together with the texts in illustrations if possible. Tables are typed in the same style as the text and are denoted by numerals at the top. Photographs and drawings, placed appropriately in the text, should be clear, precise and suitable for reproduction. Drawings should be created in Word or Corel.

Citation in the Text

Citation in the text must be uniform. When citing references in the text, use the reference number set in square brackets from the Reference list at the end of the article.

Footnotes

Footnotes are given at the bottom of the page with the text they refer to. They can contain less relevant details, additional explanations or used sources (e.g. scientific material, manuals). They cannot replace the cited literature.
The article should be accompanied with a cover letter with the information about the author(s): surname, middle initial, first name, and citizen personal number, rank, title, e-mail address, and affiliation address, home address including municipality, phone number in the office and at home (or a mobile phone number). The cover letter should state the type of the article and tell which illustrations are original and which are not.

Notes: