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Analytical Assessment of Fatigue Strength of a Dental Crown

K. D. Ganvir, N. D. Pachkawade

Abstract: ***With the accomplishment of new engineering science and technologies, machineries formulated by the the technocrats are utilized in medical field. Biomedical Engineering has thus gained a prominent status in the recent years. Few decades ago, it was considered as weird thing if any mechanical engineers performed studies on dental area, but in today's scenario mechanical engineers are doing studies as well as research in the area of dental science. In this paper an attempt has been made to select best crown material for molar tooth, So that an appropriate material can be placed in the human body which is most difficult task .so for designing a molar crown, modeling is done in pro/engineer software, it is one of the parametric 3D CAD/CAM/CAE solution widely used by mechanical engineers for designing any product .this software creates a complete 3D Digital model of the product. For this extensive research, design for all crowns will be the same but only material properties will be different. After design, failure analysis is done. Loss of ability to function normally is the study of failure analysis. This is accomplished by considering various loading conditions .Here finite element analysis is used, the standard principle underlying the FEM are simple. The word finite is used to describe the limited, or finite, number of degrees of freedom used to model the behavior of each element, the element are assumed to be connected to one another but only at interconnected joints, known as nodes. Considering a body through which the distribution of a field variable I.e. displacement or stress is required, this body could be subjected to various loads. Problem is solved by two methods: static fatigue and dynamic fatigue***

Keywords: ***Fatigue strength, Failure analysis, static loading, Finite element analysis, Molar tooth, loading conditions;***

I. INTRODUCTION

The engineering concepts can be effectively applied in several areas of medical field such as tissue engineering, image processing, surgery, implant design and many more. Enrichment in the present medical imaging techniques and its data compatibility, establishes improvement in crown design process. Thus with the new introduction of technologies and hi-tech machineries devised by the technocrats, are used by doctors. Present medical treatment method will surely improve and modernized which will ultimately be beneficial to the patients. One of the most important considerations in the field of technology, in dental area, is appropriate is Selection of material which placed significant role in the human body which is also one of the most difficult task to accomplish. Priorly the experiments shows that the certain materials like metal alloy, ceramics, polymers and composites are most effective materials to implant in human body, so materials which can be used should have some important characteristics such as it should be chemically inhert, nontoxic, non-carcinogenic, stable and mechanically strong in order to withstand the forces which can be bearable for lifetime. Biomaterial designs also include mechanical and biocompatible properties of implantable materials.

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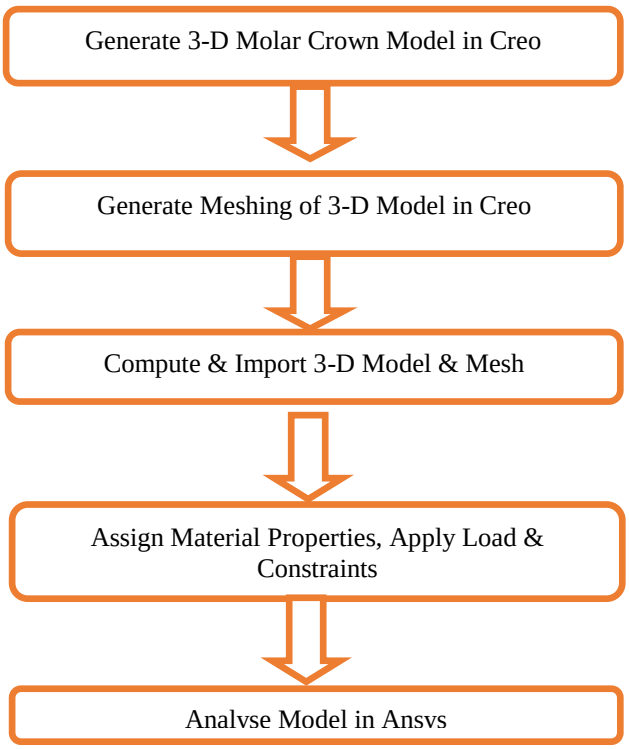
FLOWCHART FOR SHOWING THE PROCEDURE OF MODELLING AND ANALYSIS:



The above flowchart depicts the important foot-Steps in order to examine the 3D tooth model.

II. DESIGN OF THE MOLAR CROWN

The design and analysis has been carried out with the help of 3D modeling software and FEA technique using standard FEM tool. Pro-E 5.0 is used for the modeling and assembly of crown. ANSYS 12.0 has been used for the analysis of model.

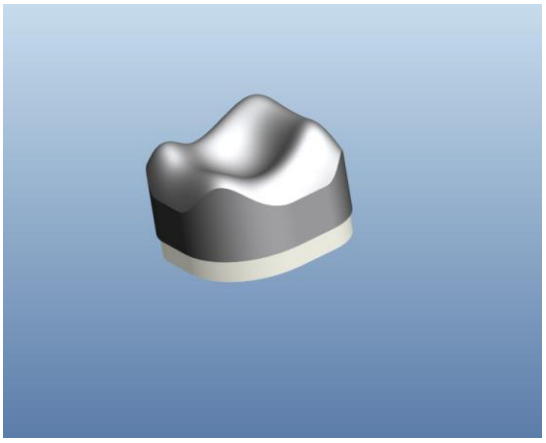


Fig 1: Pro-E Model of Molar tooth

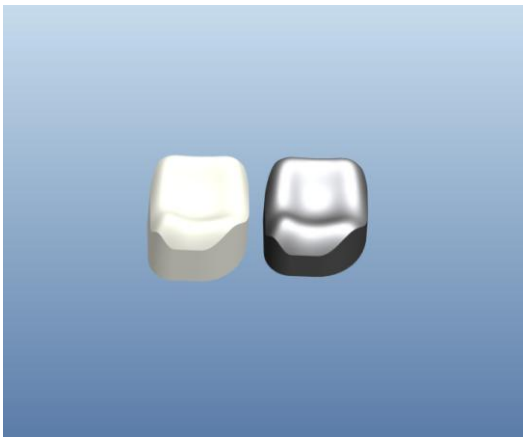


Fig 2: Top view of pro-E model of tooth and cap

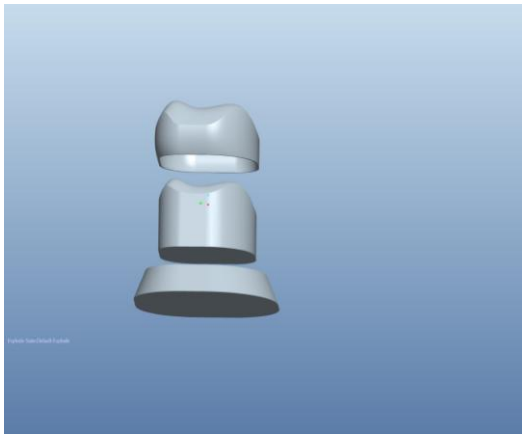


Fig 3: Crown tooth and bone

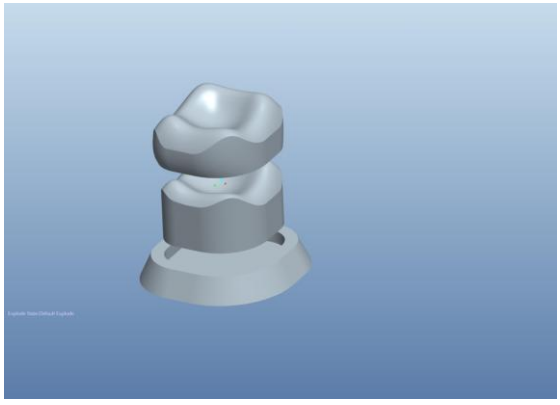


Fig 4: Assembly of crown, tooth and bone

III. METHODS TO SOLVE THE PROBLEM

i) Static fatigue

ii) Dynamic fatigue

I.STATIC FATIGUE:
GENERAL CONSIDERATIONS.

A human biting force system can be discovered when an individual takes a bite while eating. Now the exact range of particulate bite force can vary depending upon p0erson to person. It mainly depends upon age of an individual for example a child of 3 years old has low capacity to bite hard material hence the force may be minimum similarly if we talk about about adult age the force of bite can be high while at the old age again, the force of the bite eventually decreases. Also it depends upon gender of an individual and its strength. The study shows the force of the bite can be higher or lower irrespective of missing teeth or perfect teeth hence an average amount of force of human bite can be assumed from 200N to 700N (45 to 160 lbs)

LOADING CONDITIONS: As per the human bite forces Ranges from 200 to 700N, that's why considering on higher side and taking 700N as loading conditions.

MECHANICAL PROPERTIES OF MATERIALS: Now mechanical properties of materials for different crowns is taken to find out stress and displacement.

Table 1: Distinct Mechanical properties based on 3D FEA models.

SR NO	MATERIAL	YOUNGS MODULUS (Gpa)	POISSONS RATIO
1.	DENTIN	18.6	0.31
2.	CERAMIC	65E3	0.19
3.	ZIRCONIA	210E3	0.3

Using all these above parameters static fatigue is been done. Ansys as a tool for analysis is been used. Design for all the crowns of different material is same only, material properties are different, using this .stress and displacement for three types of crown has been found out.

1. CERAMIC CROWN STATIC LOADING

In order to analyze the steps using ANSYS software, first examining of the structured model of crown with ceramic material properties is taken into account. To test the model a 700N axial load is subjected on it.Study shows that an approximate force of 700N load is acting while chewing. In ANSYS the output is shown is compression which is indicated by grey areas which is the result of magnitude of tensile stress.

STATIC LOADING ON CERAMIC CROWN.

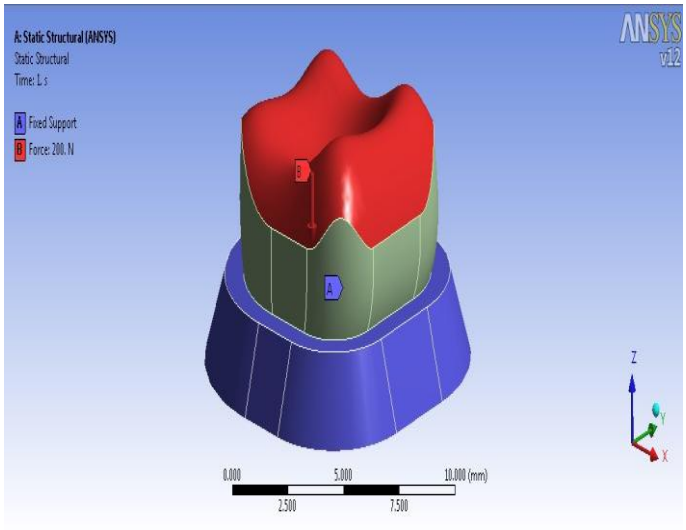


Fig 5: 700N load applied on ceramic crown in ANSYS.

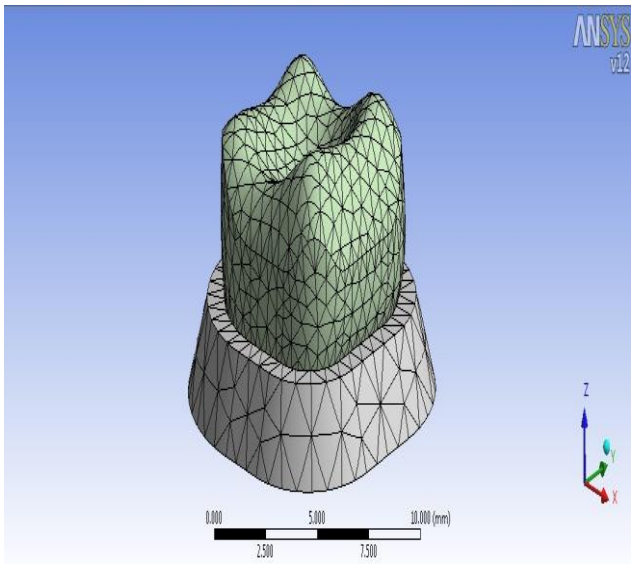


Fig 6: Meshed crown model of ceramic imported into ANSYS to be analyzed

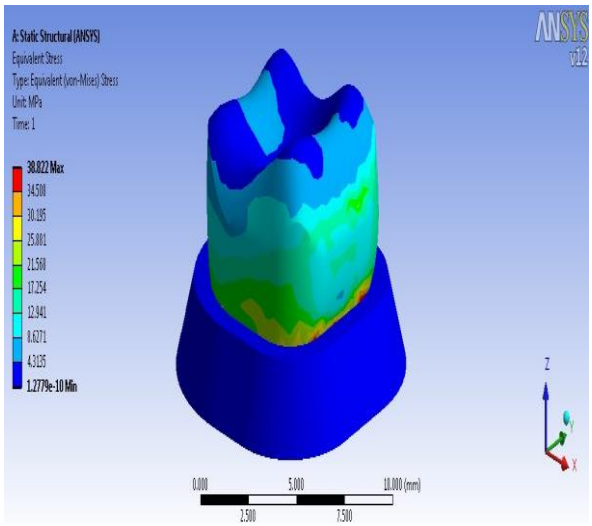


Fig 7: Axial load of 700N on ceramic crown subjected to stress distribution (von misses stress).

2. ZIRCONIA CROWN STATIC LOADING

After completion of first test, second test was carried out using ANSYS for analysis of material properties of Zirconium. A average load of 700N is subjected on occlusal surface of model of crown in vertically perpendicular direction that can be generated while chewing.

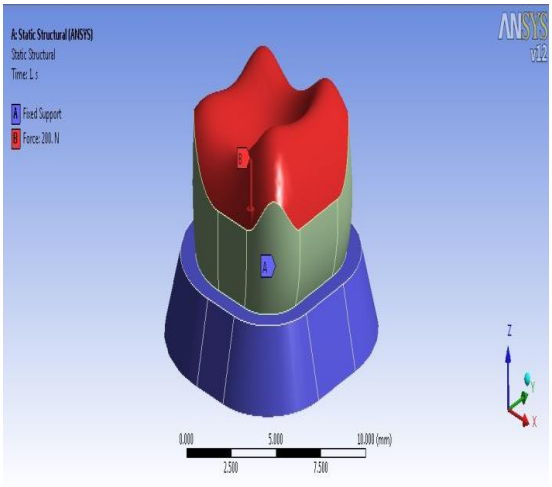


Fig 8:700N load applied on ceramic crown in ANSYS.

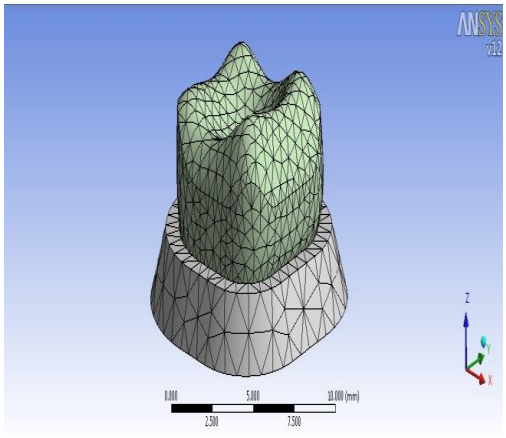


Fig 9: Meshed crown model of Zirconia imported into ANSYS to be analyzed

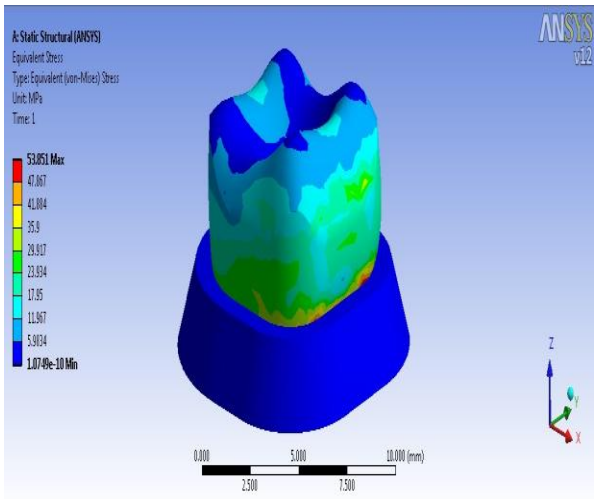


Fig 10: Stress Distribution due to 700N Vertical Load Applied to the zirconia crown (von mises stress)

3. DENTIN CROWN STATIC LOADING:

For the third series of analysis with ANSYS the crown structure of the model is defined with material properties dentin which is basically original tooth material. This model is subjected to a 700N vertical load (shown by red arrow). A 700N load is used because it is a good average of the force that can be generated while chewing. Vertical loading has been taken because it is perpendicular to occlusal surface. As per above two cases same newton load has been taken so as to find out the strength of material The output of ANSYS is a tensile stress distribution in the crown, that is color coded by the magnitude of tensile stress with gray areas indicating compression.

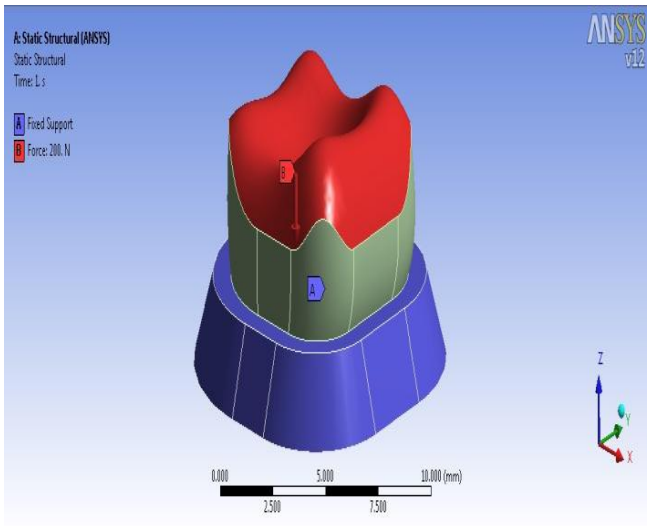


Fig 11:700N load applied on DENTIN (original tooth material) crown in ANSYS.

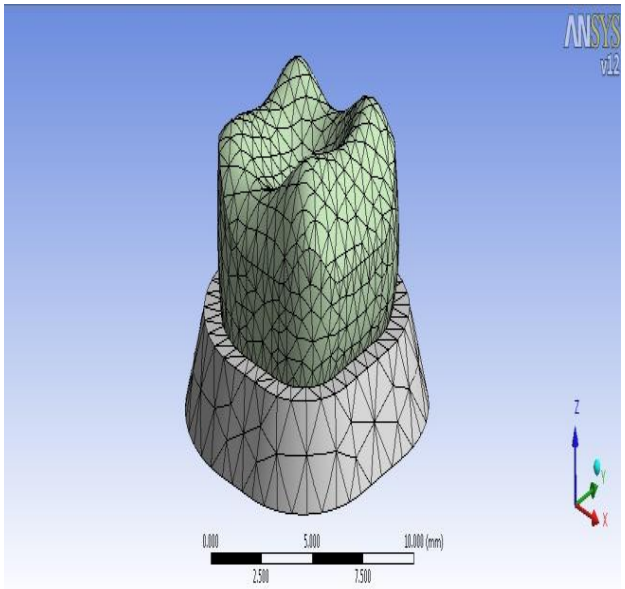


Fig 12: Meshed crown model of dentin imported into ANSYS to be analyzed.

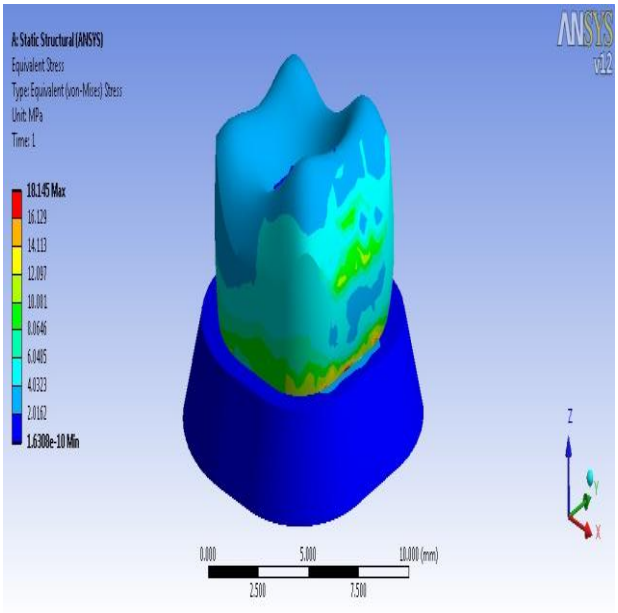


Fig 13: Original tooth material crown I.e Dentin subjected to 700N perpendicular load.

INPUT:

Loading –Normal rate of human biting force = 200N to 700N. We will consider on higher side therefore loading force = 700N.

Table 2: Showing the input loading parameters.

SR. NO.	MATERIAL NAME CONSIDERED	MATERIAL	YOUNGS MODULUS(MPa)	POISSON'S RATIO
1.	AL-2024	CERAMIC	65E3	0.19
2.	AL-1100-O	ZIRCONIA	210E3	0.3
3.	AL-2024-T4	DENTIN	18.6	0.31

OUTPUT

Table 3: Showing the output loading parameters.

SR. NO.	MATERIAL	VON MISES STRESS(MPa)	TENSILE STRENGTH(MPa)	RATIO
1.	CERAMIC	35.039	48.8	1.392
2.	ZIRCONIA	53.851	745	13.83
3.	DENTIN	18.145	105.5	5.81

Higher the ratio higher the strength of material. As we have seen in table 2 zirconia having the higher ratio as compared to remaining materials among all the materials.

IV. RESULTS AND CONCLUSION

This paper show case all the possibilities and potentialities of CREO for designing with FEA analysis for examining the 3 Dimensional structure design. The ANSYS software permits and evaluate the stress distribution and fatigue life of crown while experimenting various materials and loads which can give deeper study for different materials ,its impact and effects. In this research article a model of crown structure is analyzed which consist of crown, dentin and bone assembly so as to bear the load capacity and to identify its fatigue life, for this different materials are considered.

The results for static fatigue shows that the analysis done by ANSYS, shows that constant load for different materials tends to substantial effect on the structure of crown which develops the distinct pattern of stresses. Higher the ratio higher the strength of material. As we know, zirconia having the higher ratio as compared to the materials taken into consideration.
Hence we conclude that the best suited material for the molar crown is zirconia.

V. FUTURE SCOPE

Zirconia manufacturers can produce and designing dental crowns custom milled from solid block of the material and baked at ultra-high temperatures to ensure that the finished crowns are almost indestructible.
The aesthetic effects alone of a zirconia crown can be the biggest advantage i. It is important that having dental crowns that will look natural. Especially if it will be placed at the front teeth and will be visible beside the natural teeth.
Total implant can also be made up of zirconia, as it is one of the toughest material.

REFERENCES

1. Black, G.V. The force exerted in the closure of the jaws. *Dent Cosmos*.1895; 37:469.
2. 2)Weiguo Wang, Litong Chen, Jianjun Chen, Yan Li, Ming Tian and Shaofeng Zhang: Optimal design of occlusal thicknesses and shoulder width in monolithic all-ceramic crown based on continuous variation of parameters.(2010).
3. Thompson Van P., Dianne E. R.: Dental Ceramics and the Molar Crown Testing Ground. J Appl Oral Sci *2004;* 12 (sp. issue): 26-36
4. M. Toparli, N. Gökay, T. Aksoy: Analysis of a restored maxillary second premolar tooth by using three-dimensional finite element method.Journal of Oral Rehabilitation (1999) 26 (2), 157–164.
5. Ricks-Williamson L J, Fotos P G, Goel V K, Spivey J D, Rivera E M, Khera S.: A three-dimensional finite element stress analysis of an endodontically prepared maxillary central incisor. J Endod 1995; 21: 362-367.
6. Alisa Madson et.al: Examining the Methods and Materials Used to Replace Lost Tooth Structure in Preparation of an Indirect Restoration Paper 6 October 27, 2003 Section 6
7. Thompson Van P., Dianne E. R. : Dental Ceramics and the Molar Crown Testing Ground. J Appl Oral Sci *2004;* 12 (sp. Issue): 26-36
8. Y.Nakasone and S. Yoshimoto: Engineering Analysis With ANSYS Software.
9. Lin CL, Chang CH, Ko CC. Multifactorial analysis of an MOD restored human premolar using auto-mesh finite element approach. J Oral Rehabil 2001;28:576–85.
10. Ausiello P, Rengo S, Davidson CL, Watts DC. Stress distributions in adhesively cemented ceramic and resin-composite class II inlay restorations: a 3D-FEA study. Dent Mater 2004;20:862–72.
11. Mehl A, Kunzelmann KH, Folwaczny M, Hickel R. Stabilization effects of CAD/CAM ceramic restorations in extended MOD cavities. J Adhes Dent 2004;6:239–45.

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About her achievements, she has been awarded BEST PAPER from engineering background in International conference 2019 organized in Tashkent, Uzbekistan. She also won 1st position in national conference and also received certificate of appreciation for organizing the conference event. She has lifetime membership of various engineering bodies such as ISTE, IAENG, AMM, STAMI, IAER, IRED, IASTER. She is also editorial board, member, and reviewer of IJETIR Journal and HBRP Journal India.

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