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Influence of Nickel coating on flexural and dynamic behaviour of Aluminium

A. Sankar Kumar*[a], K.Mohanam[a], G. Venkatachalam[a], S. Karthikeyan[a], S. Narayanan[a]

[a]*School of Mechanical and Building Sciences, VIT University, Vellore-632 014, India;*

Abstract

Electroless deposition is an autocatalytic chemical technique to deposit a layer of metal on a thin work piece in the presence of a reducing agent. In this work the changing structure of nickel deposits on aluminum and its alloys at the early stage of electroless nickel deposition using sodium hypophosphite ion as a reducing agent has been studied. The influences of nickel coating on flexural and dynamic behaviour of aluminium are investigated using experimental and numerical methods. Three-point bending tests are performed on coated & uncoated aluminium. The natural frequency of coated specimen and uncoated specimen has been studied. The nickel coating increases the natural frequency in aluminium. Experimental results are compared with finite element Analysis.

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Keywords: Specimen, Electroless Nickel plating, Stress-strain curve, FEA,

1. Introduction

Electroless nickel–phosphorus deposition is an established industrial practice as a protective and decorative coating in various industries due to its superior corrosion and wear resistance, excellent uniformity, wide range of thickness as well as mechanical and physical properties. Extensive research has been carried out on the characterization of the electroless nickel deposition process.

Understanding the basics and fundamentals of vibration analysis are very important in forming a solid background to analyze problems on rotating machinery. Switching between time and frequency is a common tool used for analysis. Because the frequency spectrum is derived from the data in the time domain, the relationship between time and frequency is very important.

2. Literature Survey

Brenner and Riddell [1] first developed autocatalytic nickel deposition using a sodium hypophosphite bath. There are numerous parameters affecting the electroless nickel process as suggested by Baudrand & Brad Durkin [2]. Temperature, pH, nickel ion concentration, reducing agent concentration, the loading in the bath and agitation affect the nickel deposition rate. Gutzeit [3] concluded that the nickel ion is catalytically reduced by means of the active atomic hydrogen with simultaneous formation of orthophosphite and hydrogen ions. In addition, he has shown that the plating rate is dependent on hypophosphite concentration, but independent on the nickel concentration when it is above 0.02 mol/L. Cheonga et al [4] reported that electroless nickel deposition bath is known to have a major problem of sudden bath decomposition, which results in an increase in

*A. Sankar kumar. Tel:+919994243007 Fax: +91 (416) 2243092,

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E-mail: asankarkumar@vit.ac.in

the operating cost of the process and the generation of environmentally hazardous waste. Gorbunova and Nikiforvoa [5] discussed that atomic hydrogen is released as a result of the catalytic dehydrogenation of hypophosphite molecules adsorbed at the surface which then reduce nickel at the catalyst surface. It is concluded that electroless nickel deposition therefore cannot be solely chemical but is controlled by an electrochemical mechanism. The phosphorus content during electroless nickel deposition controls the microstructure of the coating. Aly and Younan [6] developed an electroless Ni-Co-P electrolyte solution containing sodium citrate and lactic acid as complexing agents in order to obtain a relatively high deposition rate. Agarwala and Agarwala [7] observed that coatings can be tailored for desired properties by selecting the composition of the coating alloy, composite and metallic to suitable specific requirements. Khan et al [8] reported that Ni–P deposition is closely related to the dissolution of the zincating layer, followed by progressive nickel nucleation. Baldwin et al [9] observed another serious consequence of phosphite presence in the ENP solution is its effect on the internal stress of Ni-P deposit. As the phosphite concentration increases, the internal stress becomes more tensile. Chandrashekhara, et al has described the Exact solutions are presented for the free vibration of symmetrically laminated composite beams [10].

The present problem is to investigate the influence of nickel coating on flexural behaviour of aluminium. Both experimental and numerical investigations are carried out for the same. Vibration analysis studies are also carried out on coating samples.

3. Methodology

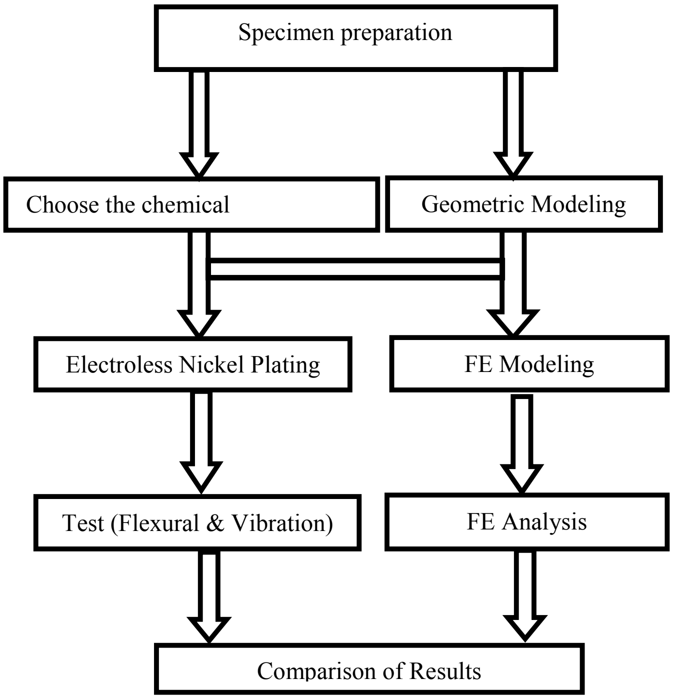

Figure 1. Methodology

Fig.1 shows the methodology adapted for this work. Aluminium alloys were used as samples for electroless nickel deposition. These aluminium specimen samples were prepared for the following dimensions: 150mm x 30 mm x 2.02 mm. Two samples of aluminium were prepared, one with nickel coated and another without coated. The bath for electroless plating was prepared as per the chemical composition given in Table1. Fig.2 gives the experimental setup used for this work. Instron machine, shown in fig.3, was used to study the flexural behaviours of nickel coated aluminium and aluminium. Fig.4 presents the specimen used for the study.

Table 1.The bath used for metallization of aluminium had the following chemicals

Chemical composition	Weight
Nickel Sulphate-0.12M	35gr/L
Sodium acetate-0.6M	50g/L
Sodium Hypo phosphate-0.32M	28g/L
Temperature	70^0C

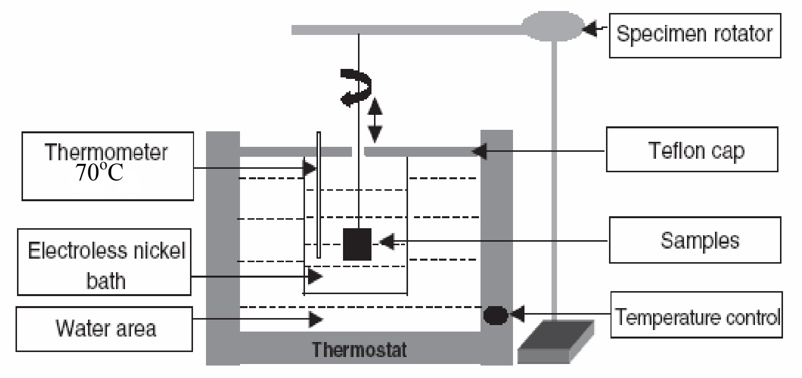

Figure 2. Experimental apparatus of electroless nickel plating

Figure 3. Instron machine

Figure 4. Aluminium with nickel coated

3.1 Three Point Bending Test

Three-point bend tests were performed on servo hydraulic test frame at a constant displacement rate of 1 mm/min The aluminium and nickel coated aluminium, tested using three-point bending, were loaded into an Instron machine with a three point fixture, as shown in Fig. 5.

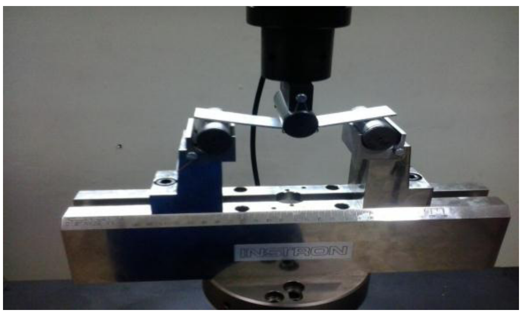

Figure 5. Three point bending with specimen

4. Results and discussions

Table 2. Flexural test results for aluminium & nickel coated aluminium

Specimen	Maximum Load (N)	Flexural Extension (mm)	Maximum Flexural Stress (MPa)	Flexural Strain
Uncoated Aluminium	109.08	5.62	192.46907	0.0044
Aluminium Nickel coated	112.50	4.12	167.36098	0.00386

Table 2 presents the flexural test results of aluminium & nickel coated aluminium Figures 6 - 11 present the coated and uncoated aluminium in numerical analysis for load, stress, strain, layer& mesh analysis for a Load of 7N.

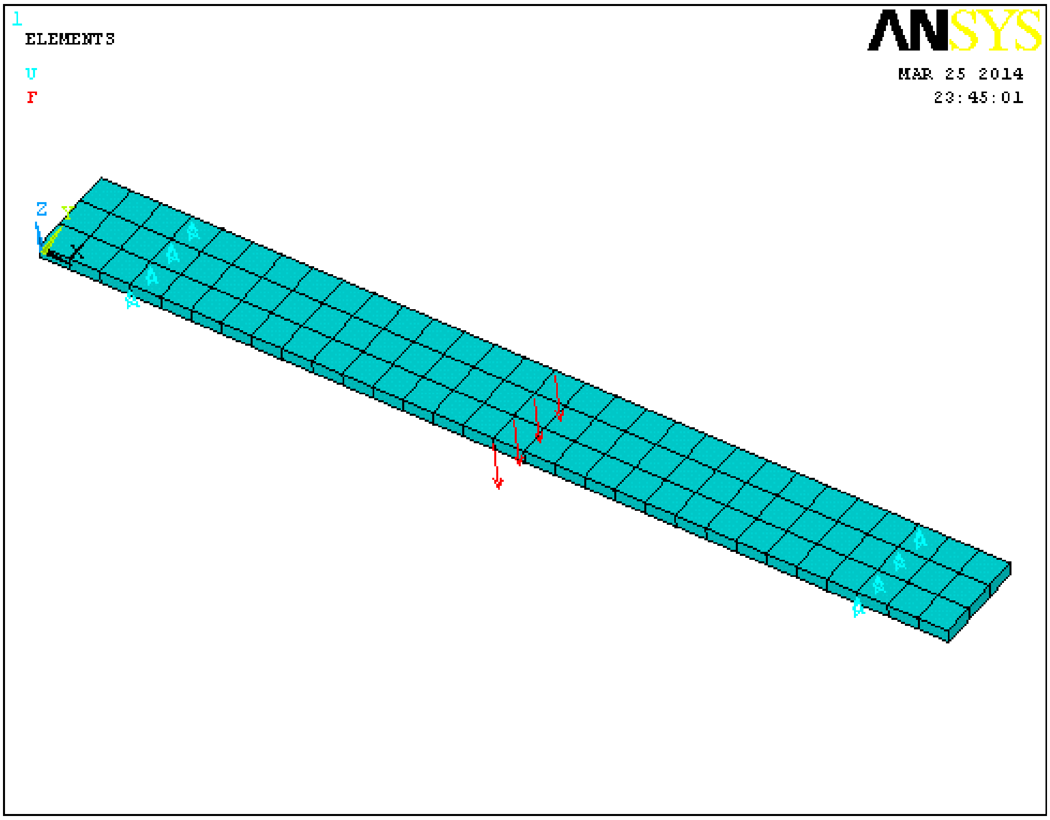

Figure 6. Aluminium mesh with load

The stress strain behaviours of the aluminium & nickel coated aluminium are shown in figs. 12 and 13.
Fig.12 compares the stress strain behaviours of aluminium uncoated experimental and numerical curve.
Fig.13 shows the stress strain behaviours of nickel coated on aluminium and aluminium. The experimental and numerical analysis results are similar. There is minor difference in the curve. This is due to the nature of coating the experimental analysis and numerical analysis.

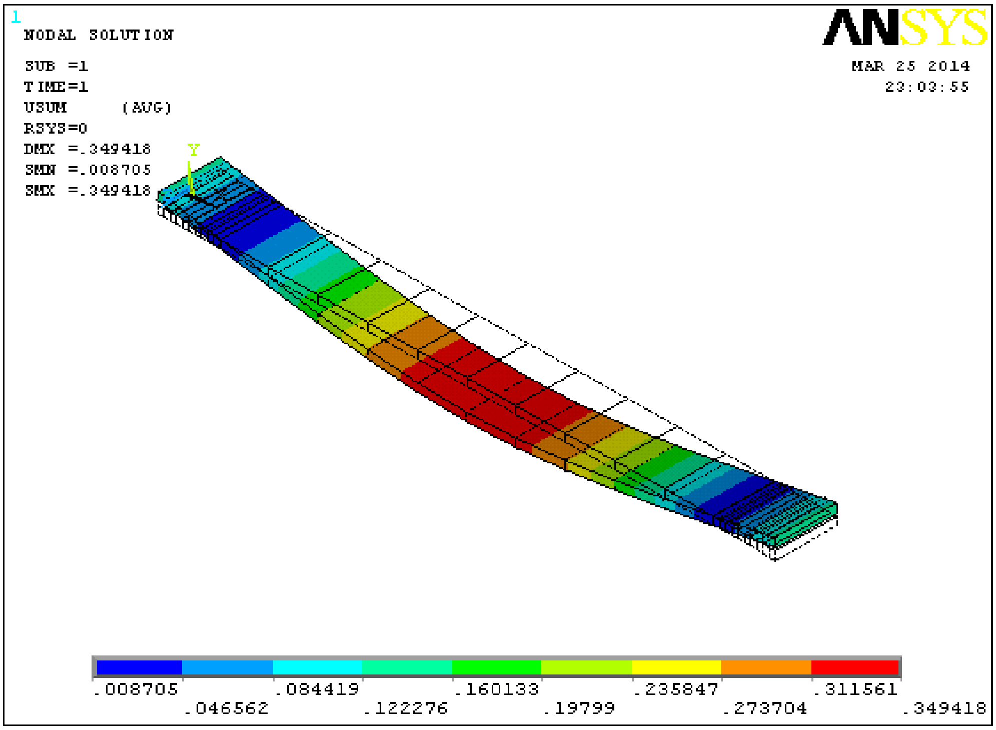

Figure 7. Dissplacement of uncoated aluminium

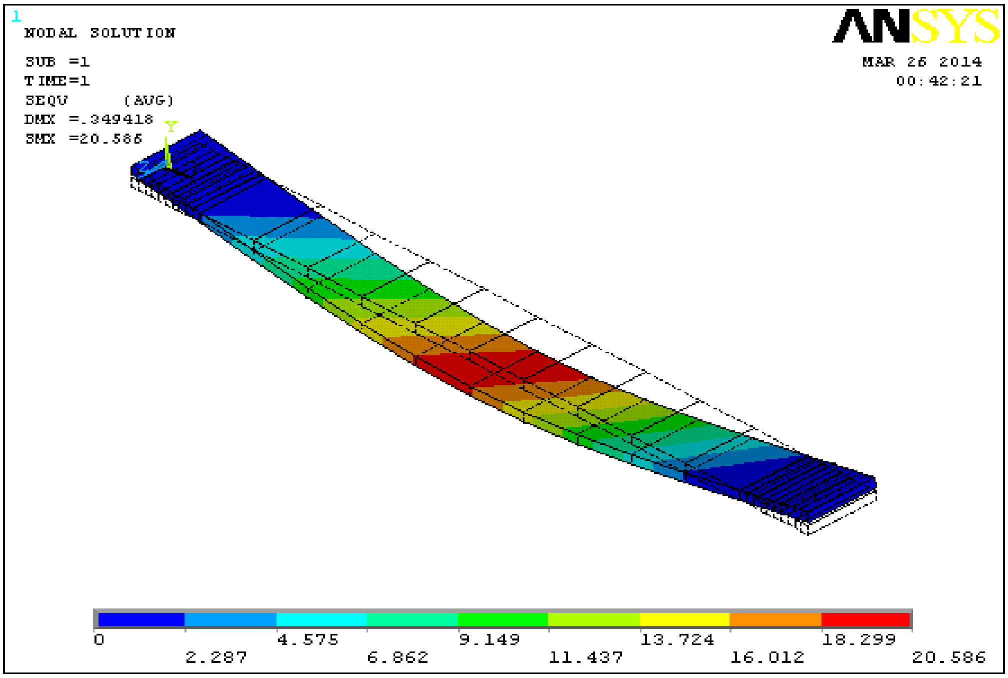

Figure 8. Uncoated aluminium of stress

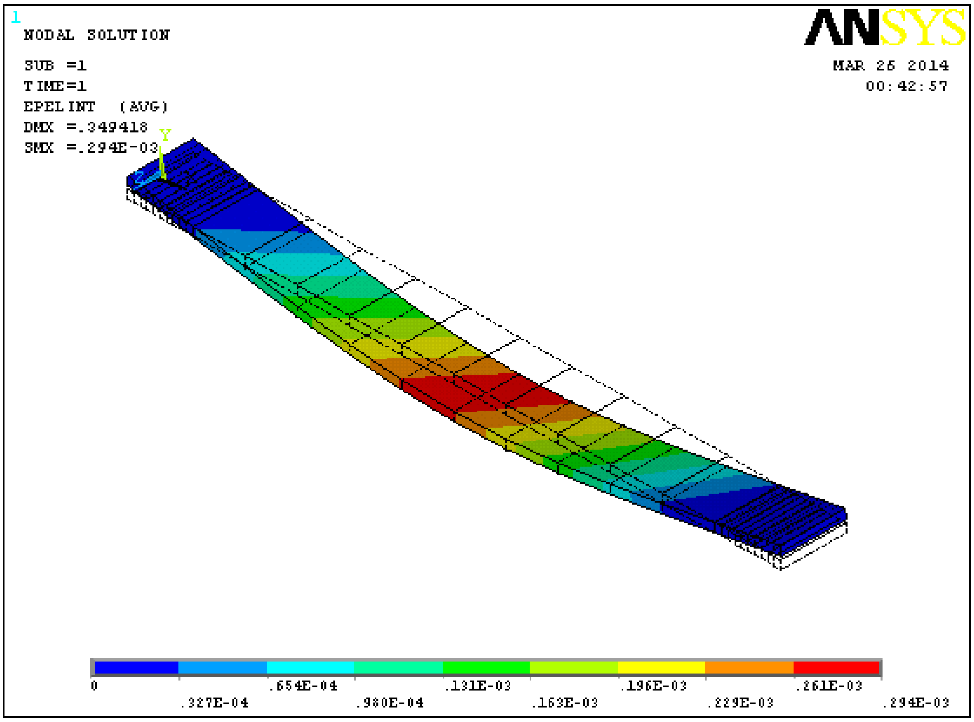

Figure 9.Uuncoated aluminium of strain

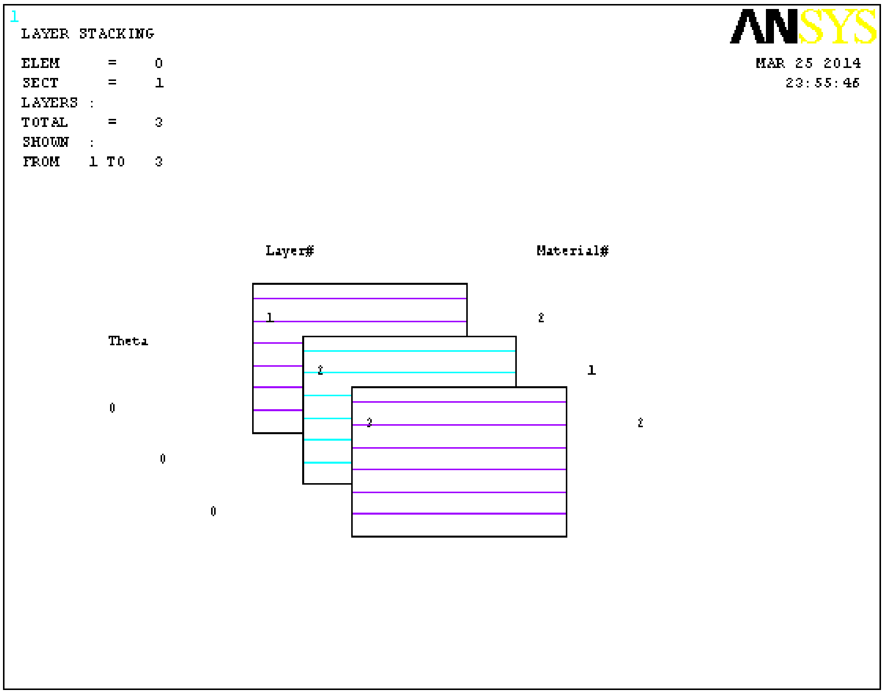

Figure 10. Three Layers are Ni, Al, & Ni

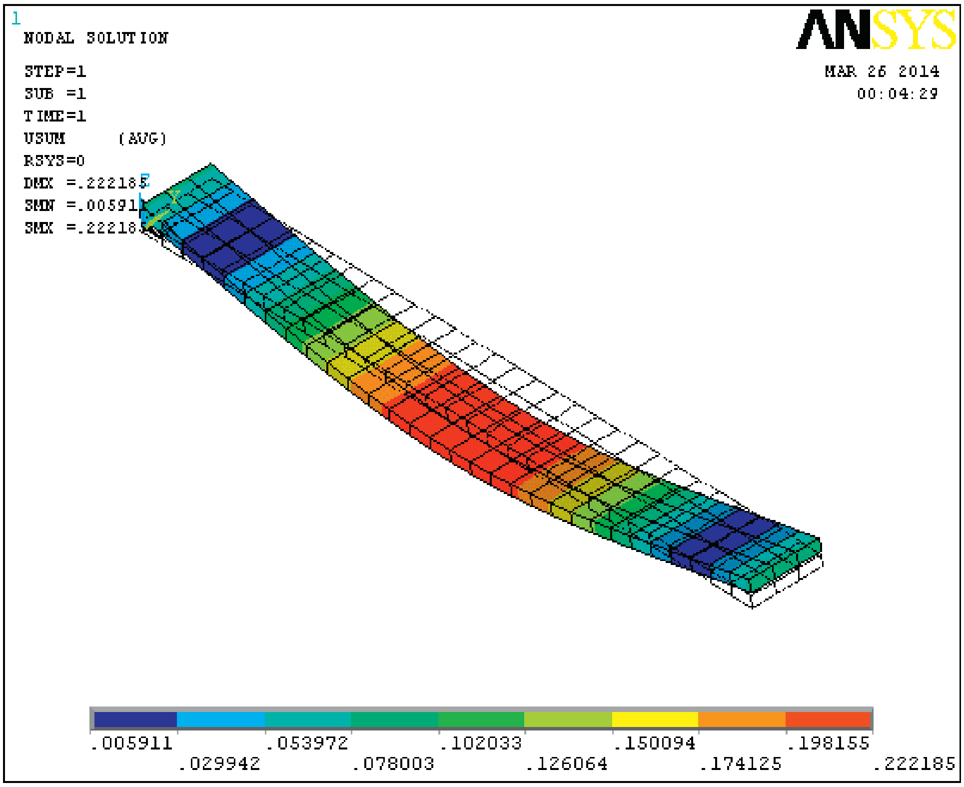

Figure 11. Displacement of al with ni coated

4.1 Flexural Test Results

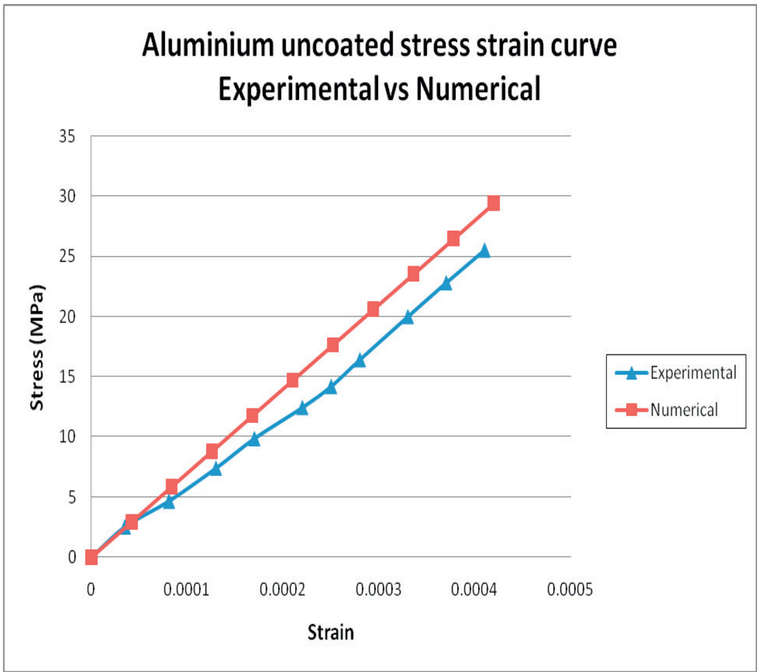

Figure 12. Aluminium uncoated stress strain curve

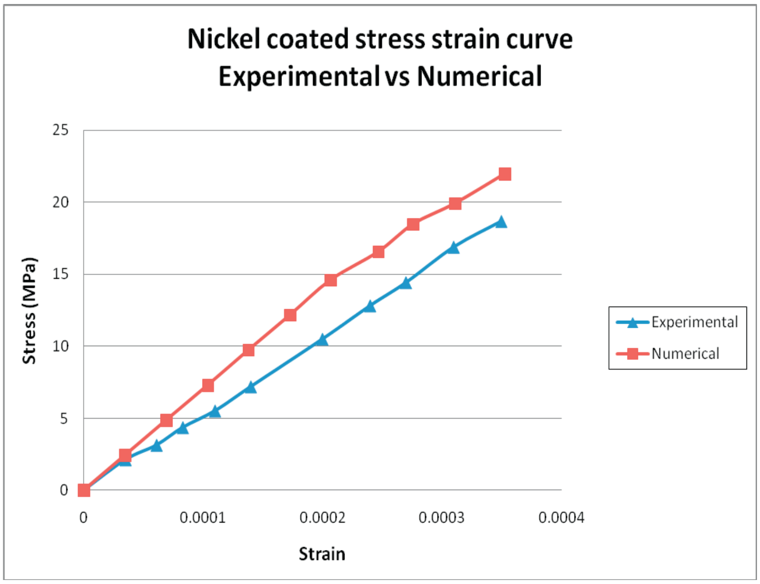

Figure 13. aluminium & nickel coated aluminium stress vs strain

4.2 Modal Analysis

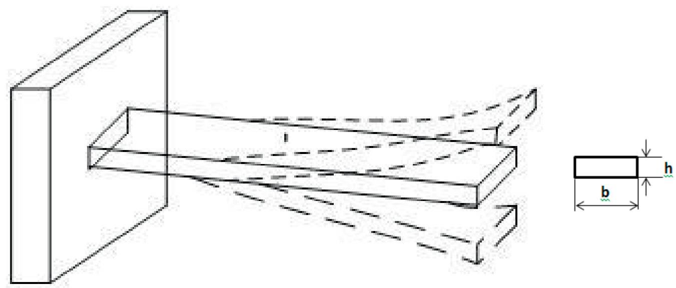

Figure 14. Nomenclature of experimental set up

Fig.14 shows the setup of modal analysis. The natural frequency of coated specimen and uncoated specimen has been studied using experimental method with the help of DEWESOFT software. The changes in natural frequency increases from uncoated specimen to coated specimen. i.e. coated specimen exhibits high natural frequency when compared to uncoated one.

Table 3 presents the natural frequency results of aluminium and nickel coated aluminium. After experimental analysis, FE analysis is carried out using ANSYS to compare the results. This uses the Modal solution method. In numerical method the free vibration of a cantilever beam is modeled with beam elements and natural frequencies and mode shapes at these frequencies are also extracted. Figures 15-18 present different modes of natural frequency of the uncoated aluminium using numerical analysis.

Table 3. Nature frequency results of aluminium and nickel coated aluminium

Experimental Method		
Frequency	Uncoated	Nickel Coated
f1	64.75	265.8
f2	399.38	843.31
f3	1054	1398.5
f4	1964.74	2004.5

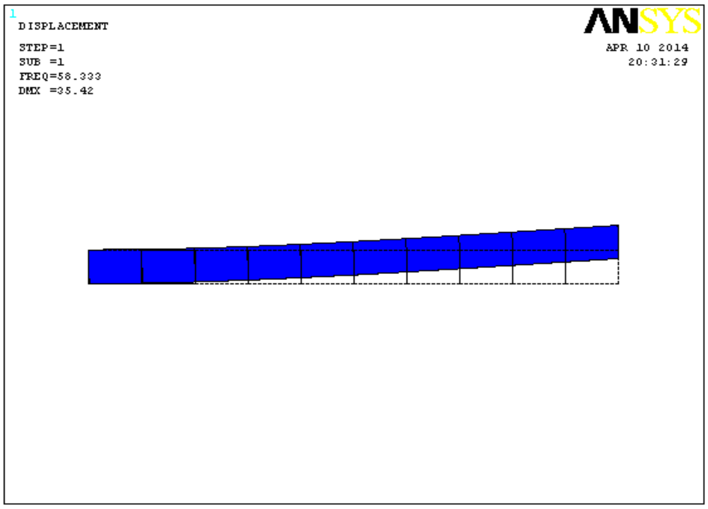

Figure 15. 1st Mode Natural Frequency

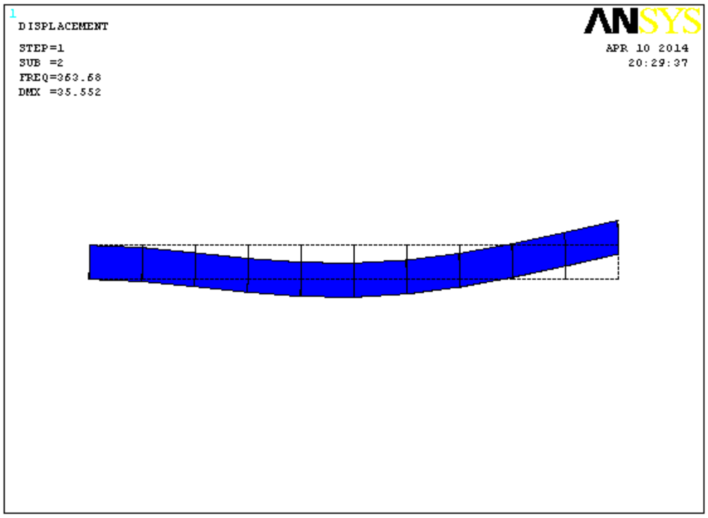

Figure 16. 2nd Mode Natural Frequency

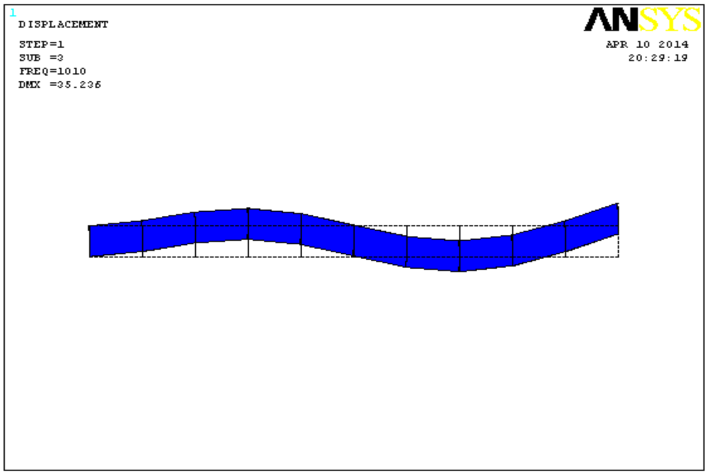

Figure 17. 3rd Mode Natural Frequency

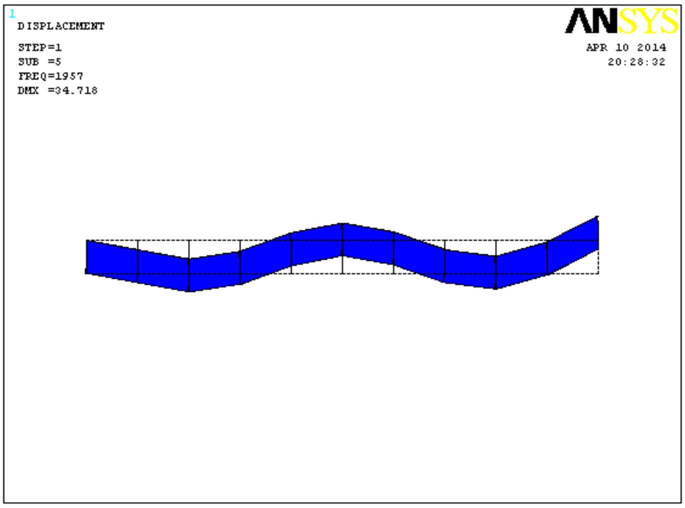

Figure 18. 4th Mode Natural Frequency

Table 4 presents the natural frequency results of aluminium uncoated specimen. Modal Analysis for the uncoated specimen has been studied and the Natural frequencies at different modes were found out. The table also presents the percentage of variation of experimental and numerical values.

Table 4. Nature frequency results of uncoated aluminium

Uncoated Aluminium			
Frequency	Experimental	Numerical(FEM)	% deviation
f1	64.75	58.333	9.33
f2	399.38	363.67	8.94
f3	1054	1010	4.18
f4	1964.74	1957	0.45

4.3 Modal Analysis Nickel Coated Aluminium Using FEM

Table 5 presents the natural frequency results of nickel coated aluminium. Modal analysis for the nickel coated specimen has been studied and the natural frequencies at different modes were found out. It also compares experimental and numerical analysis of nickel coated specimen.

Table 5. Nature frequency results of nickel coated aluminium

Aluminium Nickel coated			
Frequency	Experimental	Numerical(FEM)	% deviation
f1	265.8	246.66	7.2
f2	843.31	794.87	5.74
f3	1398.5	1386	1.01
f4	2004.5	1917	4.37

The coated specimen exhibits higher natural frequency when compared to uncoated one. The nickel coating increases the natural frequency in aluminium. There are major differences found in natural frequency when coated and uncoated specimens are compared. This is due to the material properties of aluminium and nickel and also due to the nature of coating in the experimental analysis.

5. Conclusions

The Nickel coating on Aluminium was successfully developed. Three-point bending tests were also performed on coated & uncoated aluminium. There is minor difference in the stress due to the material properties of aluminium and nickel. Experimental results were compared with finite element Analysis. The natural frequency of coated specimen and uncoated specimen has been studied. The nickel coating increases the natural frequency in aluminium. Experimental results were compared with finite element Analysis.

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