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Life Prediction of Cam and Follower through Ansys and Artificial Neural Network

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Abstract: *The life prediction of cam and follower with static and dynamic analysis by finite element analysis (FEA) are studied in this paper. The performance of machine or engine depends on the precise working and life of cam and follower. The current cam and follower mechanism in four stroke engines employs a knife edge follower. In static analysis different types of stress developed in cam and follower are considered and in dynamic analysis natural frequency or vibration analysis with respect to given loading condition. The modelling, static and dynamic analysis of Cam and follower is done by using ANSYS 14.0 and life prediction is done by using ANN.*
Keywords: *Static Analysis, Dynamic Analysis, FEA, ANSYS, ANN.*

I. Introduction

A cam is a rotating mechanical element which gives reciprocating or oscillating motion to another element known as follower. Cam makes a higher kinematic pair with follower. Cam mechanisms are widely used because with them, different types of motion can be possible. Cam can provide unusual and irregular motions that may be impossible with the other types of mechanisms. In other word, the cam may be defined as a machine element having a curved outline or a curved groove, which by its oscillation or rotation motion, gives a predetermined specified motion to another element called the follower. Cam mechanism transforms a rotational or oscillating motion to a translating or linear motion. The variety of different types of cam and follower systems depends on the shape of contacting surfaces of the cam and the profile of the follower. The cam and follower has a very important function in the operation of many classes of machines, especially those of the automatic type, such as printing presses, shoe machinery, textile machinery, gear-cutting machines and screw machines. R. J. Deshbhratar and Y.R Suple (2012) have been analyzed 4- cylinder crankshaft and model of the crankshaft were created by Pro/E Software and then imported to ANSYS software. The maximum deformation appears at the centre of crankshaft surface. The maximum stress appears at the fillets between the crankshaft journal and crank cheeks, and near the central point. The edge of main journal is high stress area. The crankshaft deformation was mainly bending deformation under the lower frequency. And the maximum deformation was located at the link between main bearing journal and crankpin and crank cheeks. So this area prone to appear the bending fatigue crack. Abhishek Choubey and Jamin Brahmbhatt (2012) have been analyzed crankshaft model and 3-dimentional model of the crankshaft were created by SOLID WORKS Software and imported to ANSYS software. The crankshaft maximum deformation appears at the centre of crankpin neck surface. The maximum stress appears at the fillets between the crankshaft journals and crank cheeks and near the central point journal. Mahesh R. Mali, Prabhakar D. Maskar, Shravan H. Gawande and Jay S. Bagi (2012) has presented most of the internal combustion engines used in various applications such as automotive to power generation have disk cam and follower mechanisms, having a line contact between the cam and follower. In order to improve the mechanical efficiency of the mechanism, an attempt is made to study the static and dynamic analysis of cam at low speed. In static analysis to study the deflection of cam and follower with respect to angular velocity and in dynamic analysis to calculate natural frequency with respect to given loading condition. Rinkle Garg and Sunil Baghl (2012) has been analyzed crankshaft model and crank throw were created by Pro-E Software and then imported to ANSYS software. The result shows that the improvement in the strength of the crankshaft as the maximum limits of stress, total deformation, and the strain is reduced.The weight of the crankshaft is reduced. There by, reduces the inertia force. As the weight of the crankshaft is decreased this will decrease the cost of the crankshaft and increase the I.C engine performance.

II. Material and Methodology

i. Material- In the present analysis material taken is aluminium alloy and alloy steel. Aluminium alloy is the alloy in which aluminium is the predominant metal. The typical alloying elements are copper, magnesium, manganese, silicon, tin and zinc. Aluminium alloys have properties such as cheap, low density, light weight, high thermal and electrical conductivity, moderate strength, high resistance to corrosion etc. Application in aircraft industries, automotive parts, electrical wiring, decorative purposes, drink cans, window frames etc.Steels are the most important engineering materials, and cover a wide range of alloys based on iron and carbon. Alloy steels containing other elements as well as carbon are classified into low alloy and high alloy, depending on the amount of additional alloying elements. Alloy steel have properties such as high density, heavy weight, poor electrical and thermal conductivity, high strength, poor corrosion resistance etc. Application in railway track, bearings, pressure vessels, shaft, gears, cutting tool, hand tools (spanner, hammer) etc.

ii. Stress Analysis- Analysis of cam and follower is done in ANSYS 14.0 software by different stress parameters and natural frequency. Various stresses are Equivalent stress (von-mises), shear stress, maximum shear stress, and stress intensity. The Cam and Follower is analyzed in ANSYS in three steps. First is pre-processing which involves modelling, geometric clean up, element property definition and meshing. Next step includes solution of problem, which involves imposing boundary conditions on the model and then solution runs. Next in sequence is post processing, which involves analyzing the results plotting different parameters like stress and natural frequency.

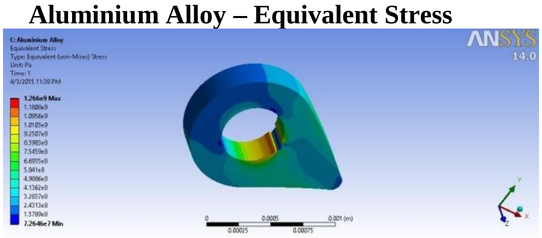
iii. Mode Shape- Analysis of both material of cam and follower is performed by ANSYS 14.0 software to determine the vibration characteristics such as natural frequencies and mode shapes. The natural frequencies and mode shapes are important parameters in the design of a cam and follower. And from static analysis check out various deformation and stresses on cam and follower mechanisms.

iv. Artificial Neural Network- An artificial neuron network (ANN) is a computational model based on the structure and functions of biological neural networks. ANNs are considered nonlinear statistical data modeling tools where the complex relationships between inputs and outputs are modeled or patterns are found. ANNs have three layers that are interconnected. The first layer Neurons. Verification of the result is done through ANN consists of input neurons. Those neurons send data on to the second layer, which in turn sends the output neurons to the third layer. An artificial neural network (ANN) is composed of interconnected artificial neurons that mimic some properties of biological Neurons.

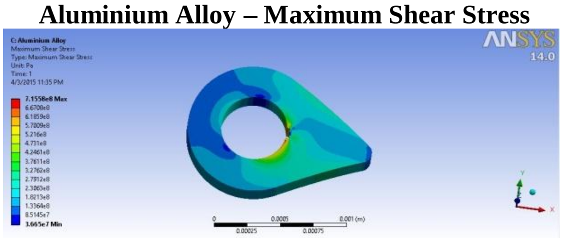
Problem Description

In order to predict the life of cam and follower for both material, an attempt is made to study static analysis and dynamic analysis of cam and follower through ANSYS 14.0 software by considering various types of stresses as well as natural frequency and life prediction through ANN.

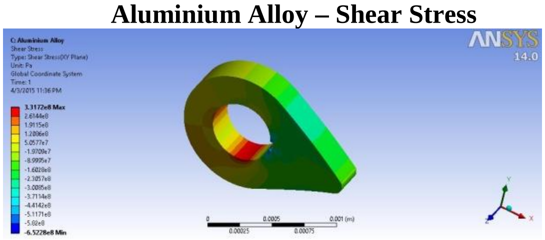
Aluminium Alloy – Equivalent Stress



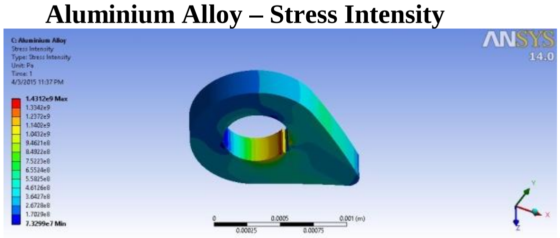
Aluminium Alloy – Maximum Shear Stress



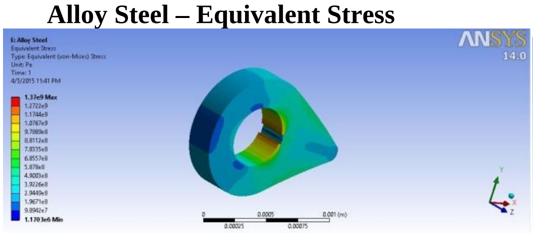
Aluminium Alloy – Shear Stress



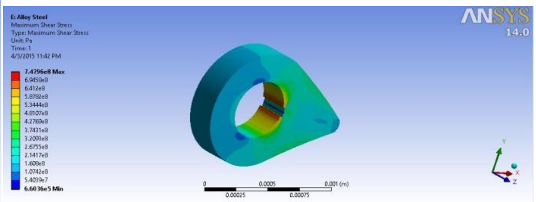
Aluminium Alloy – Stress Intensity



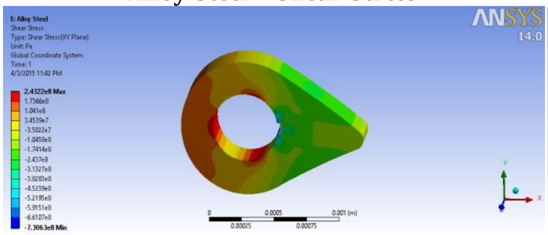
Alloy Steel – Equivalent Stress

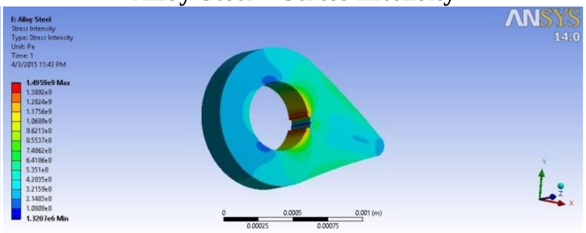


Alloy Steel – Maximum Shear Stress

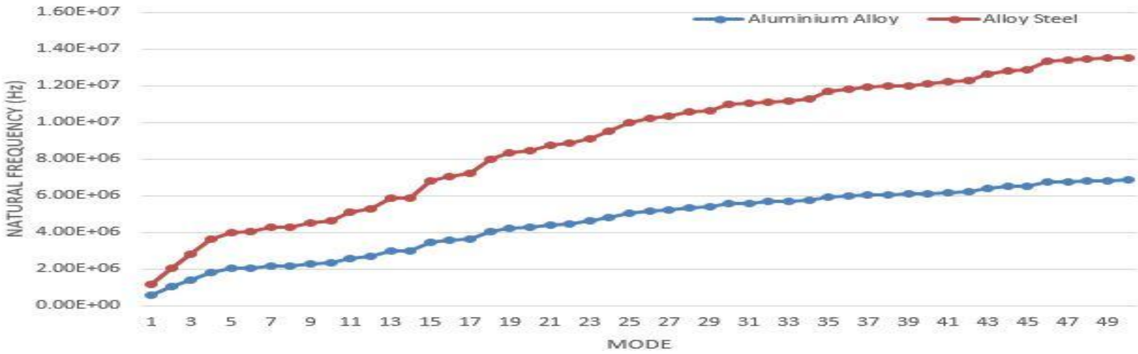


Alloy Steel – Shear Stress **Alloy Steel – Stress Intensity**

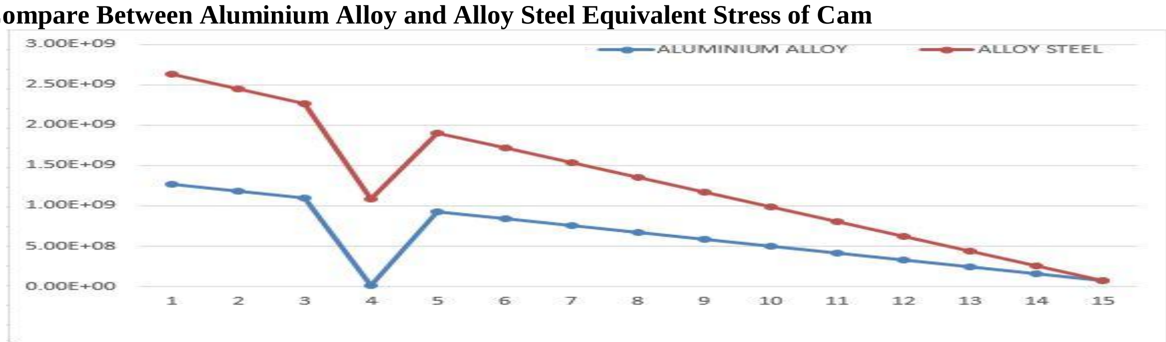




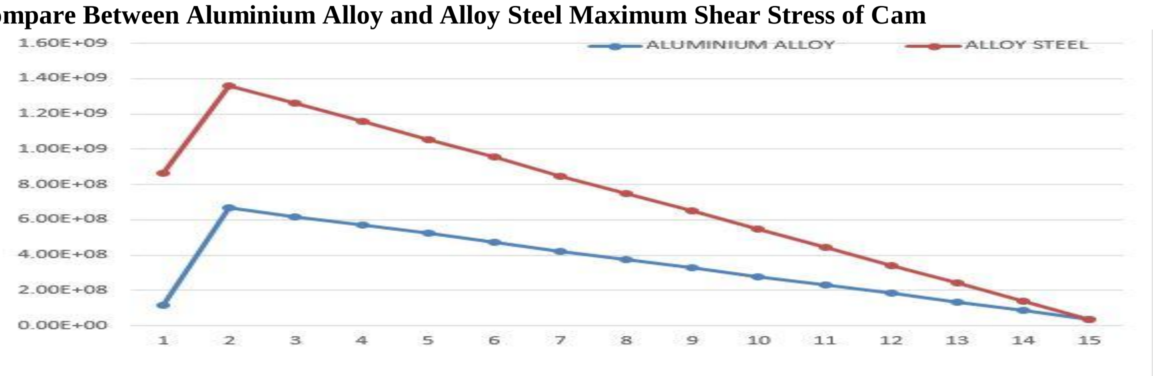
Natural Frequency Vs Mode Shape of Aluminium Alloy and Alloy Steel Cam



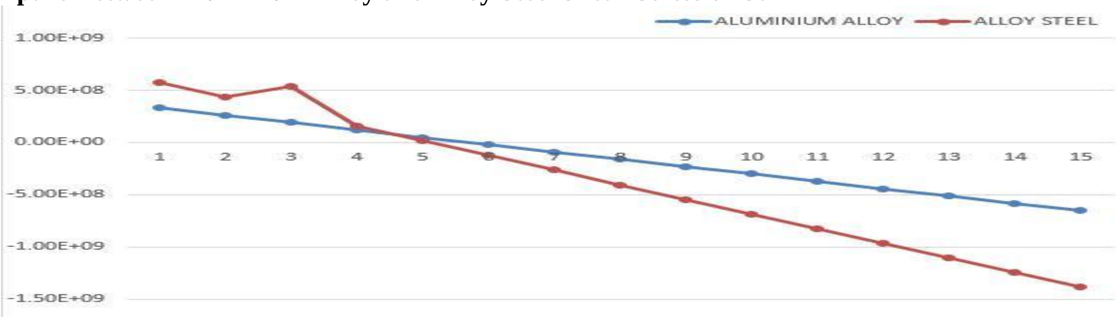
Compare Between Aluminium Alloy and Alloy Steel Equivalent Stress of Cam



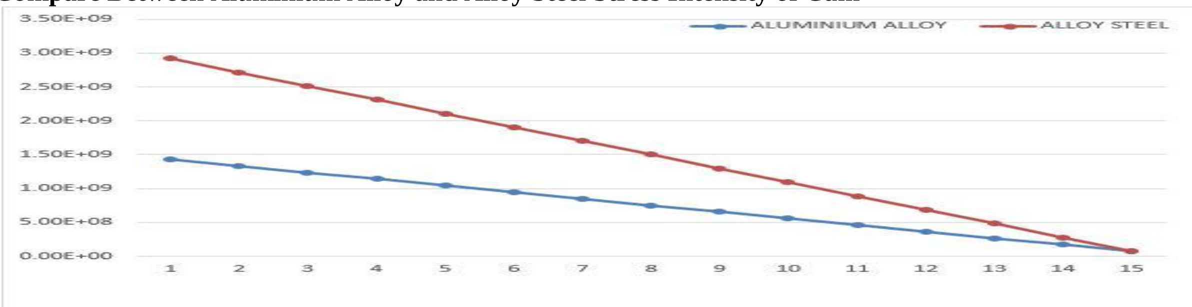
Compare Between Aluminium Alloy and Alloy Steel Maximum Shear Stress of Cam



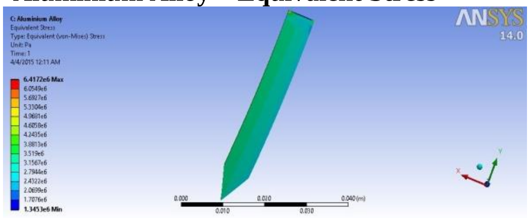
Compare Between Aluminium Alloy and Alloy Steel Shear Stress of Cam



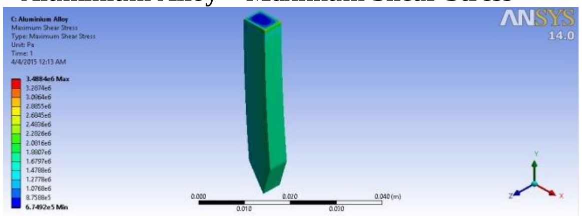
Compare Between Aluminium Alloy and Alloy Steel Stress Intensity of Cam



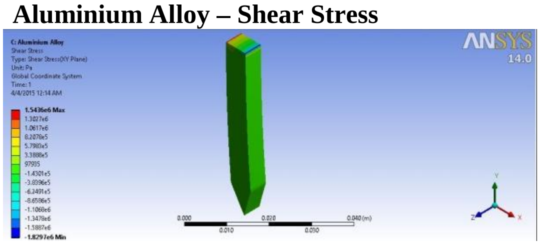
Aluminium Alloy – Equivalent Stress



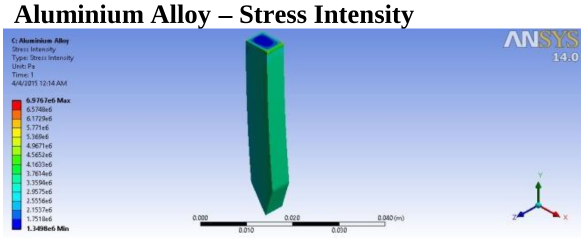
Aluminium Alloy – Maximum Shear Stress



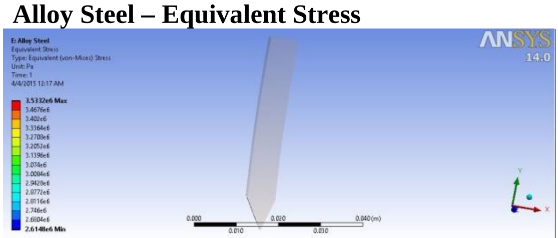
Aluminium Alloy – Shear Stress



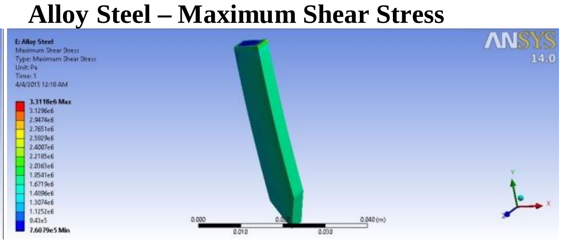
Aluminium Alloy – Stress Intensity



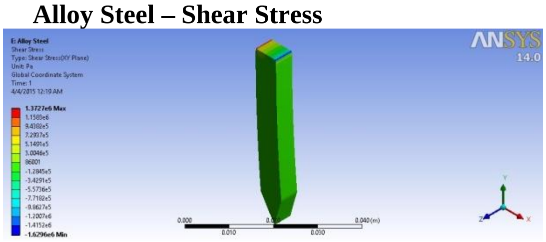
Alloy Steel – Equivalent Stress



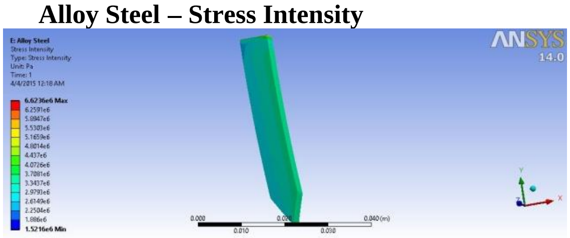
Alloy Steel – Maximum Shear Stress



Alloy Steel – Shear Stress

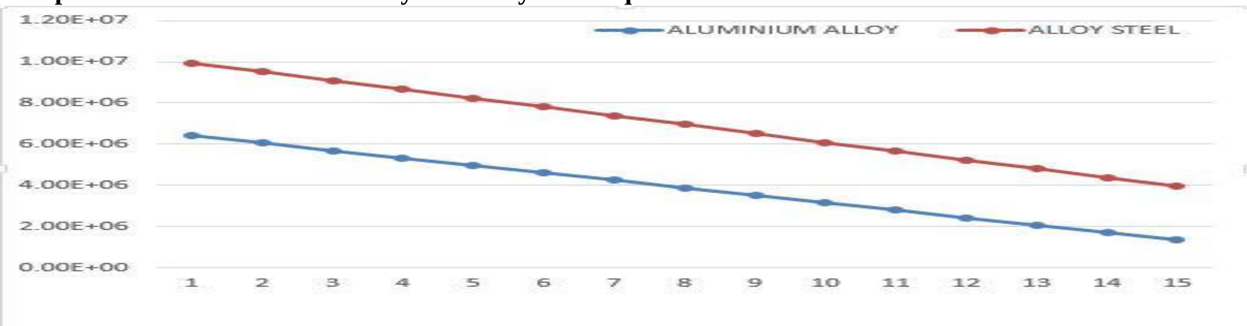


Alloy Steel – Stress Intensity

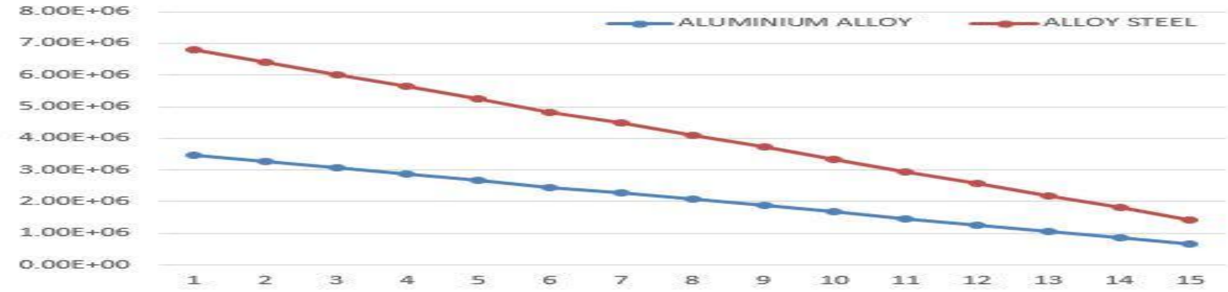


Natural Frequency Vs Mode Shape of Aluminium Alloy and Alloy Steel Follower

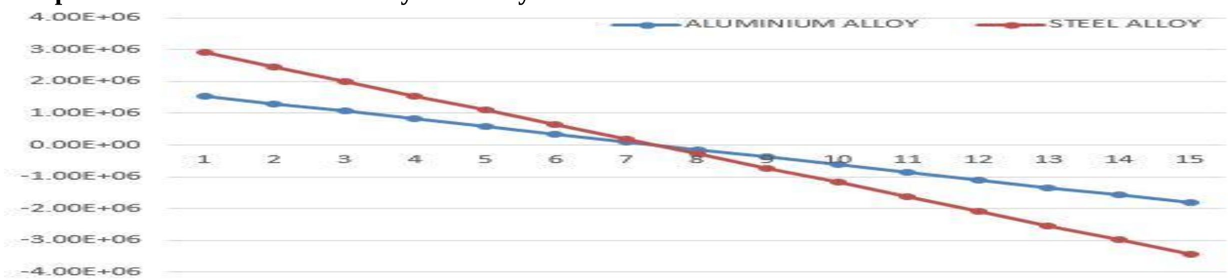
Compare Between Aluminium Alloy and Alloy Steel Equivalent Stress of Follower



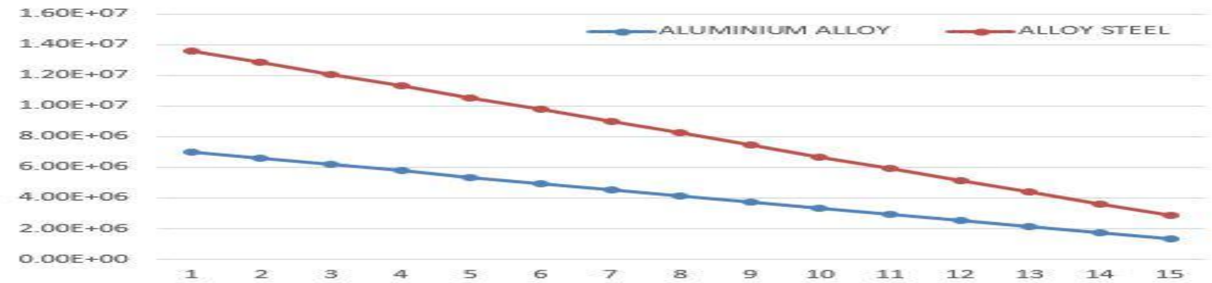
Compare Between Aluminium Alloy and Alloy Steel Maximum Shear Stress of Follower



Compare Between Aluminium Alloy and Alloy Steel Shear Stress of Follower



Compare Between Aluminium Alloy and Alloy Steel Stress Intensity of Follower

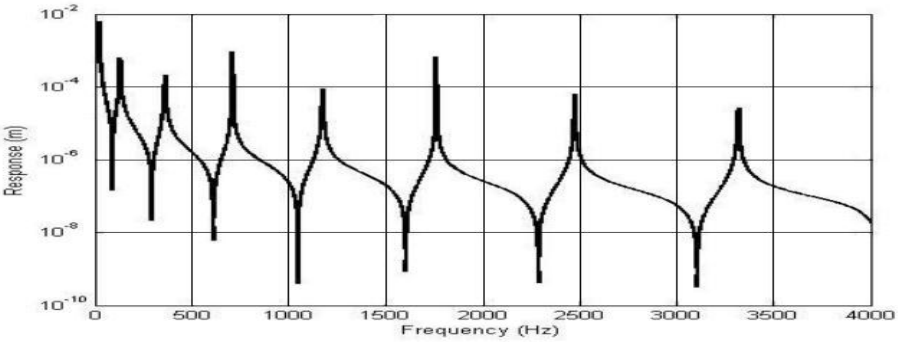


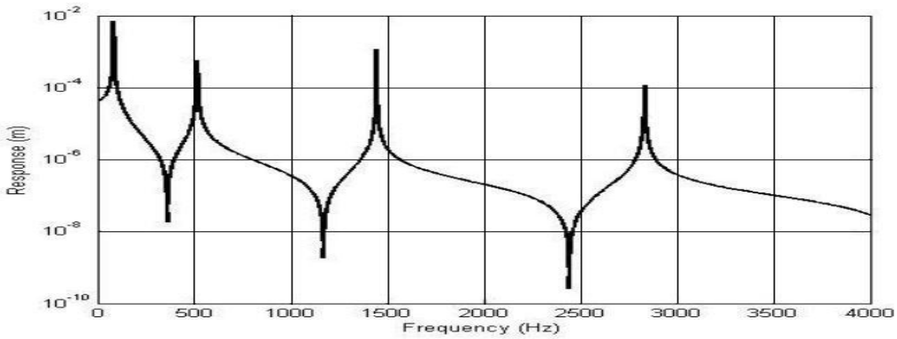
III. Artificial Neural Network (ANN)

Artificial neural systems are that physical cellular systems which acquire, store and utilize experimental information. Powerful learning algorithm and self-organizing rule allow ANN to self-adapt as per the requirements in continually varying environment (adaptability property). The ANN architecture is a multilayer, feed forward back propagation architecture. Multilayer perception (MLP) has an input layer, output layer and hidden layer. Input vector is incident on input layer and then to hidden layer and subsequently to final layer/output layer via. Weighted connections. Each neuron operates by taking the sum of its weighted inputs and passing the results through a non-linear activation function.

For the prediction of life of cam and follower of both the material an ANN network is developed.

Output of ANN





IV. Conclusion

Static Analysis

Aluminium Alloy CAM

From the graph the equivalent stress in cam is continuously increase and its maximum value is 1.2646×10^{9} Pa and its minimum value is 7.2646×10^{7} Pa. The stress intensity in cam is continuously increase and its maximum value is 1.4312×10^{9} Pa and its minimum value is 7.3299×10^{7} Pa. The shear stress in cam is continuously increase and its maximum value is 3.3172×10^{8} Pa and its minimum value is -6.5228×10^{8} Pa. The maximum shear stress in cam is continuously increase and its maximum value is 7.1558×10^{8} Pa and its minimum value is 3.665×10^{7} Pa.

Alloy Steel CAM

From the graph the equivalent stress in cam is continuously increase and its maximum value is 1.37×10^{9} Pa and its minimum value is 1.1703×10^{6} Pa. The stress intensity in cam is continuously increase and its maximum value is 1.4959×10^{9} Pa and its minimum value is 1.3207×10^{6} Pa. The shear stress in cam is continuously increase and its maximum value is 2.4322×10^{8} Pa and its minimum value is -7.3063×10^{8} Pa. The maximum shear stress in cam is continuously increase and its maximum value is 7.4796×10^{8} Pa and its minimum value is 6.6036×10^{5} Pa.

From the analysis of aluminium alloy and alloy steel cam, alloy steel cam is better than the aluminium alloy cam.

Aluminium Alloy FOLLOWER

From the graph the equivalent stress in follower is continuously increase and its maximum value is 6.4172×10^{6} Pa and its minimum value is 1.3453×10^{6} Pa. The stress intensity in follower is continuously increase and its maximum value is 6.9767×10^{6} Pa and its minimum value is 1.3498×10^{6} Pa. The shear stress in follower is continuously increase and its maximum value is 1.5436×10^{6} Pa and its minimum value is -1.8297×10^{6} Pa. The maximum shear stress in follower is continuously increase and its maximum value is 3.4884×10^{6} Pa and its minimum value is 6.7492×10^{5} Pa.

Alloy Steel FOLLOWER

From the graph the equivalent stress in follower is continuously increase and its maximum value is 3.5332×10^{6} Pa and its minimum value is 2.6148×10^{6} Pa. The stress intensity in follower is continuously increase and its maximum value is 6.6236×10^{6} Pa and its minimum value is 1.5216×10^{6} Pa. The shear stress in follower is continuously increase and its maximum value is 1.3727×10^{6} Pa and its minimum value is -1.6296×10^{6} Pa. The maximum shear stress in follower is continuously increase and its maximum value is $3.3118x10^6$ Pa and its minimum value is $7.6079x10^5$ Pa.

From the analysis of aluminium alloy and alloy steel follower, alloy steel follower is better than aluminium alloy follower.

Dynamic Analysis

From the analysis, the natural frequency obtained through the graph shows that the frequency of alloy steel cam and follower is higher than aluminium alloy cam and follower.

Life Prediction

From the analysis through artificial neural network, the output graph of ANN shows that the life of alloy steel cam and follower is greater as compared to the life of aluminium alloy cam and follower on the basis of static analysis and the dynamic analysis.

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