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Design Optimisation of Cam Shaft Angle Monitoring System For Industrial Improvements

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Abstract: - Camshaft is used in the engine for transfers' motion to inlet & exhaust valve. If transfer of motion is not proper then the strokes of the engine will not done in proper way. It also effects on performance of engine. This research deals with the optimization of drive camshaft using the substitution of composite material over the conventional steel material for drive shaft has increasing the advantages of design due to its high specific stiffness and strength. Drive shaft is the main component of drive system of an automobile electronics. Use of conventional steel for manufacturing of drive shaft has many disadvantages such as low specific stiffness and strength. Conventional drive shaft is made up into two parts to increase its fundamental natural bending frequency. As its simplest a camshaft inspection system can consist of a Roll scan, camshaft sensor, sensor arm and manually rotatable stand for the camshaft. The camshaft, which controls when the inlet and exhaust valves open and close, plays a significant role in this process. To Measure the angle of cam shaft with 0.5mm precision level and also control product quality.

Keywords: - *Cam shaft, LVDT Sensor, Servo Motor, Electro Mechanical Valve, Drive Shaft*

I. INTRODUCTION

Automotive control and electronics is increasing its presence and importance every day in today's industrial operations. Consequently, complicated electronic angle monitoring systems have been around for decades. Their complexity is steadily increasing due to increased levels of conflicting demands on allowed levels of undesired emissions. The increased complexity of angle monitoring systems is made possible by advances in embedded control hardware and the use of advanced control methods. Automobile control systems exist as code in an Electronic Control Unit (ECU) in production vehicles. The review is structured as cam shaft modeling, vibrations and mounting areas and revealed the gaps and untouched parts that requires further research. Camshaft is used in the engine for transfer's motion to inlet & exhaust valve. If transfer of motion is not proper then stokes will not work in proper way. Also it effects on performance of engine. It is required in order to design a good mechanism linkage, the dynamic behavior of the components must be considered; the shaft mounts should have characteristics of high stiffness and high damping in the low-frequency range and of low stiffness and low damping in the high-frequency range. Hydraulic mounts do not perfectly satisfy such requirements. Although hydraulic mounts greatly increase damping at low frequencies, they also degrade isolation performance at higher frequencies. Also hydraulic mounts are not cost effective; they had complexity in design and low reliability.

II. SHAFT ENGINE VIBRATIONS, LINEAR VARIABLE DIFFERENTIAL TRANSFORMERS (LVDT) OPERATION

The vibration caused by the engine at the supports is torsion vibration and the longitudinal vibration. The torsion vibration is caused at the crankshaft due to the fluctuating engine combustion pressures and engine loads. The longitudinal vibrations are caused at the block and the mounts by the reciprocating and rotating parts of the engine. They modeled the engine parts as rigid bodies connected to the rubber mounts which were modeled with spring and damping elements. They used encoder signal, to measure the speed of the shaft, to develop the instantaneous angular speed (IAS) wave form which is the significance of torsion vibration.

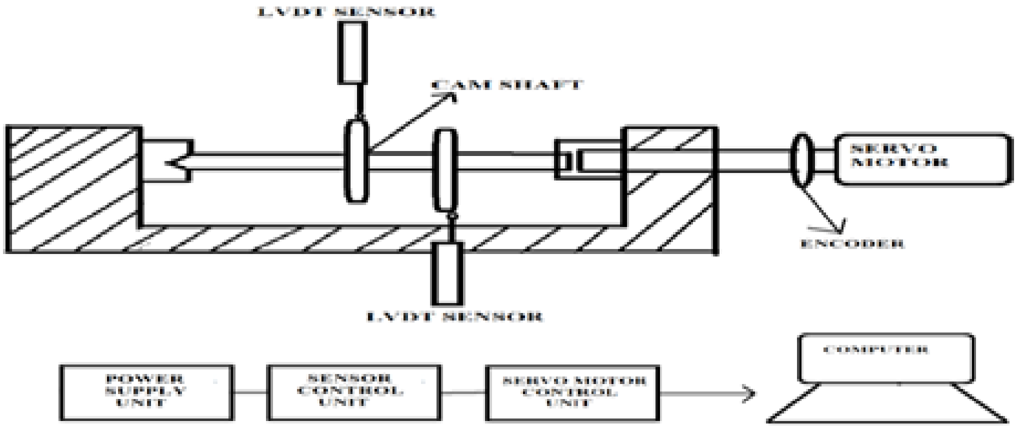

Fig.1: Operational Electro Mechanical Rotation System

They used IAS and fast Fourier transform (FFT) to monitor the shaft. In this investigation enhanced FFT was used by improving signal processing to determine the IAS signal. They also introduced a novel method to present IAS signal through polar coordinates. They identified that cylinder wise non-uniform torque was the reason for the increased torsion vibration and stresses at the mechanical parts of the engine. The non-uniform torque in each cylinder can be balanced by adjusting and controlling the cylinder wise fuel injections so that the balancing of torque will be obtained. The linear variable differential transformer (LVDT) is an accurate and reliable method for measuring linear distance. LVDTs find uses in modern machine-tool, robotics, avionics, and computerized manufacturing. The LVDT is a position-to-electrical sensor whose output is proportional to the position of a movable magnetic core. The core moves linearly inside a transformer consisting of a center primary coil and two outer secondary coils wound on a cylindrical form. The primary winding is excited with an AC voltage source (typically several kHz), inducing secondary voltages which vary with the position of the magnetic core within the assembly. The core is usually threaded in order to facilitate attachment to a non ferromagnetic rod which in turn in attached to the object whose movement or displacement is being measured.

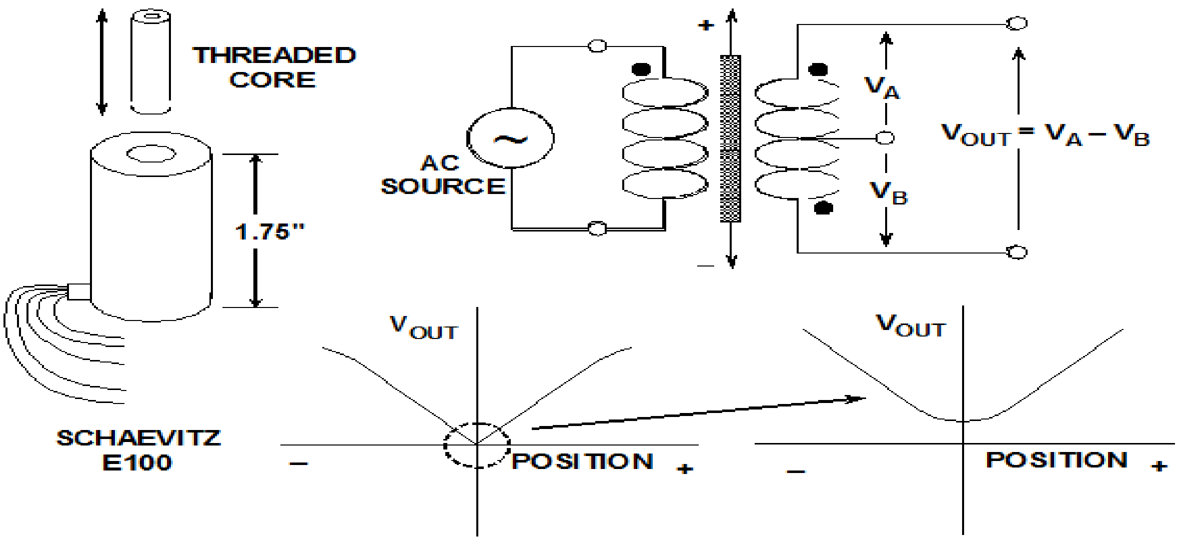

Fig.2: Position and Angle Measurement of LVDT Sensor

The industry-standard AD598 LVDT signal conditioner performs all required LVDT signal processing. The on-chip excitation frequency oscillator can be set from 20 Hz to 20 kHz with a single external capacitor. Two absolute value circuits followed by two filters are used to detect the amplitude of the A and B channel inputs. Analog circuits are then used to generate the ratio metric function [A – B]/[A + B].

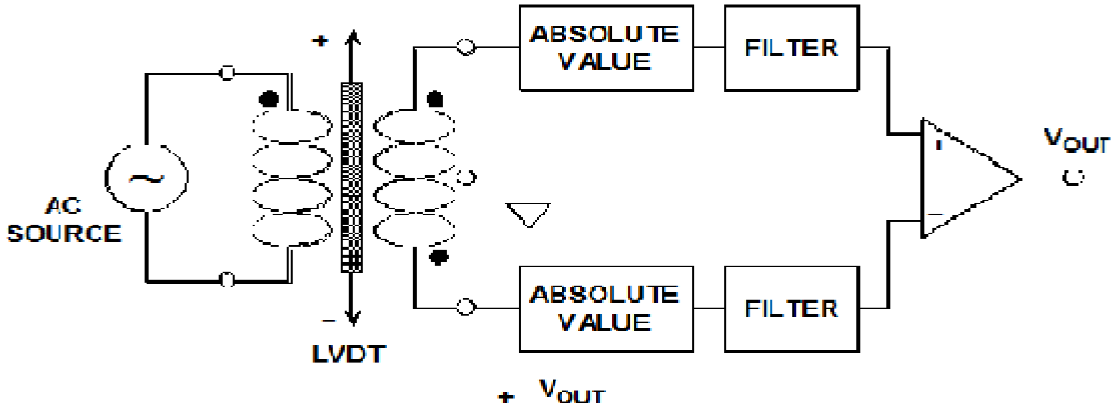

Fig.3: LVDT Configuration in Signal Processing Unit

Note that this function is independent of the amplitude of the primary winding excitation voltage, assuming the sum of the LVDT output voltage amplitudes remains constant over the operating range. Using this technique, both positive and negative variations about the center position can be measured. While a diode/capacitor-type rectifier could be used as the absolute value circuit, the precision rectifier shown in Figure 3.3 is more accurate and linear. The input is applied to a V/I converter which in turn drives an analog multiplier. The sign of the differential input is detected by the comparator whose output switches the sign of the V/I output via the analog multiplier. The final output is a precision replica of the absolute value of the input. These circuits are well understood by IC designers and are easy to implement on modern bipolar processes.

III. CAM OPERATION TIMING MODULE SYSTEM TESTING APPARATUS

When the starting point of cam lift comes, the electromagnetic valve switches on. The oil that has been pumped out from the cam cylinder flows to the oil tank through the oil pump line and it will identify the different flaw errors. When cam comes to the angle of the valve needs to open, the electromagnetic valve closes. Then all of the oil that has been pumped out from the cam cylinder goes into the valve cylinder. When the force of oil acts on the valve piston is greater than the sum of valve spring's pre-tightening force and the friction force between the valve piston and valve cylinder, the valve opens and the opening of valve gradually increases until the end of cam lift. The oil flows back to the cam cylinder. The pressure of oil decreases at the same time.

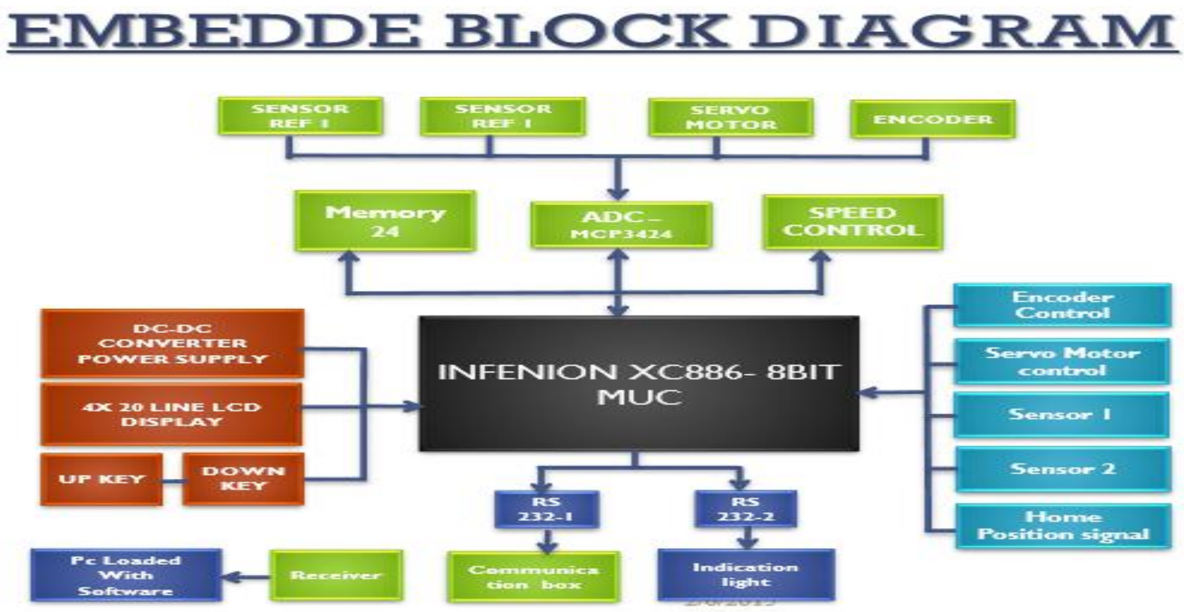

Fig.4: CAM Operation Embedded Block Diagram

When the force of oil acts on the valve piston less than the sum of valve spring's pre-tightening force and the friction force between the valve piston and valve cylinder, the valve seats. If the oil pressure of system under the set value, the oil filling system would supply oil to keep the pressure. From the working process of the system, the electromagnetic valve closing time affects the time of hydraulic oil flows into the valve cylinder, the volume and the time of hydraulic oil flows from it. When the force of oil acts on the valve piston is greater than the sum of valve spring's pre-tightening force and the friction force between the valve piston and valve cylinder, the valve opens. While cam is in return, the valve falls back under the action of the valve spring. When the force of oil acts on the valve piston less than the sum of valve spring's pre-tightening force and the friction force between the valve piston and valve cylinder, the valve seats. The time and the volume of oil into the valve cylinder are controlled by controlling the on-off time of the electromagnetic valve in the system. The control signal of electromagnetic valve depends on the cam angle signal. The servo motor simulates the engine to provide power for the cam shaft. The different shaft design is to be simulated by the servo driver adjusts the rotating speed of servo motor. Servo motor, electromagnetic valve and the motor of oil pump are controlled by Programmable Logic Controller (PLC). The signals of LVDT sensor are processed by PLC and then used to control the on-off of the electromagnetic valve. Human Machine Interface (HMI) is used to input the rotating speed of servo motor and human-computer interaction of other information of system. Phase sensor is used to measure the phase of camshaft. The real-time cam design is measured by LVDT sensor. Laser displacement sensor is used measured the real-time displacement of valve. All signals are collected and recorded by the data acquisition system, and are processed and analyzed by computer.

IV. MOUNTINGS

Mounts are designed to satisfy two important criteria the first is the support function, reduction of the large amplitude vibration, at lower resonance bands. It requires the mountings to have higher stiffness and damping. The other is noise control; the mountings have to reduce the noise in the supporting structures induced by small amplitude vibration of the engine, at higher bands. It requires the mountings to posses lower stiffness and damping. These two requirements are contradictory, and the main aim in the design of engine mounts is to stabilize these two different conflicting requirements. The electrometric part of the mount provides the basic isolation and the expandable volume provides the additional isolation by pressurized/exhausted air, supplied from the engine, with help of control valves. The simulations were made to find mount displacements during taxi, climp, cruise and decent conditions of the air craft. The authors stated that the heat transfer rate between inlet and outlet air was excessive and will be considered in future study. The design variables are geometry of inertia track, resultant stiffness and damping characteristics. The parametric studies were presented the relation between the equivalent viscous damping coefficient and the design variables. The authors discussed the lumped parameter and dynamic performance characteristics of the mounts. Based on these two combinations the efficient design technique for the hydraulic mount was made. A Multi-Body Dynamic Simulation (MBDS) of the shaft was carried out by simulating to estimate the forces acting on the cylinder block. The dynamics of the engine is described taking into account the effects of the gas pressure and the inertia forces of the moving parts.

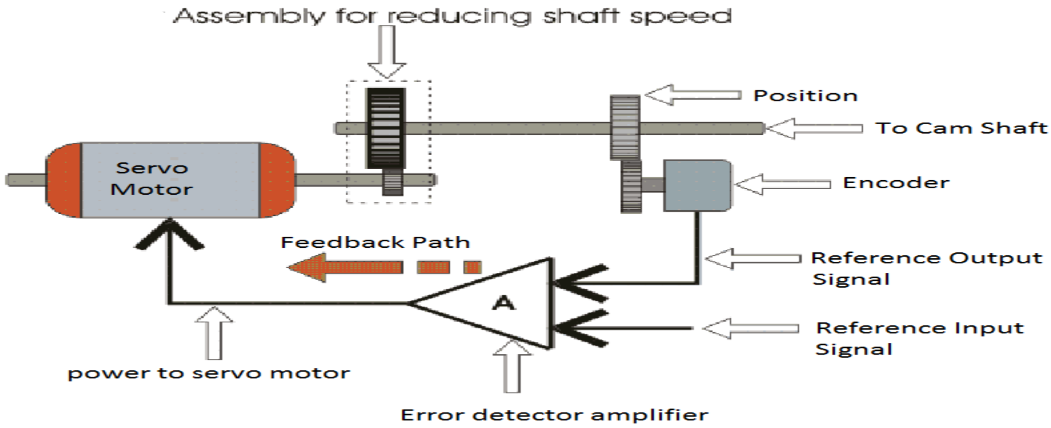

Fig.5: Mechanical Block Diagram

In this work to identify the real engine operating behavior, both the crank and the block have been considered as flexible bodies. They developed a set of equations for the fluid transfer analysis of mass flow rate and pressure difference between the lower and upper chambers. The fluid structure interaction finite element (FSI FE) modeling of lower and upper chamber was done they were bridged and finally the HDM integrates the FSI FE and fluid transfer characteristics models. The author states that such type of integration of hydrostatic FSI approach with lumped parameter modeling of fluid track can reduce the computational cost of FSI in HDM.

The developed model was considered as basic model and modification were made for the large deformation and endurance analysis of the rubber mounts. The model was simulated in the bush type rubber mount for optimization of the shape of the mount and subsequently for the desired stiffness values. They arrived the fatigue life equation for the natural rubber material based on uniaxial tensile test and fatigue life tests of the natural rubber and the strain distribution contours and the maximum total principal strains at different loads in the x and y directions were obtained using FEA method. The survey was on the basis of overview and development of different shaft mounts and optimization of the electrical and mechanical mount systems. They made a study about the ideal angle monitoring and mounting system which would isolate the vibration excitations from the concentration requirement of improvement of frequency and amplitude dependent properties. They explored how the rubber mounts trade-off the static deflection and provides the vibration isolation.

V. DESIGN REQUIREMENTS FOR CAM SHAFT

The conventional steel material is replaceable by advanced composite materials. Composite materials are favored by most of the scientist in the design of automobiles due to its higher specific strength and stiffness. Weeton et al stated the possibilities of replacing the conventional steel material by composites in the field of automobile also describe the possibilities of composites used to replace the steel leaf spring as well as steel drive shaft. In metallic shaft design, knowing the torque and the allowable service shear stress for the material allows t he size of the shaft's cross-section to be determined. Jerwin prabu.A et al. is also states that the art of creating machines that performs functions that require intelligence when performed by people. A re programmable, multi functional manipulator designed to move material, parts, or specialized devices through various tools, or specialized devices through various programmed motions for the performance of a programmed motion for the performance of a variety of tasks. Conventional steel drive shafts are manufacture in two pieces to increase its fundamental natural bending frequency. The conventional assembly of drive shaft is made up in two pieces and joined together by u-joints due to which the overall weight of the assembly is increased. The second achievement was to develop a fault generator program for cam shaft speed sensor signals. This program is able to handle simulation of broken, disturbed or amplified signals for individual cam speed sensor teeth (pulses) as well as synchronization faults between crank and cam shaft sensor signals

Table 1: Different Parameter of Shaft Values

Parameter of Shaft	Symbol	Value	Unit
Outer Diameter	D_o	85	Mm
Inner Diameter	D_i	78.42	Mm
Length of the Shaft	L	1130	Mm
Thickness of shaft	T	3.32	Mm

5.1 Design of Steel Drive Camshaft

Mass of the steel drive shaft,

"m= ρAL
= ρ × Π/4 × (do2- d 2) ×L" … (1)
= 7600 x 3.14/4 x (852 – 78.422) x 1130 [m = 7.24 Kg]
Torque transmission capacity of steel drive shaft,
"T= Ss× Π /16 × [(do4- di4) × do]" … (2)
[T = 55.93 ×103 N-m] Fundamental Natural frequency,

The natural frequency can be found by using the two theories:

1) Timoshenko Beam theory
2) Bernoulli Euler Theory

Timoshenko Beam Theory-Ncrt
"fnt= Ks (30 Π p2) / L2 X √ (Er2 / 2ρ)" …..(3)
"Ncrt = 60 fnt" …..(4)

fnt= natural frequency base on Timoshenko beam theory,
HZ Ks = Shear coefficient of lateral natural frequency

p = 1, first natural frequency r = mean radius of shaft

Fs = Shape factor, 2 for hollow circular cross section
n = no of ply thickness, 1 for steel shafts

"$1 / Ks\,2 = 1 + (n2\Pi\ 2\ r2) / 2L2\ X\ [1 + fs\ E / G]$" …. (5)
$1 / Ks\ 2 = 1 + (12\Pi\ 2\ 76.822) / 2\ x11302\ X\ [1 + 2x207x103 / 80\ x103]$ [Ks= 0.782]
$fnt = 0.782\ (30\ x\ \Pi\ x\ 12) / 1250\ x\ \sqrt{}\ (207x103\ x\ 78.422/2x\ 7600)$
[fnt= 276.54 Hz] [Ncrt = 15972.4 rpm]

VI. RESULT AND DISCUSSION

When an elastic system free from external forces can disturbed from its equilibrium position and vibrates under the influence of inherent forces and is said to be in the state of free vibration. It will vibrate at its natural frequency and amplitude will gradually become smaller with time due to energy being dissipated by motion. The main parameters of interest in free vibration are natural frequency and the amplitude. Modal analysis is used to determine the vibration characteristics such as natural frequencies and mode shapes of a structure or a machine component while it is being designed. The natural frequencies and the mode shapes are important parameters in the design Cam shaft of a structure for dynamic loading conditions. Separate program with a graphical user interface has been prepared to create these two waveforms offline, i.e. before the simulation. This program also allows the user to create crank and camshaft signals with a variety of faults. Possible faults which can be created by the program include missing peaks in the crank or camshaft sensor, changes in width or height of chosen parts of the signal (usually the peaks) and the addition of sensor noise.

Fig.6. Final Electro Mechanical Module

The actual level of these stresses as compared to design or expected stress levels in their studied engine was unknown. Cams are designed to control the open and close intervals of the inlet and exhaust poppet valves. The radial cam used for this purpose consists of a circular disc having a semi- oval triangular protrusion. Rotation of the cam causes its profile to slide against the smooth flat closed end of a cylindrical shaft. The cam profile has a follower lift or valve opening side and a corresponding follower fall or valve closing side. Both the lift and fall sides of the profile can be divided in to three phases which are; the cam ramp, the cam flank and, the cam nose and measure the angle of cam shaft with 0.5mm precision level. Reference of given graph form computer, we can measure the Camshaft profile to obtain on line data logging system and also identify whether the casting dimension within the specification and Control the product quality. Data transmit from PC to Controller through CAN. For generation of cam shaft sensor signals, APU was used in this system instead of analog I/O channels. Analog output channels were used for simulation of other pressure and temperature sensor signals. Since the APU handles generation of the crank and cam shaft signals when the waveform is given, the CPU processing power can be used for running engine models or for other computational operations.

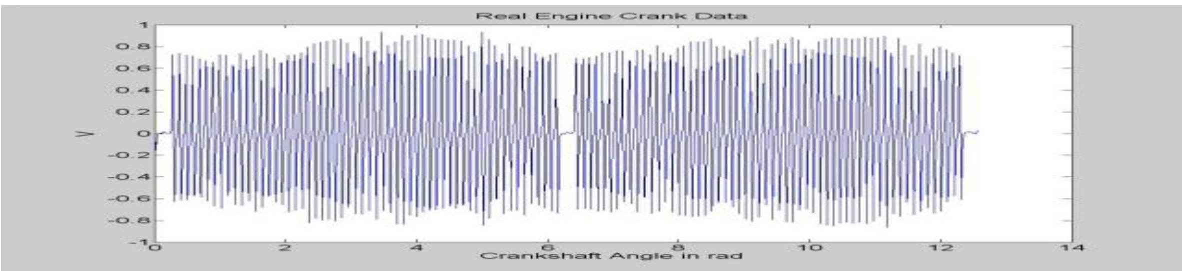

Fig.6: Engine Crank Data Monitoring

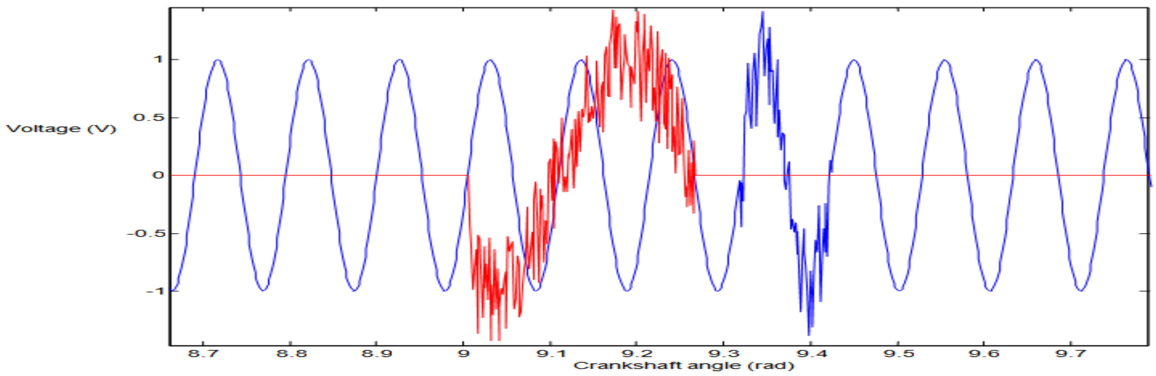

Fig.7: Crank Shaft Angle Monitoring

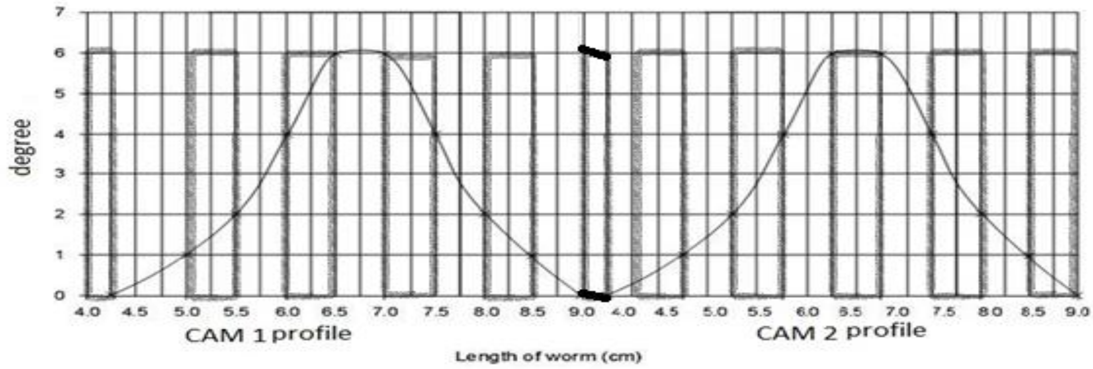

Fig.8: CAM Profile I and II Output Flow Graph

VII. CONCLUSION

Use of this impact model for an industrial cam-follower system can guide mechanical engineers through the designing stage of assembly machines with impact and over-travel more efficiently. This model will allow the elimination time-consuming methods, which will reduce machine development costs and development time. It is seen that, the analyzed camshaft is fractured after a very short period of usage of the industry. The finite element analysis is used in this work to predict the deformation of shaft. The results of the work are encouraging and suggesting to Measure the Machine ADC reading by means Camshaft Angle and servo Motor Drive reading. The analog o/p from LVDT Sensor will convert to Digital via ADC and feed to controller compares this i/p & ref. value and give control signal to relay unit. Based on control signal Relay unit will cut supply to Servo Motor. The A and B signal processors each consist of an absolute value function and a filter. The A output is then divided by the B output to produce a final output which is radiometric and independent of the excitation voltage amplitude. Complete work piece verification takes between two to five minutes. The cycle times vary depending on the type and size of each camshaft. During the measuring run, the active CNC steps are displayed on the screen of the measuring computer. The measured characteristics, such as cam base circle, cam pitch, diameter, roundness and parallelism, are then evaluated automatically. The DOT NET software operates in Windows and is easy to program and use. Work pieces that are outside the tolerance are classed as NOK (not OK) and automatically rejected. The paper finally addressed aspects for achieving reliable information, which interacts with measurement system parameters. To further evaluate the presented techniques, more experiments are currently being carried out on some common types of rotating machines.

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