Disturbance Investigations in Vehicle-Roads & Cam Follower Systems –A Review Paper.

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Abstract-Dynamics in vehicle motion is an important area of research . Many studies and experiments show that vehicle motion is affected by undesired dynamics, which may reduce its accuracy of travel on road surface. Different methods and techniques are used to reduce such undesired forces and vibrational effects. This paper is to seek an opportunity in an investigation of controlling vehicle motion as well as the effects of roads on vehicle comfort and safety. Different researchers have directed their studies to the same goal. In this paper we tried to review and analyze such studies. Minimizing the sum of the amplitudes of the forces transmitted to the adjacent structures is always critical in vehicle dynamics. Simultaneously a precise control of vehicle stability is needed. We tried in this paper to combine the study of vehicles on road speed breakers, correlated to the cam and follower systems. The cam dynamics involves phenomenon like jump and jerk. These effects are correlated to the vehicle dynamics, which will be an exhaustive attempt towards zero accidents and failures.This paper reviews cases of dynamic effects and results of undesired and uncontrolled motion in vehicle-road as well as cam-follower systems.

Keywords: cam, followers, dynamics, jump, vehicles, vibration

I. INTRODUCTION

It is always important to analyse the vehicles on roads for safety and comfort [1]. To study the dynamic behaviour of such systems is always crucial in analysis for deformations and failures. This is a realistic approach to study the failure of vehicles which is mainly a function of stress [1, 2]. The problem of surface fatigue wear becomes severe as the contact between road and vehicle exceeds the limit. This paper illustrates the behaviour pattern of road-vehicle systems with the help of surveying different papers and also reviewing papers on cam follower pairs, which undergoes rolling-sliding contact conditions. Thus, for comparing any measured data, like jumping of a vehicle from road can be correlated to cam-follower dynamics [3,4]. At some point of operation, vehicles on roads or cam-follower systems may suffers from surface fatigue failures because of the repetition of contact load. This is characterized by pitting of the surfaces, and it rather occurs suddenly without any prior visible warning. When the surface fatigue wear occurs, the particles are removed and the resulting pits are relatively large. Studying the impact parameters in vehicles and cam-followers is always a key in handling and analysing the accident data, if at all it happens. Human lives are valuable and any new approach in progress towards zero breakdown or failures of such systems is always desirable [5].

II. OVERVIEW OF VEHICLE ACIDENTS & CAM-FOLLOWER DYNAMICS

A report on Road Accidents in India by Ministry of Road Transport & Highways, 2016 ,Government of India [1], highlights on facts that road transport is the dominant mode of transport in India, both in terms of traffic share & in terms of contribution to the national economy. To meet the demand for road transport, the number of vehicles & the length of road network have increased over the years. A negative externality associated with expansion in road network, motorization & urbanization in the country is the increase in road accidents & road crash fatalities. Today, road traffic injuries are one of the leading causes of death, disabilities & hospitalization in the country causing huge socio-economic costs. Report also provides overview on road length, type of motor vehicles & accidents on Indian Roads. In section III, accidents by road categories & road features-accidents according to road conditions, report highlights that over nine thousand five hundred accidents occurred on speed breakers during the calendar year 2016.Also potholes accounted around six thousand four hundred accidents. Cars, Jeeps & taxis accounted for 23.6% of accidents & two wheelers are accounted for 33.8% of accidents.

A report on , Mumbai-Pune Expressway Road Accidents Study,2017,Office of the Additional Director General of Police (Traffic) [2],highlights on the facts about speeding, that influencing immensely on accident occurrence. The results are severe on speed breakers or on unevenness surfaces .At least 20 % of the driver jumps on the speed breakers unknowingly. Report also highlights on rumble strips and vibration in vehicles. It is also highlighted that traction of tires getting reduced due to the weight in the car.

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Paper named as, measuring cam follower performance, presented by author T.K.Naskar and S. Acharyya [3] introduced an experimental analysis on dynamic response of jerk optimization and size optimized cam. They make the use of the advanced techniques like data acquisition and data processing. The cam surface is being prepared by a precision manufacturing process. In this paper author got what they really expected for the real ground, it means that experimental output get matched with the theoretical predictions. The method adopted here was considering the elastic deformation of the cam surface in order to measure the performance.

Fred Mannering [4] presented a paper on temporal instability and the analysis of highway accident data. He found that every statistical analysis of highway safety data is predicted on the assumption that the estimated model parameters are temporarily stable. He discussed on overview of accident data analysis and the temporal element. His main focus was on better interpretation of accident data findings.

Authors Sriram Sundar et al. [5] introduced a paper on Estimation of Impact damping parameters for a cam-follower system based on measurements and analytical model. In this paper a new cam-follower system experiment was performed, capable of generating periodic impacts to estimate the impact damping model parameters. The experiment was focused on acceleration during impulsive events. They summarised the results in terms of damping parameters.

Livija Cveticanin [6] presented a paper, stability of motion of the cam-follower system, in which he analysed the dynamics of cam mechanisms. The mechanism is modelled as a cam-follower-driveshaft system where the flexibility of the camshaft and of the follower is considered. The non-linear & damping properties are also considered. Most importantly the cam mechanism is modelled as a two-degree of freedom system. The mathematical model of the system is considered with two coupled non-linear second order differential equations. The stability of motion of the system is investigated. Based on the criterion of stability the method for obtaining cam profile is developed. And then the results are validated analytically.

Niccolo Baldanzini et al. [7] presented paper on designing the Dynamic Behavior of an Engine Suspension System through Genetic Algorithms. They really presented an innovative approach towards the work to develop a method for predicting the dynamic behavior of an automotive subsystem as part of the optimization process. They make the use of the genetic algorithm to optimize the dynamic behavior of the engine-sub frame system and its links to the chassis. The main importance of the optimizations to minimize the sum of the amplitudes of the forces transmitted to the chassis from each mounting, while complying with the static and dynamic constraints. A new improved system is derived from applying the genetic algorithm to multi body system model.

A paper, synthesis of inertially compensated variable-speed cams is presented by B. Demeulenaere & J. De Schutter [8]. In cam-follower systems, vibration prevention is must in order to avoid further security issues. This can be done by designing a sufficiently smooth follower-displacement program. They explained that a constant camshaft speed is considered while designing the cam- follower system. As per their consideration the speed fluctuation problem is there in the cam-follower systems, especially which causes the follower motions to be inaccurate. This paper therefore explained a novel design procedure that considers the camshaft speed variation. They design method for rigid cam-follower systems with dominating inertial forces has been developed. The method is based on the assumption of a conservative, purely inertial system, and has only few design parameters.

G.Verros & S.Natsiavas [9] presented a paper, ride dynamics of non-linear vehicle models using component mode synthesis. In this paper a general methodology is presented for investigating ride dynamics of large order vehicle models in a systematic & computationally efficient way. The important system parameters are assumed to be constant, leading to linear formulations. More accurate & involved models are examined by including typical nonlinearities in the tires & the shock absorbers. Emphasis is placed on taking into account the possibility of temporary separation of a wheel from ground. Finally results are also presented for transient road excitations.

Forrest W. Flocker [10] discusses the topic as addressing cam wear and follower jump in single-dwell cam-follower systems with an adjustable modified trapezoidal acceleration cam profile. They developed a modified trapezoidal cam profile with an adjustable forward and backward acceleration. The main importance of this profile is it allows cam designers to choose easily a value for the maximum forward or maximum backward acceleration to achieve design objectives. They deal with two main concerns that are large forward acceleration and backward acceleration tends to reduce the cam-follower interface force, Because of this profile one can easily reduce forward or backward acceleration to prevent these problems.

Jiaxi Zhou et al. [11] presented a paper on nonlinear dynamic characteristics of a quasi-zero stiffness vibration isolator with cam-roller-spring mechanisms. In this paper they explain that the property of quasi-zero stiffness (QZS) of vibration isolation system (VIS) could be realized by using the conceptual design of cam-roller-spring mechanism (CRSMs).They developed this idea into a physical prototype and studied vibration isolation performance.

Walter V. Wedig [12] presented a paper, new resonances & velocity jumps in nonlinear road-vehicle dynamics. He

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explains that the vertical vibrations of the vehicle determine the characteristics of the stationary driving force needed to control & maintain a constant velocity. First and second order profiles are modeled by linear filter equations under white noise which allow forward & backward drives. The contact between road & vehicle leads to a nonlinear resistance force determined by damper & spring force of the vehicle multiplied by the road process which represents the vertical road velocity relative to the moving vehicle .The paper deals with half car model and also a quarter car model for resonance investigations.

Authors Nigam Chandra Parida et al. [13] presented paper on topic, Rollover-Preventive Force Synthesis at Active Suspensions in a Vehicle Performing a Severe Maneuver with Wheels Lifted Off. They show that a nonlinear constrained vehicle dynamics model of rollover stabilization is possibly useful as an enhancement of existing models with a view of providing fault tolerance and increased safety to existing rollover-preventive active suspension systems. In this paper, they gave an algorithm for the problem by solving it as a dynamic optimization problem. Their main aim was to synthesize and allocate the roll-stabilizing time-dependent active suspension forces in terms of sensor output data.

Paper named as, on the direct control of follower vibrations in cam–follower mechanisms, is presented by Gianluca Gatti & Domenico Mundo [14]. They addressed issues in this paper about control of follower vibrations in cam–follower mechanisms. The accuracy may get compromised because of the follower motion by undesired dynamics. As there were various technique that actually help to reduce the vibration but may raises some in built problem that doesn't support the proper results. The main objective of this paper was to investigate the feasibility of controlling follower motion by applying a secondary force directly onto it.

Authors Hsien-Ping Chui et al. [15] wrote paper on topic named as self-tuning of safety-assistance brake controller of wheeled vehicles. In that paper they deal with the safety of the vehicle when they loss the control in the speed. There was vehicle active control system provided to assist the driver in such extreme condition to avoid the accidents. They provide a safety-assistance brake controller to perform anti-lock control, brake-based traction control, yaw-stability control and brake-force distribution. This paper tried to compile all the objectives of brake controller.

Paper named as, A Nonlinear Estimator Concept for Active Vehicle Suspension Control, by Guido Koch, Tobias Kloiber et al. [16] deals with the nonlinear damper characteristics of a vehicle suspension setup. Driving comfort is the rising customer demands that actually form the seed for the development in the field of modern vehicle suspension systems. They introduced a new signal estimation concept for active vehicle suspension. They investigated how accurate the road profile can be estimated with the proposed concept. The nonlinearity of the damper is taken into account by using the damper force as an additional input.

III. DISCUSSION

The previous section of this paper suggests that there is a scope as well as need for experimental setup of a vehicle model and road surface, which resembles like running on an uneven road surface. During the motion of a vehicle, at any time, when the contact force becomes zero then the vehicle will lose contact with the road surface [12]. Same thing happens in cam and follower mechanisms. Cam moves independently till the contact is established. Preloading by spring or self-weight is required to be modelled for followers and the same modelling was required for different vehicles. The methods introduced for jump detection with accuracy are, vibration measurement by FFT analyzer on real time basis along with accelerometers and other sensors. Sound level measurement is also a key feature for road induced noise in vehicles and cam-followers subjected to jump.

Usually the cam-follower systems include a force closed cam joint and a follower train, containing both substantial mass and stiffness [3]. If cam and follower remains in contact, then it is a single degree-of freedom system. It becomes a two degree of freedom system once the cam and follower separate or jump, creating two new natural frequencies [5]. Unevenness in the cam surface, while the contact force is on the brink of incipient separation, may cause a spontaneous switch to the two-DOF mode and begin vibrations at resonance. One of the many potential problems with unwanted vibrations in high-speed vehicles is the possible introduction of jump. When vehicle gets come back on road the impact introduces large forces and thus large stresses, which can cause both vibrations and early failure of the vehicle chassis or sub systems [9].

IV. COMPARATIVE ANALYSIS

Comparison of dynamic analysis in cam- follower and vehicle- roads is based on following parameters.

1. Mass
2. Stiffness
3. Damping
4. Preload
5. Surface irregularities and defects
6. Speed
7. Maintenance
8. Accident patterns
9. Cost & Comfort
10. Test rigs
11. Detection of jump

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Table1. Comparison of Cam- Follower and Vehicle-Road Dynamics with measurement parameters

Sr. No	Parameter	Cam-Follower	Vehicle-Road
1	Mass & Stiffness	Material constraint	Design constraint
2	Preloading & Damping	Spring controlled	Damping controlled
3	Speed	Controllable	Uncontrollable
4	Jump Detection	Possible with accuracy	Errors occur due to high speed
5	Maintenance	TPM	Irregular
6	Life & Cost	Predictable	Unpredictable
7	Test Rigs	For jump & noise detection.	For vibration measurement with FFT analyzer

V. SUMMERY AND CONCLUSION

Dynamic behaviour of vehicle is dependent on natural frequencies of components inside and also on a vehicle as a whole. If the speed of the vehicle is close to the natural frequency then the system will go into resonance. Resonance is a form of free vibration in which the system will vibrate violently, which is extremely harmful to high speed vehicles. The system parameters are decided on the basis of constraints like mass and stiffness. Other parameters like unbalance, vibration severity and safety concerns for high speed vehicles on road surface are manipulative through testing procedure. The unevenness in road surface contributes to the unbalanced forces and increased stress values, which are required to be analysed for better safety and comfort issues. Vibrations, together with noise and wear, will occur in the dynamical system of vehicles and cam-followers. The forces and stresses from vibrations are usually superposed on those resulting from normal operation. The operation is affected by the flexibility or elastic deformation of the parts of the system. The parts of the system act as springs of various stiffen values. Therefore, the moving parts should be both as rigid and as light as possible. Our concerns therefore are towards minimization of vibrations and jump in high speed vehicles on speed breakers and on uneven surfaces.

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