www.ijiarec.com

ISSN:2348-2079

Volume-5 Issue-2

International Journal of Intellectual Advancements and Research in Engineering Computations

An analytic report on design, cross section and material specification of protective structures for earth moving machinery

M.Jayakumar[1], Dr.N.V.Dhandapani[2], S.Palanisamy[3]

ABSTRACT

Roll over protective structure (ROPS) are passive safety structures fixed on off-highway and highway earth moving machines. The structures provide a survival zone to safe guard the operator during an accidental roll over. Since decades in use of Off-Highway mining equipment, ROPS performance with respect to operator safety and reducing fatality has been consistently improved. Various research on simulating and testing the passive safety structures are carried out with respect to worldwide safety standards used for earth moving machines like wheeled loader, dozer, Dump truck, Motor Grader etc.,

ROPS design standards require full scale destructive testing to understand performance behaviour in post yield and energy absorption capacity. Destructive testing is very expensive and time consuming method, only very few reputed companies have been conducting these destructive experiments and the results are classified as confidential. The more economical and time saving test is the virtual test applying finite element analysis and simulation using CAE (Computer Aided Engineering).

The main objective of this research work is to optimise the design concept, cross section and material specification to provide ROPS to off-highway mining equipment and carrying out virtual CAE simulation of roll over protective structure of an operator cabin with respect to energy absorption criteria and gross vehicle machine mass (GVMM). Evaluating the design of passive safety structure for its Deflection Limiting Volume and to generate more data for further research in designing of roll over protective structure (ROPS).

Keywords: Roll Over Protective Structure, Passive Safety, Energy Absorption, Deflection Limiting Volume, Computer-aided engineering.

INTRODUCTION

Heavy vehicles which are used in the mining and construction industries are susceptible to rollovers since they have a high centre of gravity and frequently operate on sloping and uneven terrain. A steel frame with either two or four structural post is usually attached to these vehicles above the operator's cabin for resisting moment during rollovers. This safety structure is called a Rollover Protective Structure (ROPS), they may be an integral part of the cabin or external independent structure which is kept outside the cabin. These structures should protect the operator from life threatening injuries [1-5].

Off-Highway mining equipment is in extensive use, the population of this equipment as drastically increased with varied load capacities. There is a persistent requirement to improve their ability with respect to operator safety and to reduce fatality. Therefore integration of safety in the operator cabin structure plays a major role which leads to derive the next level of standard in designing of ROPS for earth moving machines [6-10].

Author for correspondence:

[1]Assistant Professor/Mechanical, Suguna College of Engineering, Coimbatore.

[2]Professor-Mechanical, Karpagam College of Engineering (Autonomous), Coimbatore.

[3]AP/Mechanical, Suguna College of Engineering, Coimbatore.

LITERATURE REVIEW

Clark, B.J. and Thambiratnam, David P. and Perera, N.J. (2006) [4] have investigated on an experimental investigation and a detailed finite element analysis on response behaviour of Roll over protective structure (ROPS) fitted on Dresser 125 tonne 630E dump truck. The design and analysis of ROPS structures is complex and requires dual criterion that ensures that they are flexible enough to absorb energy and rigid enough to maintain a survival zone DLV (dynamic limiting volume) around the operator. Experimental testing has been conducted for 1/2 scale model for static load to simulate the impact forces created during the testing corresponding stresses and deflections are measured with respect to Lateral, vertical and longitudinal axis of the ROPS. ROPS consisted primarily of a two post three dimensional moment resisting frame that cantilevered directly from a tapering box beam that was fixed directly to the chassis of the vehicle. All impact loads sustained by the ROPS during a rollover are transferred through this beam directly into the chassis of the vehicle. Member types employed for this structure consisted of 350 grade steel rectangular/square. Strain and deflection a measurement was taken during loading sequence using Agilent Technologies' 120 channel VXI data acquisition system. 8 Strain rosettes was positioned throughout the structure in regions of predicted high levels of strain and measurement has been taken. Also 4 LVDT's (Linier variable differential transformer) was positioned and true displacement readings have been measured about each axis of the ROPS. Load generation for each stage was performed using hydraulic calibrated jacks powered by an electric pump. in addition to this non-linear finite element analysis has been done using the ABACQUS version 6.3 and calibrated model was created by solid model package SOLID WORKS on Roll over protective structure (ROPS) result obtained from experimental investigation and calibrated computer model was used evolutes the level of energy absorption and enhance performance and operator safety [11-23].

Thambiratnam, David P. and Clark, Brian J. and Perera, Nimal J. (2008) [5] have investigated dynamic impact analysis of a K275 bulldozer ROPS using calibrated finite element models with respect to Australian standard for earth moving machinery protective structures AS2294–1997. The experimental testing has been done followed by finite element analysis of the ½ scale ROPS model under required lateral, vertical and longitudinal load using the program ABAQUS standard v6.3 with the 2 set of results they got very close values between the experimental and analytical results (lateral load v/s lateral deflection) they have used Finite element techniques to carry out dynamic impact simulations on ROPS encountered during a sideward rollover of an earthmoving vehicle.

Jacek Karliński , Eugeniusz Rusiński, Tadeusz Smolnicki (2008) [7] This paper presented selected problem on passive safety of the operators construction and mining machines. in this paper cabins are classified in three category 1) site i.e. machine working on the ground's surface, working underground and self-propelled machine 2) according to the aim of protective measure like mechanical impact protection, vibration insulation, sound insulation, thermal insulation and protection against harmful chemical environment agent.3) the most important is load bearing cabin structure distinguish cabin with surface load bearing (shell) structure, load bearing beam structure, load bearing beam structure with sheathing. 3-D cabin's load-bearing structure has been developed and through numerical simulation virtual prototype was tested as per standard (PN-EN 13510:2004 'Earthmoving machines. Rollover protective structures (ROPS). Requirements and laboratory tests) in FEM method for Boart Longyear Face Master 2.0 boring machine to speed up the project as well as reduction of project cost. the outcome of this study is selection of proper material model (appropriate to the velocity phenomenon) , precisely determined the material properties and used the effective method of solving the equations of motion.

Thambiratnam, D. P. and Clark, B. J. and Perrera, N. J. (2009) have investigated on Performance of roll over protective structure for a bull dozer with a gross vehicle weight of approximately 5 tonnes using experimental and analytical techniques to understand post yield behavior and energy absorption capacity of two post rollbar type ROPS. Effort has been made combined analytical, numerical and experimental approach to validated analytical ROPS 1/2 scale model was designed based on the principle of

Buckingham Pi theorem to develop the relationship between the proto type and model. The pre and post processing MSC Patran 2004 software package was used to construct the finite element models, and the Program ABAQUS standard v6.3 which is a general purpose FEA package with the ability to model both linear and highly nonlinear structural problems. 1/2 scale ROPS was fabricated and tested for to meet the performance criteria of the Australian Standard AS2294-1997 The full scale FE model of the K275 ROPS developed for further numerical investigation has been done this investigation found that correlation between analytical and experimental results was excellent under the lateral loading phase which represents the most crucial loading condition of the standard.

Petru Dumitrache, (2011) Created the parametric modelling of the Roll Over Protective Structure and Falling Object Protective Structures (ROPS/FOPS) in order to study of their behaviour using finite element method. This paper in mainly content three parts. First part of this paper briefly presented the main reference documents governing the mechanical protection of human operator of mechanical and equipment's and it construction including optimization process of protective structure using CAD and FEA platform. Second part presented a parametric analysis of the protective structures geometry, in order to determine the main geometric parameters that define the geometry of protective structures. These study proved parametric modelling of geometry of the protective structures is a preferable alternative to classical modelling of these geometries, the major advantage is it considerably shorten the time to generate the geometry of the protective structures. these research work further discuss about the protective structures and its character and criteria like Overall geometry of the protective structure, Structural composition of the protective structure, Geometric shape and sizes of the cabin windscreens, Fixation method of the protective structure on the machine chassis etc. in this phase a Case study also made to focused on the protective structure of a front loader cabin. Parametric modelling of the geometry is a very powerful method of modelling compared with traditional modelling, parametric modelling of their geometries is the best way to get, simple and efficient, versions of the same geometry, by changing the parameters considered in the optimization.

J. Karlin´ ski, M. Ptak_, P. Działak (2013) this paper presents the methodology of conducting strength tests for protection structures with the application of finite element method. An analysis was conducted of the protection structure of the Face Master 2.3NV self propelled drilling rig. in accordance with PN-EN ISO 3471:2009 ''Earth-Moving Machinery. Roll-Over Protection Structures. Laboratory Tests and Performance. Test has been conducted in two stage, in first stage increasing lateral force until damage occurs (increments of displacement) and in second stage three forces were applied: 1. lateral force, 2. vertical force, and 3. longitudinal force. In the analysis the structure was loaded with lateral force, at which the structure satisfies the requirement of absorbed energy. Operator protection structure satisfied the minimum requirements established in PN EN 3471:2009.

Syed Khaisar Sardar, Kiran Narkar,D.R Panchagade (2014) studied the Optimization of Roll over Protection Structure for newly designed SD190 Design of the cabin structure was developed by using CAD tool CATIA V5.

The present work was aims to optimize the existing design to reduce weight, cost and to increase stiffness of the structure.

Methodology for simulating the rollover conditions were validated and then MODAL and NON–LINEAR analysis were carried out using Hyper mesh and ABAQUS software, Nonlinear analysis was done based on the loading standards.

The Baseline design was revised with 3 design modifications like removing gussets, adding holes and increased thickness of rear plate and extending rear isolators support plate. During the study they incorporated the 3 design modification, these modified designs were shown a slight marginal improvement (3 %) in the max displacement under the load achieved for similar strain energy. ROPS was tested for lateral loading condition. Analysis and test results are compared and concluded that modified design passed the standard ISO 3471

CONCLUSION

The present study has analyzed the various literatures. After a careful analysis of various

research studies conducted so for it has been found that sufficient studies have not been conducted on Roll over Protective Structure for off highway equipment's, there is a scope for generating the comprehensive research information using CAE (Computer Aided Engineering) simulation by finite element analysis.

REFERENCE

[1]. Australian Standard, (1997). "Earth-moving machinery-Protective structures, Part 1: General", Part2 Laboratory tests and performance requirements for roll-over protective structures" and Part 4 Specifications for deflection limiting volume, AS2294. Parts 1, 2 & 4.

[2]. Australian Standard, (1996). "Tractors-Roll-over protective structures-Criteria and tests, Part Conventional tractors", AS1636.1.

[3]. "Earth-moving machinery -Roll-over protective structures - laboratory tests and performance requirements". International standard-3471: 2008.

[4]. Clark, B.J. and Thambiratnam, David P. and Perera, N.J. Analytical and Experimental Investigation of the Behaviour of a Rollover Protective Structure. *The Structural Engineer*. 84(1), 2006, 29-34.

[5]. Thambiratnam, David P. and Clark, Brian J. and Perera, Nimal J. Dynamic Response of a Rollover Protective Structure. *Computer-Aided Civil and Infrastructure Engineering* 23(6), 2008, 448-464.

[6]. D. P. Thambiratnam, B. J. Clark, and N. J. Perera., Performance of a Rollover Protective Structure for a Bulldozer, Journal of Engineering Mechanics, 135, 2009, 31-40.

[7]. Jacek Karlinski, Eugeniusz Rusinski, Tadeusz Smolnicki Protective structures for construction and mining machine operator. Automation in Construction 17, 2008, 232-24

[8]. Jacek Karlinski, Poulina Dzialak, Mariusz Ptak Simulation tests of roll-over protection structure Archives of Civil and Mechanical Engineering 13, 2013, 57-63

[9]. Syed Khaisar, Sardar1 Kiran Narkar, D. R Panchagade. Optimization of Roll over Protection Structure IJSRD - International Journal for Scientific Research & Development 2(04), 2014 | ISSN (online): 2321-0613

[10]. Vidya Pardeshi, Design of ROPS (Roll Over Protective Structure) For Operator Cabin International Journal on Future Revolution in Computer Science & Communication Engineering ISSN: 2454-4248 1(2), 2015, 06 - 09

[11]. Wang Jixin, Yao Mingyao, Yang Yonghai., Global Optimization of Lateral Performance for Two-Post ROPS Based on the Kriging Model and Genetic Algorithm, Journal of mechanical Engineering, 57(10), 2011, 760-767.

[12]. Saini Amandeep Singh., To Study Weld Strength and Strain Energy Absorption of Roll Over Protection Structure of an All-Terrain Vehicle, IOSR Journal of Mechanical and Civil Engineering, 10(2), 2013, 27-31.

[13]. Amandeep Singh, Vinod K. Banthia, Monish Gowda., Numerical Evaluation of a Closed Cabin of Earthmovers for Structural Rigidity and Safety, TECH, 11(1), 2012.

[14]. J.R. Harris, G.L. Winn, P.D. Ayers, E.A. McKenzie, Predicting the performance of cost-effective rollover protective structure designs, Safety Science, 49, 2011, 1252- 1261.

[15]. Khaled Alkhaledi, Kenneth Means, Eugene McKenzie Jr, James Smith, Reducing occupational fatalities by using NIOSH 3rd generation automatically deployable rollover protective structure, Safety Science, 51, 2013, 427-431.

[16]. R. Lenain, E. Hugo, T. Langle (2010) Sensitivity of the absorbed energy into a ROPS during a rollover situation: Comparison to the security level proposed into OECD Code 4 International Conference on Agricultural Engineering, 2010, Clermont-Ferrand, France.

[17]. Hunckler, C.J., Purdy, R.J., and Austin, R.D. (1985). Non-linear analysis of the Terex scraper rollover protective cab SAE paper 850788

[18]. Kim, T.H., and Reid, S.R. Multiaxial softening hinge model for tubular vehicle ROPSs Mechanical Sciences, 43, 2001.

[19]. Moy, S. J. (1981). Plastic methods for steel and concrete structures Macmillan Education Ltd., England.

[20]. Srivastava, A.K., Rehkugler, G.E., and Masmore, B.J. Similitude modelling applied to ROPS testing Trans. ASAE, 24(4), 1978.

[21]. Surface Vehicle Standard, (1994). Performance criteria for ROPSs for construction, earthmoving, forestry, and mining machines Surface Vehicle Standard SAE J1040, SAE International, PA, U.S.A.
[22]. Swan, S.A. (1988). ROPS performance criteria for large mobile mining equipment Information Circular 9209, US, Bureau of Mines.
[23]. Tomas, J.A., Altamore, P., and Sheffield, S.R. (1997). Computer simulation of ROPS for earthmoving vehicles Quarry Magazine.