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FALLING OBJECT PROTECTIVE STRUCTURE (FOPS) ANALYSIS FOR EXCAVATOR CABIN

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Abstract: An excavator machine is provided with the cabin where the operator sits. Whenever the operator excavating the work equipment, chances of falling of masses of rocks, soil etc is more. In order to protect the operator from the falling objects, falling object protective structure (FOPS) is provided. Improve the stiffener of excavator cabin roof to introducing the stiffeners and thickness of cabin roof, for the large impact load 227 kg from height of 5.22m. Hypermesh will be used to mesh the excavator cabin, it will be modeled shell, and then abaqus computer programming simulation is used to solve the dynamic analysis.
Keywords: FEA, Protective roof, DLV, safety

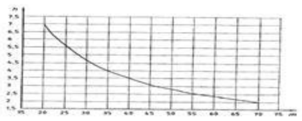
I. INTRODUCTION

Earth moving machinery was designed to carry out the different technological operations in which the mechanical protection of the human operator during accomplishment of work is very important and these machines operate in various work environments both in underground as well as above the ground. somehow all the earth moving machineries are provided with the protective cabin and in order to ensure the safety of human operator, the earth moving machine cabin must able to assure mechanical protection when machine rollover or and in case of falling objects[1].

EN ISO 3449

There are two levels of performance criteria specified for impact protection and this is based upon the machine and its use.

Level I: In this test the impact of round test object of mass between 15 kg to 75kg, which is dropped from a height varies from 1.5m to 7.5m and is sufficient to produce energy. Height and mass for test object with capability of developing energy requirements. Take it as example: 45kg x 9.807 m/s^2 x 3.1 m = 1365 J in graph 1 and test object in level I dimensions' as show in fig. 1



Graph 1 Level I energy requirement curve

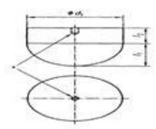
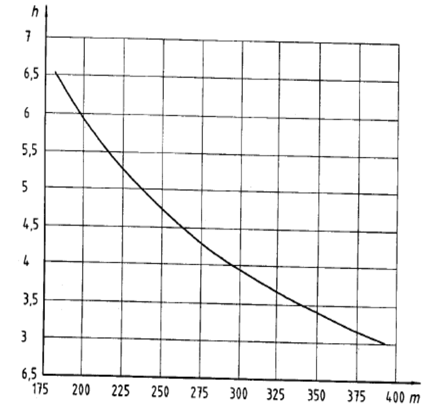


Fig. 1.3 Level I mass of 45 kg Test object

Level II: In this test procedure the impact of a cylindrical test object between of 175kg to 400kg, which is dropped from a height varies from 2.5m to 7 m and is sufficient to develop energy. Height and mass for test object with capability of developing energy requirements. Take it as example 227 kg x 9.807 m/S^2 x 5.22 = 11600 J in graph 2 and test object dimension are as show in figure 2



Graph 2 Level I energy requirement curve

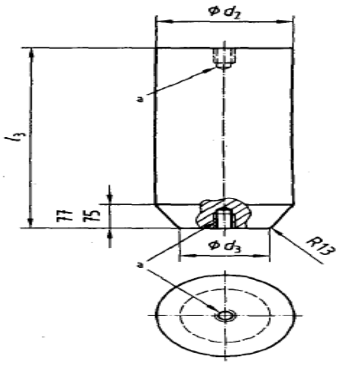
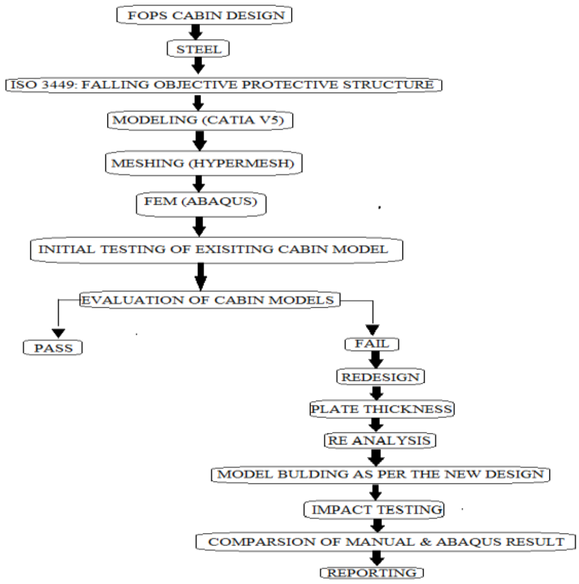


Fig. 2 Level I mass of 45 kg Test object

II. METHDOLOGY

The main aim of this study is to design and analysis a protective structure for mining machineries. The FOPS model according to 3449 will be designed. The FOPS play a major role in design and analysis of mining machineries as it is quiet often seen that accidents in mining happens sometimes due to the carelessness of the drivers and sometimes due to natural calamities; and in order to take care of all such incidents, FOPS model has been developed.



A. Geometric Modeling for FOPS

The FOPS model consists of tubes, cabin roof and cab operator (dummy). The model has been showed in figure 3 Front, figure 4 side, figure 5 Top and figure 6 Isometric views.

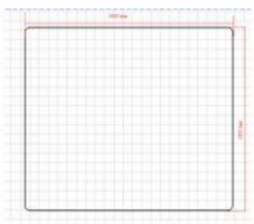


Fig. 3 Front view

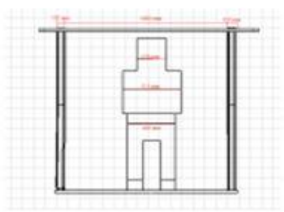


Fig.4 Top view


Fig.5 Side view

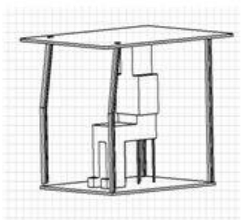


Fig.6 Isometric view

- The intended model is developed using CATIA, modelling software.
- The developed model is then meshed using HYPERMESH to make the way for FEM analysis.
- Evaluation of the CAB model is done with the aid of FEM techniques.
- Initial trials (analysis) would be conducted to check if the design attains the significant standards, if not redesigning of the model would be done.
- The redesign involves, checking for cabin roof thickness and adding stiffener.
- Impact testing would be performed on the redesigned model and compared with the manual calculation.

B. Meshing

After fully meshed excavator cabin as show in below figure 7

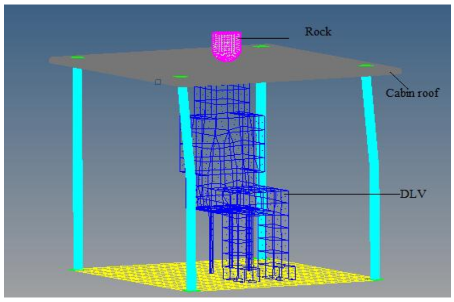


Fig.7 Meshed cabin

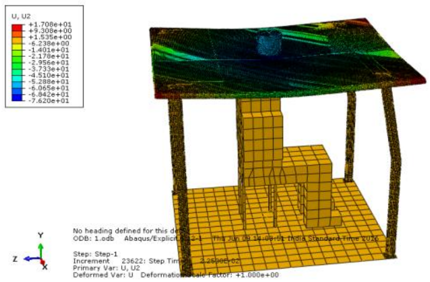
The excavator cabin structure is made of 117694 elements and 118113 nodes. Rock is made of 3714 elements and 1858 nodes.

III. RESULT AND DISCUSSION

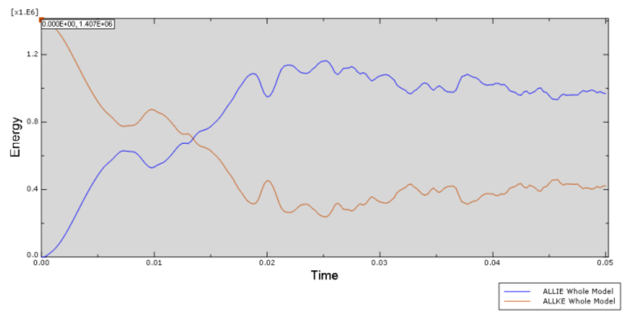
Here, the cabin roof and its pillars are made of Chromium-Vanadium steel. Different thickness of cabin roof is used for analysis and details of analysis for each size are as follows.

A. Trail - 1

Structure of Cabin roof and pillars with thickness of 4 mm and having gap of 200 mm between dummy seat and cabin roof (i.e. with 200 mm DLV – Deflection Limiting Volume) is tested for 45 kg rock falling from 3.1 meter height and hitting the centre of the cabin roof.



Above figure shows the maximum defection measuring 76.2 mm and this is mainly due to the application of load at the centre of cabin roof. The above structure is safe due to the DLV value (200 mm) is higher than the cabin roof deflection (76.2 mm).



Above graph shows 1407 J of maximum Kinetic energy during the impact and decreases with time. Whereas, internal cabin energy starts increasing from the time of impact.

Calculation:

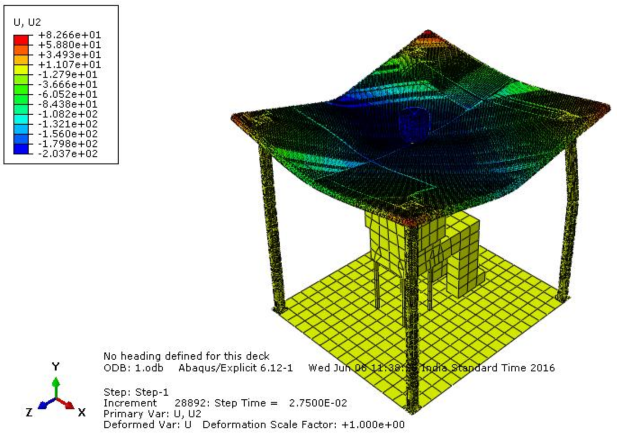
Potential energy = Kinetic Energy

Mass × acceleration due to gravity (g) × height = ½ × Mass

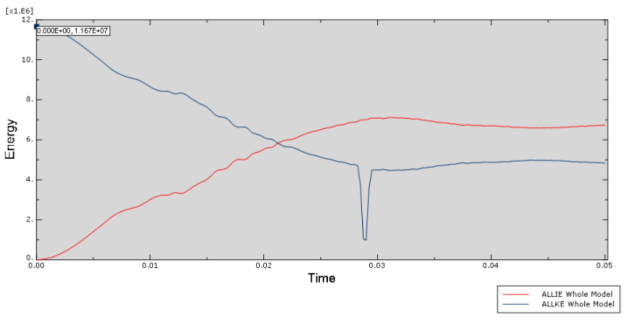
× velocity^2
The velocity just before impact is V=√2gh
For 45 kg weight of the rock with height 3.1 m
V= √ (2 × 9.81× 3.1)
V=7.798 m/s
V= 7798 mm/s
Kinetic energy:
K E = ½ mv^2
K E = 0.5 × 46 × 7.798^2
K E = 1398.906 J (N-m)

B. Trail - 2

Structure of Cabin roof and pillars with thickness of 4 mm and having gap of 200 mm between dummy seat and cabin roof (i.e. with 200 mm DLV – Deflection Limiting Volume) is tested for 227 kg rock falling from 5.22 meter height and hitting the centre of the cabin roof



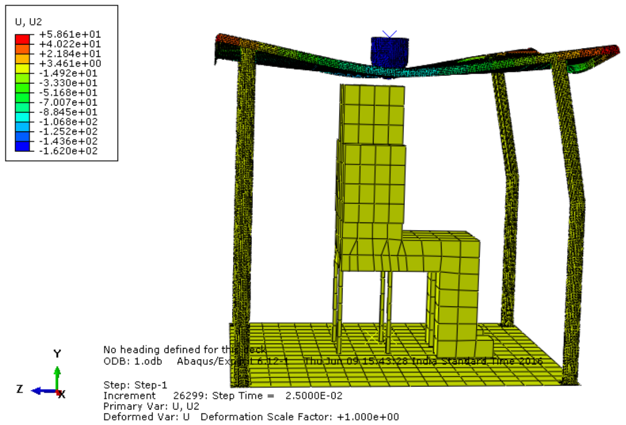
Above figure shows the maximum defection measuring 203 mm and this is mainly due to the application of load at the centre of cabin roof. The above structure is not safe due to the DLV value (200 mm) is lesser than the cabin roof deflection (203 mm).



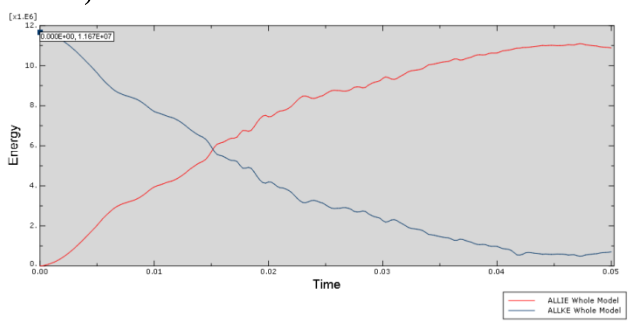
Above graph shows 11670 J of maximum Kinetic energy during the impact and decreases with time. Whereas, internal cabin energy starts increasing
: Potential energy = Kinetic Energy
Mass × acceleration due to gravity (g) × height = ½ × Mass × 〖velocity〗^2
The velocity just before impact is V=√2gh
For 228 kg weight of the rock and height 5.22 m
V= √ (2×9.81×5.22)
V=10.120m/s
V=10120 mm/s
Kinetic energy:
K E = 1/2 mv^2
K E = 0.5×228×〖10.120〗^2
K E = 11675.24 J (N-m)
K E= 11675.24 × 〖10〗^3 N-mm

C. Trail – 3

Structure of Cabin roof and pillars with thickness of 6 mm and having gap of 200 mm between dummy seat and cabin roof (i.e. with 200 mm DLV – Deflection Limiting Volume) is tested for 227 kg rock falling from 5.22 meter height and hitting the centre of the cabin roof.



Above figure shows the maximum defection measuring 162 mm and this is mainly due to the application of load at the centre of cabin roof. The above structure is safe due to the DLV value (200 mm) is higher than the cabin roof deflection (162 mm).



Above graph shows 11670 J of maximum Kinetic energy during the impact and decreases with time. Whereas, Internal cabin energy starts increasing from the time of impact.

Cabin roof thickness (mm)	Weight of the rock (kg)	Height (mts)	DLV (mm)	Deflection (mm)
4	45	3.1	200	76.2
4	227	5.22	200	203
6	227	5.22	200	162

IV. CONCLUSION

In this project report, an effort has been made to improve the stiffener of excavator cabin roof to introducing the stiffener, for the large impact load 227 kg from height of 5.22m. The interpretations of result are as fallows. For 4 mm thickness material roof made of Chromium-Vanadium steel was suitable for 45 kg weighing rock falling from 3.1Mts as the deflection was well within the DLV. The same material were Tested for same cabin by increasing the weight and height of falling rock with 227Kg and 5.22 Mts respectively. The deflection was higher than the DLV. So, this would not be safe and suitable. Hence, cabin roof was redesigned by increasing its thickness by 2 mm. Cabin roof with 6mm thickness material found to be suitable in these cases as the DLV was more than the deflection. Hence, would feel better to use Chromium-Vanadium steel of 6 mm thickness to withstand high stress.

REFERENCES

[1] http://www.mobilityengineering.com.au/ROPS-FOPS-OPG.htm (accessed on 06-04-2014)

[2] http://www.tsmattachment.com/content/44/heavy-equipment-protection-system (accessed on 06-04-2014)

[3] ISO3449https://law.resource.org/pub/in/bis/S08/is.iso.3449.2005.pdf

[4] Shuuichi Kaneda ,Tomoki Tamagawa"Introduction of Simulation of Falling Object Protective Structures" Technical Papers ,2003qVOL. 49 NO.151.

[5] Prakash Gore and R.B. Barjibhe "Design of protective structure of operator cabin against falling object (FOPS)"International Journal of Latest Trends in Engineering and Technology (IJLTET), Vol. 3 Issue 4 March 2014, pp. 228- 236.

[6] Jacek Karliński , Eugeniusz Rusiński, Tadeusz Smolnicki "Protective structures for construction and mining machine operators "Automation in Construction 17 (2008) 232–244.

[7] J.X.Wang et al. "Impact Dynamics Analysis and Laboratory Test of FOPS for Engineering Vehicle" IEEE DOI 10.1109/ICICTA.2008.105.

