Optimization and Analysis of LCV/HCV Chassis using FEM Technique – A Review

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Abstract - This paper aims to review the previous researches done on the FEM analysis of automobile LCV/HCV chassis. Chassisanalysis research is categorised into strength, analysis, material,and on the basis of various loading conditions. However an approach is made in order to refine all the previous researches done on the automobile chassis and the final conclusion is thus made from it. On studying and analyzing the various aspects of the chassis design conclusion is formulated which would highlight all the areas in which research could be enhanced further.

Keywords - FEM Technique, LCV, HCV, Chasis.

I. INTRODUCTION

A chassis is the structural supporting member on which all other vehicle component are mounted. These mounted components include engine, transmission system, differential, suspension, drive shaft, etc. A chassis generally consist of frame which is made up of two long member called side members. These two long members are connected in between with some small connecting members.

Every year the demand for the automobile industry is increasing at a very tremendous rate so, there also comes other factor like safety, affordability and many more, so there is need to consider all these factors. The demand for the high load carrying vehicles is also increasing day by day, so nowadays a type of chassis is required which can firmly and very easily carry this load and can improve the country's development. The Finite Element Method has made analyzing very easy in which we can compare all the factors correspondingly in a single operation..

Fig.1: Simple chassis

1.2 LADDER CHASSIS is one of the oldest forms of automotive chassis. These are still used in most of the SUV's. It is clear from its name that ladder chassis resembles a shape of a ladder having two longitudinal rails interlinked by lateral and cross brasses which are further used for design improvement.

Types of ladder frame: Ladder frame is classified as follows.

1. C cross section type of ladder chassis frame

2. I cross-section type of ladder chassis frame.

3. Rectangular Box (Hollow) cross section type of ladder chassis frame.

4. Rectangular Box (Intermediate) cross section type of ladder chassis frame.

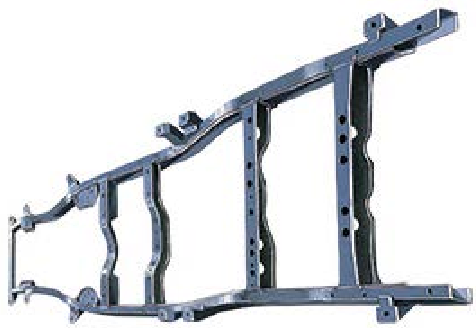

Fig. 2: Ladder Chassis

Apart from the types of ladder chassis, the construction of the body of chassis has also various types like:

1. UNIBODY CONSTRUCTION

2. BODY ON FRAME CONSTRUCTION

II. LITERATURE REVIEW

The literature mentioned below is gathered from the sources and has been reviewed. It includes the current knowledge including substantive findings as well as theoretical and methodological contributions to a particular topic.

2.1 CURRENT STATUS OF RESEARCH

The whole literature review is divided into 4 parts viz:

1. Materials
2. Strength
3. Loading
4. Weight

2.1.1 MATERIALS:

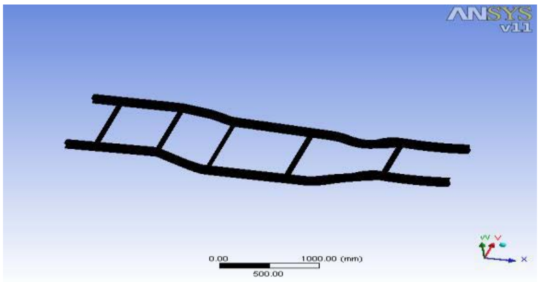

Fig.3- Material applied to a chassis using Ansys

Jurgen Hirsch et Al. (2010) established the use of aluminum in the formation of chassis, especially in European industry. Along with the aluminum one can use various alloys of it including stainless steel, magnesium, plastics or composites are known as the concept of multi-material design. The main purpose for the use of aluminum is that it tends to decrease the weight of the chassis by 37Kg which leads to the benefit of improving the dynamic of driving, ride comfort and safety due to the reduction of unsprung mass. Other properties which make aluminum suitable for this kind of method used for the manufacturing of components manufactured by aluminum, these methods include Extrusion and casting both of which are very easy and cheap to practice. Now it can be concluded that the aluminum chassis is good in use and we could perform some more experimentations on it to get a much better material for chassis manufacturing.

C Udaykiran et Al. (2014) analyzed chassis by using a different material such as glass fiber reinforced plastic which has following properties. Highly corrosion resistant and Non-conductive and impact resistant. Various properties of this material like it's Young's modulus Poison ratio density etc are 205, 0.29 and 7850 respectively. Loads are applied at 3 locations as a cumulative load which leads the total load to be 3212 Kg. The main process involves the both design and analysis of themodel. Atfirst, all calculations are made with a practical approach and then converted to 3-D model. And thus the complete analysis using different materials can be done.After doing this analysis with glass fiber reinforced plastic we find that the above said properties are appropriate and can be used in the chassis analysis. This material can be further used to make strong chassis which would give better results in the case of driving and also in the case of crashing with some other vehicle.

B.Ramya et Al. (2014).optimized design and evaluated whether the design is safe or not. Firstly the model is generated which could be done with the help of CATIA, Solidworks etc to suit the suitable FEA requirement. Material selected for this purpose is steel alloy 4310 whose properties such as Young's modulus, Poisson Ratio etc to be 5830, 0.36 etc After applying all the conditions we could conclude from the software that the stress value after applying all the three loads are 76.89 Mpa which is quite less than the yield strength of the material and also the factor of safety (FOS)comes out to be 5.65 making this design a safe design. The values of frequency configured were 11.25, 17.36, 24, 19.76 etc and the values of displacement came out to be 0.273, 0.294,0.183 mm and so on. Thus we can conclude that the above-provided design and dimensions by using steel alloy 4310 as the materialare successful in operation and it can perform according to the need.

Vishal Francis et Al. (2014) analyzed ladder chassis frame for jeep using Ansys. The material for the chassis was taken as Mild sheet steel, aluminum alloy and titanium alloy for rectangular hollow chassis. The model making and simulation was done in CATIA-V5 and ANSYS 14 respectively. Von misses stress for mild steel is 0.032MPa, aluminum alloy is 0.0047MPa and for titanium alloy is 0.0075MP. it was concluded that design is safe because the generated stress is lesser than the permissible value. Von misses stress was minimum in case of aluminum alloy and maximum in the mild steel sheet. So it can be concluded that the aluminum alloy is better of all.

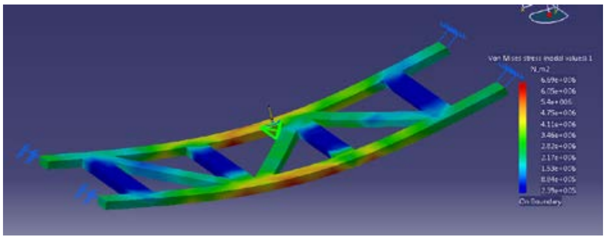

Fig.4 Shear stress on chassis frame

InduGadagottu et Al. (2015) experimented on chassis and various shapes of it and particularly honeycomb structure. The honeycomb pattern comprises of a very thin foil in the form of hexagonal cells perpendicular to the facings. For the selection of material in a honeycombdesign, one has to take into consideration the following factors like strength, stiffness, cell size and cell shape. The analysis was done using three materials which are S-GLASS EPOXY, MILD STEEL, E-GLASS EPOXY and after the complete analysis S glass comes out to be most suitable as the values came out to be 1.489 mm of displacement and 12.426 N for stress which was better than the outcomes of the other materials. So S-glass is the best suitable option which would be proved better when we are considering these types of analysis.

Sheikh Neelopher Begum et Al. (2016) keeping in mind increased competition in automotive industries, concluded that weight reduction is a major issue. In this project, the chassis of existing dimensions of Mahindra Bolero vehicle were considered for modeling and analysis with three different composite materials namely, Carbon/Epoxy, E-glass/Epoxy, and S-glass/Epoxy. The chassis of these materials turn by turn were experimented at the same pressure as that of steel chassis. The deformation and equivalent stress for these materials are reduced. The results suggest the use of these materials for the future improvement of chassis frame for light commercial vehicles. Carbon/epoxy polymeric composite vehicle chassis with I-section has superior strength compared to rest three materials. Polymeric composite chassis is lighter and economical than conventional steel chassis.

S.Sivrajet Al. (2016) worked on this project considering the automotive chassis as the backbone of any vehicle as it supports body, different components. The analysis was performed for three different materials i.e. mild sheet steel, aluminum alloy, and titanium alloy. The main criterion for chassis design was maximum shear stress and deflection under maximum load were analyzed with the help of given software. The aluminum alloy showed similitude with the theoretical ranges of stresses and natural frequency. The chassis model carried the maximum load for all designed operating conditions safely within the limits.

2.1.2 LOADING:

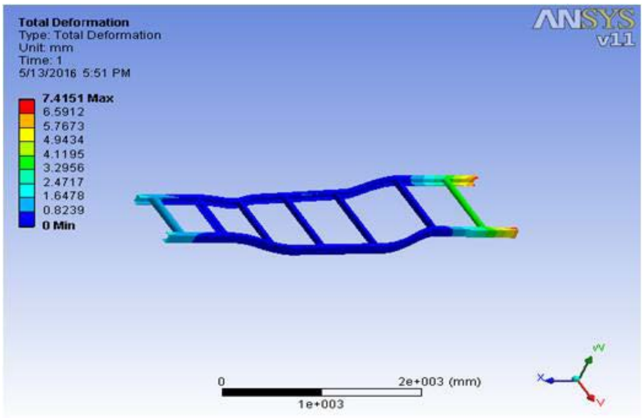

Fig.5 Load applied on chassis

T. AnandaBabu et Al. (2014) had also used the Finite Element Analysis (FEA) to perform the crash analysis of car chassis. For making the model and carrying out the simulation the software used is ANSYS. The model was put into the frontal collision with a speed of 64Kph and the results were observed for changing the present model of the vehicles.

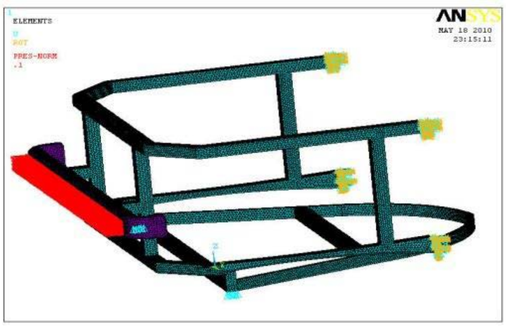

Fig.6 Car frame with imposed boundary conditions

Stresses and deformation were analyzed with a time of an 80millisecond, the Poisson ratio was 0.3, ultimate strength was 340-2100 M Pa. There were other collision tests like side impact test with a speed of 50Kph, pole impact test 29kph and 40Kph adult pedestrian impact test. It was concluded that there was a deflection of 0.978934mm for bumper made of thickness 3mm which is in the range of acceptance.

MohdAzizi Muhammad Nor et. Al (2012) carried out this project. The main objective of the paper is to model, simulate and analyze the low loader structure consisting of I-beam design for the stresses. By performing stress analysis, the variation of stress and displacement was determined to approximate maximum deflection and stress. Safety factor was also calculated for low ladder chassis for further improvement of design. There is a dissimilarity between theoretical and numerical results. The disparity should be carefully studied to improve the future model.

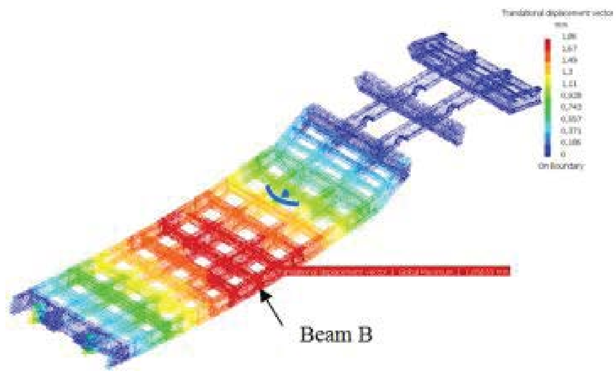

Fig.7 Maximum deflection of beam

Monika.S.Aggarwal et Al. (2013)established a method to perform the stress analysis of chassis by finite element method (FEM). The basic concept of performing this was to first design a model which was done by first using a technical drawing and information of the low loader chassis and thus a fee model can be made. By using this model one can determine the point where maximum deflection takes place and also the maximum stress that can be imposed on the chassis practically as well as theoretically. The analysis, however, leads to the adding to the knowledge that the factor of safety for low loader chassis is 3.5 This analysis also leads to the following conclusion that there was a discrepancy between the results coming out in 2-d analysis and numerical 3-D FEA results. Also, a future scope of research through this paper can be brought into account that is structural analysis to optimize the number of I-Beams that lead to weight and cost reduction would be reported imminently.

Bhupendra E et Al. (2014) performed vibrational effect on heavy duty truck chassis with the help of fem technique. Theymodeled the TATA 407 truck chassis in CATIA V5R17 software. The vibration analysis was carried out in ANSYS 14.0 FEA package. The chassis material used is

St. 52.3 steel with a Poisson ratio of .28 and Youngs modulus 200GPa. The frequencies on loading were 74.324,149.14,199.70,205.73,215.15Hz. these frequencies have their corresponding deformations of 6.82,14.71,15.20,15.14,7.53mm. the maximum frequency obtained was 215.75 kHz.

HailemariamFissehaNega et Al. (2013) on the fatigue analysis of the truck chassis. They discussed the various loading conditions which include vertical bending, shock, twist, vibration and many other stresses like torsional and fatigue loadings. They also discussed Five Box trick which is helpful in calculating the fatigue life of a chassis. According to them, the chassis analysis should mainly focus on fatigue analysis and then other types of tests. The main focus was the failure due to fatigue which mainly occurs on the joints. The rapidly applied force results in the induced stress which consequently leads to the failure of chassis due to fatigue.

N.leninrakesh et Al.(2014) investigated the major analysis techniques of automobile frames. A number of analytical methods were known to do this analysis. While designing chassis the major aspect had to be given on the various forces implying on it which were mechanical shocks and vibrations that result in the failure of the chassis. This analysis could be done by using stress life diagram. The stress analysis is still important for fatigue study and life prediction of components and to determine the critical point which has the highest t-stress. Firstly a model using software's was developed the software used could be any or Solidworks. Then the analysis of each component was done.

2.1.3 STRENGTH:

AshutoshDubeyet et Al. (2006) used the detailed model of structure for stress analysis of chassis. A lot of practical work was done before getting final boundary conditions and load cases. The results of finite element analysis were checked experimentally also and there is a perfect affinity between both the techniques. The finite element model seemed affinitive to model description and efficiency. The stress details were obtained over subsections of chassis as well as a complete section of chassis. The critical stress points were determined and the safe area where the load is normal was also taken into consideration.

NavnathV.Pande et Al. (2009) analyzed Chassis, as it is considered to be a most important part of an automobile. The important functions of chassis are to support the vehicle and components placed on it. It should withstand shock, vibration, twisting and other stresses. The basic parameters for designing chassis are torsional stiffness and natural frequency. Based on these parameters, some modification was suggested on existing chassis based on trial and error method. The modeled modified chassis being analyzed for structural, modal and experimental factors. The appreciable improvement was observed in natural frequency and torsional stiffness. Also, the equivalent stress and total deflection were found within the safe limit. Natural frequency was improved by 28.33%, torsional stiffness increased by 56.20% and total deflection was reduced by 36%.

ShaileshKadre et Al. (2011) designed a conventional full frame chassis In Heavy commercial vehicle cab mounting was utilized to isolate the driver from road generated vibrations The basic purpose of this design was to carry out strength analysis and the cab mounting system. And it was concluded that when the chassis structure contains anisolated driver, it is the best place as the jerks and various other shocks due to road conditions are not transmitted to the driver cabin as they are utilized or decreased in between their way to the driver's cabin which increases the comforts of the driver.

Helmi Rashid et Al. (2012) performed for the stress analysis of a low loader chassis which is made up of I-beams with an application of 35-ton trailer design. The whole analysis was carried out in CATIA software which is used for FEM analysis. The material of the chassis has properties like poison ratio-0.3, yield strength(Mpa)- 550, Tensile strength(Mpa)- 620. The size of each element in meshing is 50mm. A load of nearly 350KN is applied on it. From the analysis, the factor of safety comes out to be 3.5 and which depicts the maximum von misses stress to be 2*10^8 N/m^2 which is lesser than the theoretical value.

Hemant B. Patil et Al. (2013) determined the stresses on chassis before manufacturing as it is important due to the design improvements as the chassis is considered to be the backbone of the vehicle and integrates the main component system. The stress analysis of ladder type low loader chassis was performed using finite element method. The chassis structure consisted of C-beams. Five different cases were considered to study the effect of thickness on chassis stresses. The positioning member was changed in case change of thickness was not possible. Perceptible reduction in the magnitude of stresses at the critical point was recorded by varying side member thickness, cross member thickness and position of the cross member to agree on the Maximum deflection based on analytical calculation. From collation of different values, the maximum displacement is 0.288mm of 4 mm thickness with highest stress 123.83 Mpa.

S. A. Karthikeyan, et Al. (2014) updated the present model of chassis of 2214 truck in which he selected the properties as mass density and Poissonratio. They mainly considered structural resonance at 52 Hz. They made the changes as increased central section thickness by 2mm and also increased the base plate thickness to 10mm. From these changes, the natural frequency increased by 13%, torsion stiffness by 16%. Due to these changes the whole weight of chassis increases by 7%.

Vijayan S.N.et Al. (2015) studied various cross sections by which a chassis design can be made. These are C, I and Box type cross sections by which we can develop a chassis it has been taken in the consideration that equal loads have been implied in each cross section.The specification of the EICHER 10.9 vehicle used is given the capacity of the truck is 78480 N.Total load acting on chassis 117720 N. Load acting on each beam 58860 N and Stress can be given by the formula M_{ax}/ZxxAfter providing a suitable specifications they are developed with the software with various designs taken in consideration viz: C,I,Box etc and also with the use of various material in each type of the design (Steel , Carbon Epoxy, S-Glass Epoxy)With all these variations and results after the complete analysis it can be conferred that I SECTION with CARBON EPOXY is best for the formation of the chassis it is due to the fact that it provides quite a suitable amount of weight reduction in the chassis which provides positive effect. The stress distribution of I with carbon Epoxy comes out to be 130.48 and deformation equal to 2.318 mm which is better than any other matter so it comes out to be most appropriately used.

2.1.4 WEIGHT ANALYSIS:

Patel Vijayakumar et Al. (2014) worked with the modification for the weight reduction in the chassis design. They consider various types of forces acting on the chassis model which include shock, twist, vibration and other types of stresses. They simulated the chassis design in ANSYS and the model was created in PRO-E software. The load on the chassis is nearly 10,000kg. The resultant chassis design was made suitable changes as required. From the calculations and the resulting weight of chassis got reduced to 6.68% and the maximum shear stress, maximum equivalent stress, displacement also decreases to 12.14%, 8.55%, 11.20%.

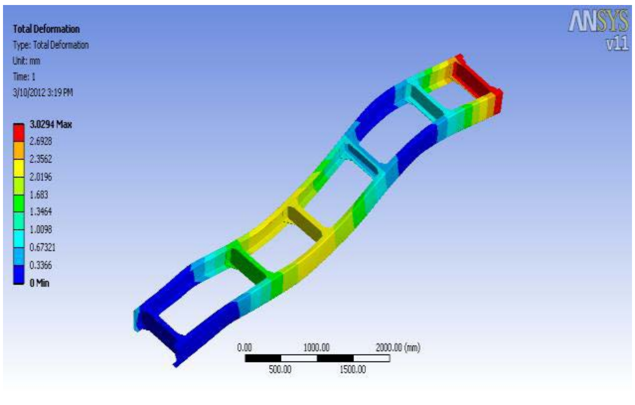

Fig.8 Displacement in chassis frame

Ahmad O. Moaaz et Al. (2014) used FEM approach. There are two approaches used in this paper to stimulate truck chassis using FEM methods: one is stress analysis and other is fatigue analysis. FEM tools are used to analyze multidisciplinary problems but not limited to thermal and fluid flow. To investigate the stress analysis of truck chassis, the side member thickness, connecting plate thickness, length of connecting plate were 8 to 12, 8 to 12, 390 to 430 respectively. This evaluation was carried out by finite element package ANSYS. Moreover, the sudden load was modified to 8 ton of 4 wheeler trailer which results in the 17% reduction of weight. It was found that the maximum stress in longitudinal was 75Mpa and if the sudden load was evaluated then the load was increased by twice the maximum load i.e 150Mpa.

ObedLungmuanaDarling et Al. (2015) used FEM approach and created two modified designs of chassis and performed various tests on them. The chassis weight, total length, total no. of cross members, no. of main rolls, front breadth of 1st and 2nddesigns are 94.817Kg and 95.562Kg, 4848mm and 4316mm, 6 and 5, 2 and 2, 730m and 785mm. the models of these designs were created in SolidWorks and the analysis was done in Ansys 14.0package. After the simulation results the chassis design no. 1 was considered to be an ideal one. It has reduced weight of 94.817Kg, the reduced von-Misses stress of 31.699MPa. The deflection of this chassis was also found out to be lesser than the existing chassis. The amount of deflection was also found to be lesser one and the weight reduced to 15.22% and stress also reduced to 28.75%.

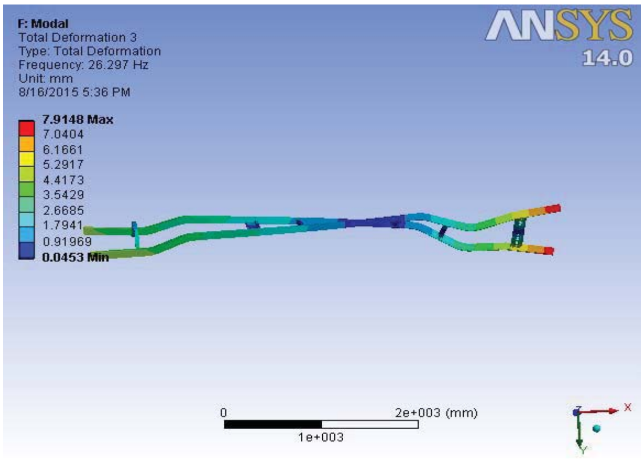

Fig.9 Deflection of chassis

N.G. Dafade et Al. (2017) analyzed the chassis model with the main objective to optimize weight and analyze the chassis model with certain loading conditions. The chassis were analyzed for various conditions to withstand shock, vibration, twist and other stresses. A proper finite element model of Bajaj maxima c was developed and analyzed for given parameters. Different observations were made considering the constraints of weight, stress, and deflection of chassis under various loads. The weight reduction up to 1.53% is achieved, hence the goal is achieved.

III. CONCLUSION

It isobserved from the above-stated literature that the basic analysis of LCV/HCV chassisis done on the basis of material, strength, loading, and weight. Following points can be concluded from the above literature.

- The aluminum chassis has good performance and further, we can enhance its usage as chassis material although not used as they get oxidized very easily forming a white pit over its surface.
- The glass fiber reinforced material also has better qualities and can be relied on for safety in case of crashing. Moreover, fiber chassis is lighter and economical than conventional steel chassis.
- Fatigue failure mainly occurs at the joints. The joints are the important part of the chassis assembly and can not be side kicked. Cruciform joints with some modifications can protect against fatigue failure.
- By iterating on various design modifications existing chassis, the chassis have become very much efficient than the earlier.
- Carbon epoxy could be a beneficial substitute for the formation of chassis having the general property of corrosion resistant, providing the same strength with weight nearly ¼ of the other materials.

Thus the best condition and the best material out of all the research papers reviewed are listed below as further investigation is to be done according to those conditions.

3.1 MATERIAL

- Analysis performed gave an overview that Carbon-Epoxy Composite Material is best.
- Properties of carbon epoxy: Compressive strength(Longitudinal) 570MPa

  Compressive Strength (Transverse) 570MPa

  Density 1.6g/cm^3

  Shear modulus in plane 5 GPA

3.2 LOADING

- The average loading is done at 1 to 25 kN which gives deflection nearly 6 to 7 mm.
- The average Factor of safety(FOS) is taken as 3.5.
- Loading is to be done at joints from where maximum failure is occurring.

3.2WEIGHT ANALYSIS

- Change in thickness of central section to 2 to 3 mm and base plate thickness to 10mm.
- The results can be obtained by changing the length, no of the cross member, front breadth.
- Maximum weight reduction can be done up to 17 -20 percent to get results in safer limits
- The deflection would be provided nearly 2-3 mm.

3.3 STRENGTH ANALYSIS

- Crash analysis is to be done with a front collision at 64 Kph, side collision at 50Kph and pole impact test at 29 Kph.
- Changing the applied frequency to obtain various deflection and maximum frequency is nearly 230 Hz
- Honeycomb structure can be used.

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