Design and Analysis of Grass Trimmer

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Abstract -HAV (Hand Arm Vibration) is a major problem in workers who operates hand held machine in day to day life, Hand arm vibration is form of vibration that is transmitted into your hands and arms, usually as a result of carrying out mechanized, hand-held work tasks. In this experiment the test RIG is manufactured to give comfort as well as help in reduction for Vibration, this rig also isolated by trimmer using MR elastomer.

1.INTRODUCTION

Product lifecycle is being reduced drastically due to rapid changes in technology and customers' requirements. The global marketplace is changing so rapidly that industrialist needs to adopt new strategies to respond customer's requirement and in order to satisfy the market needs more efficiently and quickly. Many companies especially in Japan, USA and Europe have already started to implement techniques and tools that would enable them to respond more quickly to consumer's demand in delivering high quality product at reasonable costs. The delay in time-to-market can be interpreted as a loss in profit (Alan F & Jan Chal,1994).

Currently, the implementation of Design for Manufacturing and Assembly (DFMA) methodology are applied either manually or computer-aided. Most of the applied interested in implementing DFMA are hindered by lack of clear guidelines or procedures and no integration of isolated design and manufacturing teams. The advantages of the integration are to decrease the number of part design and indirectly to reduce cost and time. At the same time, it fulfills customer's requirement. In this project, DFMA has been applied in design and development the grass cutting machine. The design also must be concerned to the requirement of the DFMA methodology in order to achieve high rank of market selling.

2. PROBLEM STATEMENT

In developing this project, there are several problems that need to be concerned and the most suitable method that can be used to solve the problems is by applying the Design for Manufacturing and Assembly (DFMA) methodology. In identifying of grass cutting machine problems, the most important aspects that need to be concerned is the design of the grass cutting machine. Some of the part grass cutting machine are being designed quite complicated with accessories and need to be eliminated, in the same time reduced the manufacturing cost and assembly time. Besides that, there are several parts had been recognized that difficult to handle. So, with the application of Design for Manufacturing and Assembly (DFMA) methodology is highly expected in solving these problems to suit the customer requirements and convenient.

3. Design for Manufacturing and Assembly(DFMA)

Design for Manufacturing and Assembly (DFMA) is a design philosophy used by designers when a reduction in part counts, a reduction in assembly time, or a simplification of subassemblies is desired. It can be used in any environment regardless of how complex the part is or how technologically advanced this environment may be. DFMA encourages concurrent engineering during product design so that the product qualities reside with both designers and the other members of the developing team (D- ESPAT, 2007).a

According to Geoffrey Boothroyd, Professor of Industrial and Manufacturing at the University of Rhode Island, the practices now known as Design for Assembly (DFA), and Design for Manufacture (DFM) had their start in the late 1970's at the University of Massachusetts. Of all the issues to consider, industry was most interested in Design for Assembly. When developing a product, the maximum potential cannot be achieved without considering all phases of the design and manufacturing cycle. DFMA meets this demand by addressing key assembly factors before the product goes on to the prototype stage. These key factors are the product appearance, type, the number of parts required in the product, and the required assembly motions and processes (D-ESPAT,2007).

The Term "DFMA" comes with the combination of DFA (Design for Assembly) and DFM (Design of Manufacturing). The basic concept of it is that the design engineers apply the DFMA paradigm or software to analyze the manufacturing and assembly problems at the early design stage. By this means, all of considerations about the factors that affect the final outputs occur as early as possible in the design cycle. The extra time spent in the early design stage is much less the time that will be spent in the repeatedly redesign. And meanwhile, the cost will be reduced. DFM is that by considering the limitations related to the manufacturing at the early stage of the design; the design engineer can make selection among the deferent materials, different technologies, estimate the manufacturing time the product cost quantitatively and rapidly among the differentschemes.Theycompareallkindsofthedesignplansandtec hnologyplans,and then the design team will make revises as soon as possible at the early stage of the design period according this feedback information and determine the most satisfied design and technology plan.

The three goals in DFM are:

1. Increase the quality of new produces during the development period, including design, technology, manufacturing, service and so on.

2. Decrease the cost, including the cost of design, technology, manufacturing, delivery, technical support, anddiscarding.

3. Shorten the developing cycle time, including the time of design, manufacturing preparing, and repeatedlycalculation.

DFA is considering and resolving the possible problems in the assembly process at the early stage of the design which can make sure the part will be assembled with high speed, low cost and productivity. DFA is a kind of design paradigm with which, the engineer use all kinds of methods such as analyze, estimating, planning and simulating to consider all the factors that will affect the assembly process during the whole design process; revise the assembly constructions to satisfied the characteristics and functions of the final products; and meanwhile, lower the cost as most aspossible.

DFA is a kind of design method that can be used in two ways. The ways is a tool for assembly analysis and a guide for assembly design. The former usage is that at the time after the beginning of the product design, the engineer makes estimation of assembly possibility by analyzing all the factors that can affect the assembly process, and give suggestions. The second one is that collecting the knowledge and experience from the assembly experts and recording them as design guides. By the help of these guides, the engineer can choose the design plan and determine the product construction such as under the guidance of thoseexperts.

4. Metods of DFA

- **Boothroyd Dewhurst DFAmethod**

In the history of DFMA, Ford and Chrysler use the DFM philosophy in their design and manufacturing process of the weapons, tanks and other military products. Dr. Geoffrey Boothroyd and Dr. Peter Dewhurst who founded the Boothroyd Dewhurst, Inc (BDI) in 1982 are the first persons doing the research job in this new technology at the beginning in the early 1970's. Actually, the "DFMA" is a trademark of their company. They created and developed the DFMA concept which is used in developing the products of their company --- DFMA software system. Currently these programs are used to help the design in almost all the industrial fields including circuit boards (G. Boothroyd & W. Knight**,** 1993)**,** with manual assembly, with robotic assembly, and with machining. They also do a lot of work examining the economic justification of each design revision (G. Causey**,** 1999).hey created and developed the DFMA concept which is used in developing the products of their company such as DFMA software system. Currently these programs are used to help the design in almost all the industrial fields including circuit boards, with manual assembly, with robotic assembly, and with machining. They also do a lot of work examining the economic justification of each design revision.

In generally, Boothroyd Dewhurst DFA method can determine the appropriate assembly method and reducing the number of individual parts to be assembled. This method also can ensure that the remaining parts are easy to assemble. The methods of assembly are classified into three basic categories such as manual assembly, special-purpose transfer machine assembly and robot assembly.

- **The Lucas DFAmethod**

Although the Boothroyd-Dewhurst method is widely used, it is based on timing each of the handling and insertion motions. Although tables of data are available, the most accurate numbers are compiled through time studies in particular factories.

The basic construction of Lucas DFA is very similar to the DFA of BDI, it is the result of the cooperation of Lucas Organization and the University of Hull in U.K. Now, the logic of Lucas DFA has been integrated in the engineering analysis software "TeamSet" which is the product of CCI Lucas DFA separates the product design process into three stages: FcA (Function Analysis), HA (Handing Analysis) and FtA (Fitting Analysis). The relations of these three stages are shown in Figure 2.1. Before the manufacturing and assembly process, the PDS (Product Design Specification) occurs which change the requirements of the customs into engineering specifications. After that, the design engineers perform the design job according to this information. This is a kind of process to change the engineering specifications into the real design and meanwhile, all the requirements should be satisfied.

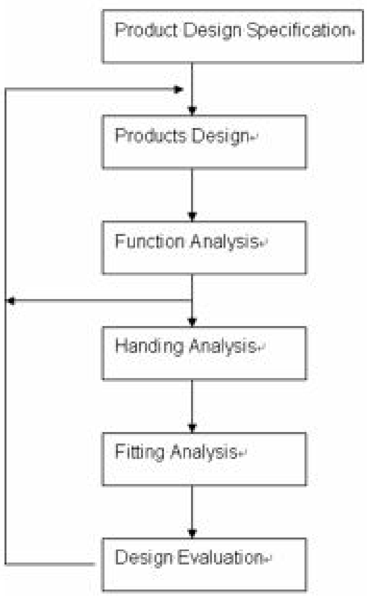

Fig.Lucas Hull method

The Guidelines ofDFA

The general guidelines of DFA that attempt to consolidate manufacturing knowledge and present them to the designer in the form of simple rules to be followed when creating a design. The process of assembly can be divided naturally into two separate areas, handling assembly which means acquiring, orienting and moving the part. The secondly area is insertion and fastening assembly which means mating a part to another part group or group ofpart.

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A DFAguideline

A DFA guideline is given below.

a)Aim forsimplicity

Minimize part numbers, part variety, assembly surfaces; simplify assembly sequences, component handling and insertion, for faster and more reliableassembly

b)Standardize

Standardize on material usage, components, and aim for as much off-the-shelf component as possible to allow improved inventory management, reduced tooling, and the benefits of mass production even at low volumes

c) Rationalize productdesign

Standardize on materials, components, and subassemblies throughout product families to increase economies of scale and reduce equipment and tooling costs. Employ modularity to allow variety to be introduced late in the assembly sequence and simplify JITproduction

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Design Guidelines for PartHandling

a) Design parts that have end-to-end symmetry and rotational symmetry about the axis of insertion. If not try to design parts having the maximum possible symmetry.

b) Design parts that, in those instances where the part cannot be made symmetric, are obviouslyasymmetric

c) Provide features that will prevent jamming of parts that tend to nest or stack when stored inbulk

d) Avoid features that will allow tangling of parts when stored inbulk

e) Avoid parts that stick together or are slippery, delicate, flexible, very small or very large or that are hazardous to thehandler.

5.DFAProcess

Once parts are manufactured, they need to be assembled into subassemblies and products. The assembly process consists of two operations, handling followed by insertion. The DFA is a two steps process (Shih-Wen Hsiao, 2001): -

a) Evaluate the assimilability of the individual parts whether they are easy to be assembled ornot.

b) Evaluate the theoretical minimum number pf parts that should be in theproduct.

In step 1 the designer uses some established rating system to evaluate each individual part with respect to its:

Grasp ability: Tocheckthatthepartiseasytobegraspedornotduringtheperiod of assembly.

Orientability: To check if the part is easy to be oriented or not when it is being assembled

Transferability: To check whether the part is easy to be transferred to the work position or not.

Insert ability: To check if the part is easy to be inserted into the correct position or not when it is being assembled.

Secure ability: To check whether the part or the product is secure or not after the part has been assembled.

6.Design for ManufactureGuidelines

Design for manufacture or 'Manufacturability' concerns the cost and difficulty of making the product. At a simple level manufacturability, design for manufacture (DFM) at a part level, involves detail such as ensuring that where a pin is to be assembled into a hole that is only slightly larger in diameter, then it is much easier if the end of the pin or the entry to the hole (or both) are chamfered or finished with a radius. This applies whether the assembly is carried out manually or automatically. This is a fine-tuning process carried out once the product form has been decided. Indeed, automatic assembly would be very difficult / expensive if neither component of a close-fitting pair was chamfered. At a more complex level, product DFM tackles the more fundamental problem of deciding on the product structure and form. Design for assembly (DFA) is an important part of this. Some 'manufacturability' software is available, relating both to manufacture and to assembly. This section starts with some simple but important principles of manufacturability (David Grieve,2003).

General Principles ofmanufacturability

a) Reducing the number of parts frequently reduces the weight of the product which is advantageous. Eliminating the need for a separate housing or enclosure can be beneficial. One method that has been successful in many cases is to replace a fabricated sub - assembly, which may utilize many fasteners, with a single casting. In some cases, this has given weight savings as well as costsavings.

b) A robust design is one that has been optimized so that variations from the nominal specification cause a minimum loss of quality. To determine these optimal values will normally necessitate experimental work on aprototype.

c)The assembly of products made up from 4 to 8 modules with 4 to 12 parts per module can usually be automated most readily. It is also helpful to maintain a generic configuration as far as possible into the assembly process and install specialist modules as late aspossible.

d)Assembly from 1 direction is beneficial whether manual or automated assembly is to be used. Generally assembling top down, along the z axis, like making a sandwich, is the bestsolution.

e)Designing so only correct assembly is possible is useful where semi - skilled labor is used and it is also an electricdesirable if there are safety considerations if the product were to be incorrectly assembled. Manufacturers of mains powered consumer electrical appliances frequently supply them with a flex having a moulded on supply plug.

This minimizes the danger of the consumer incorrectly wiring a plug and suffering shock.

f) Using standard sizes will reduce costs directly and reduced delivery times will indirectly give savings. This will also reduce the cost of repairs andmaintenance.

g)Fasteners can add significantly to costs, frequently the cost of installation will greatly exceed purchase cost. If fasteners must be used then minimize the sizes and types. Small fasteners and parts should beavoided.

h) Mechanical adjustments add to the cost of fabrication and cause assembly, test and reliability problems. The need for adjustments can often be negated by using dowel pins, detents, notches or spring mounted components. If a designer understands why an adjustment has been recommended, a way of eliminating or reducing the need can often befound.

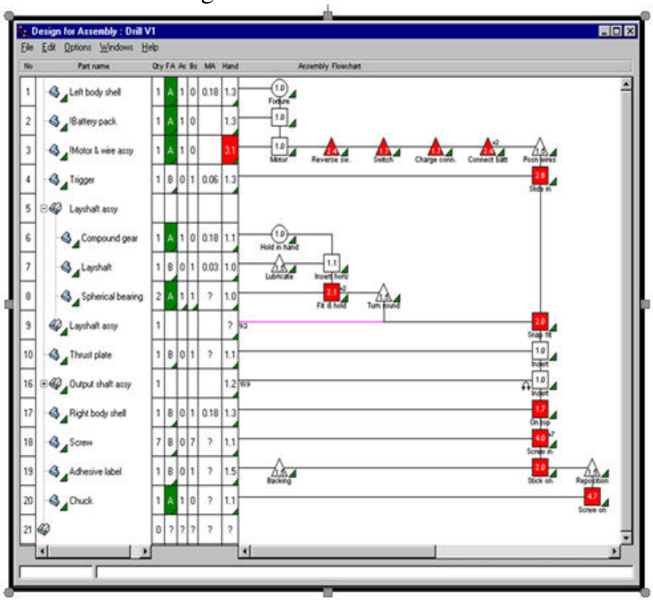
i) Wiring and other flexible components are difficult to handle during assembly. The use of rigid or process applied gaskets, circuit boards rather than electric wiring helps to minimize thisproblem.

j) Dimensioning from 1 datum simplifies gauging and minimizes errors in tolerances. Dimensions should also be measured from points or surfaces on a component, not points inspace.

k) Using large radii is generally good practice for most processes, casting, forming etc. as material flow is facilitated - and stress concentration is reduced. However sharp corners are inevitable with some processes, e.g. 2 intersecting machined surfaces and punch face - wall edge in a powdered metal component. There is no cost advantage in preventing these sharpcorners.

- **TeamSET**

TeamSET is a PC based software package which helps designers produce better products at reduced cost and in shorter times. TeamSET is a PC based software package based integrated set of applications that support design team working and encourages a multidisciplinary culture. The TeamSET concurrent engineering software toolkit includes Quality Function Deployment (QFD) to help to understand the customers wants, and develop the product specification, Design for Assembly (DFA) to simplify product structure and optimize component handling and assembly, Manufacturing Analysis (MA) to select the most appropriate materials and processes for component manufacture, Failure Modes and Effects Analysis (FMEA) to ensure the design is robust, Design to Target Cost (DTC) to monitor product costs throughout the design process, and Controlled Concept Convergence to select the best options. The result from the tool kit will helps product design teams to produce better products at lower cost and in a shorter time (TeamSet, 2008). DFA analysis is carried out on a graphical chart as shown in Figure2.2



The benefits of TeamSET are:

a) The provision of such a focus allows design team to explore and compare design or re-design options quickly and with minimumeffort.

b) Will allow user addressed such problems as time to market, quality, reliability and cost by ensuring that the design to which user are committing is simple to manufacture and assemble has a minimum of non-essential parts, keeps tooling costs down and will meet customerneeds.

c) Work from previous products, assemblies and part analysis can be re-used in later design activities negating the need to start from scratch eachtime.

d) This will not only shorten analysis times but also enable user to capitalize on the benefits that accrue from standardization, consistency andpredictability.

7.Method ofStudy

In this section, the explanations are more on the project development which is based on the chart to ensure the procedure and the steps of the project will be done properly in the appropriate time which had been planned before. The methodology of the project starts with the introduction of product to be studied and then some literature review on the design for manufacturing and assembly method, application of DFMA and techniques for case study. The data for literature review was founded from journals, related reference books from library, and also internet. After that, the procedure goes on gaining the information from the existing product. The method used for collecting data was from the reassemble the existing product. These data were used to apply analysis using

TeamSET software. DFA analysis will be applied to the existing product design. The purpose of this analysis is to verify the design efficiency of existing product including assembly process, parts included and etcetera. Then from the result achieved, the result will be analyzed in order to get the best design for redesign purposed. Solidwork software will be used in order to make a drawing of redesign the existing product. Figure 3.1 shows the flow chart of the planning of the study.

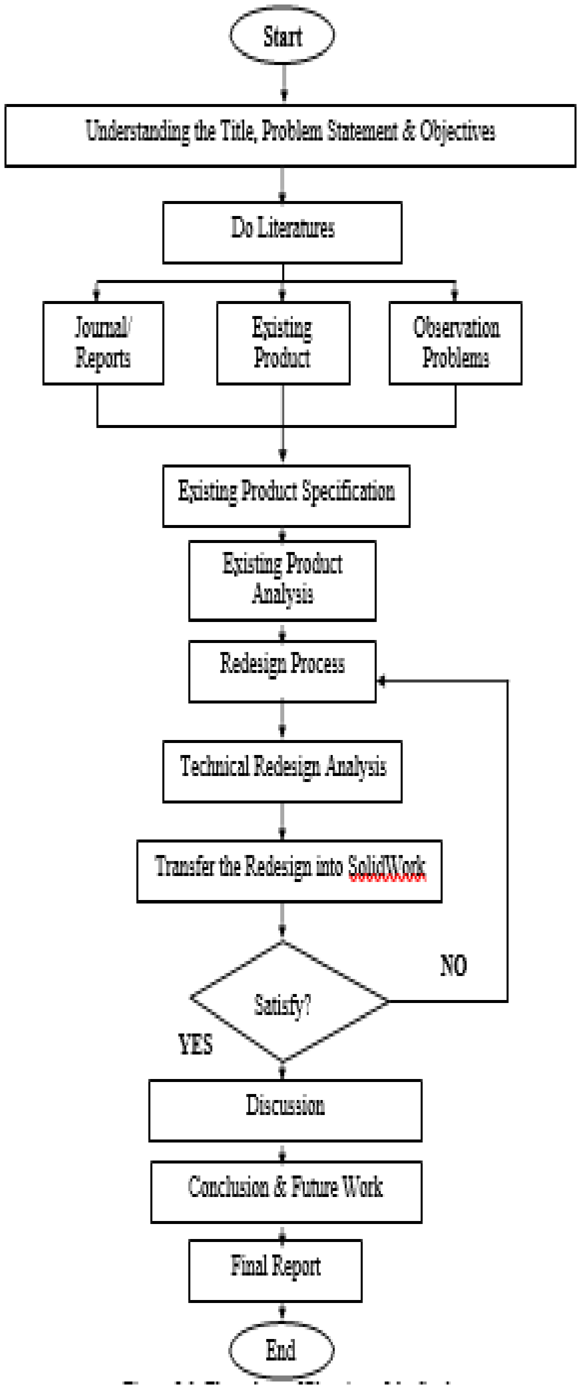


Fig.Flow chart of Planning of the Study

8.Experimental set up

In the Experimental Model Analysis, we will make fast response functions (FRFs) with FFT analyser, modal excitation techniques and modal parameter. Experimental modal parameters (Natural frequency and amplitude) are obtained from a set of FRF measurements. All the tests were performed at the S.S.G.B College of Engineering, in the Mechanical engineering lab.

Experimental Setup Consists of

1. A-2 channel FFT analyzer to compute vibration in grasstrimmer.
2. Laptop as a Display unit for FFT Analyser
3. Upper and lower accelerometers attached tohandle.

FFTAnalyser

FFT Analyser is used to measure the frequency range of grass trimmer in which the grass trimmer subjected to various length with various isolator gives different conditions with amplitude. This will help us in designing the trimmer with different length where the vibration is less and which material is perfect isolator to rig.

Display unit for FFTAnalyser

This is mainly in the form of PC (Laptop) when the excitation occurs due to the electric grass trimmer then the signals transferred to the portable PULSE and after conversion comes in graphical form through the software. Mainly the data includes graphs of frequency Vs amplitude, frequency Vs time resonance frequency etc

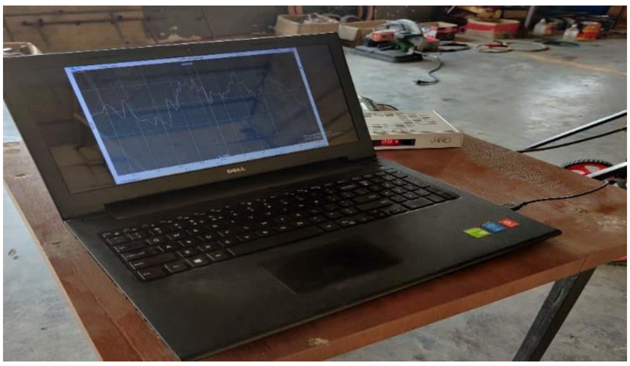


FIG THE SET UP WITH HOLDING GRASS TRIMMER

Procedure for Experimental Setup by using FFTAnalyzer

- First of all electric grass trimer is fixed in rig assembly which is fabricated, to reduce vibration & give comfort to the operator.
- The connections of the FFT analyzer, laptop, and accelerometer sensors along with the requisite power connections were made with electric grasstrimmer.
- The accelerometers were fixed at the handle of electric grass trimmer.
- Then excitation starts as electric grass trimmer is started and the vibration from motor to shaft is transmitted tohandle.
- Then in electoral grass trimmer handle on X Y & Z axis amplitude Vs frequency graph was obtained from graphical user interface.
- By moving the cursor to the peaks of the FFT graph, the cursor values and the resonant frequencies wererecorded.
- The above procedure is repeated for various length & isolators used in experiment and natural frequencies aremeasured.
- The values (i.e., amplitudes) obtained from the FRF spectrums were compared withrespect to all axis and isolator material.

Construction And Testing

The experimental set up consist of portable dead channel FFT, electric grass trimmer with rig, laptop and two accelerometers (one placed near or on the vibration exciter and other on top on mass pan).The electric grass trimmer with rig was used in this study. Prior to the start of the experiment the whole set up of electric grass trimmer with rig is connected with FFT and was ran for 10 min. means at which condition resonance occurred. The electric grass trimmers when operated then vibration actuated in grass trimmer are measured in FFTsoftware.

In experiment the amplitude of grass trimmer in various condition with various isolators material are taken are as follow

- Amplitude in short & longlength.
- Amplitude on variousaxis.

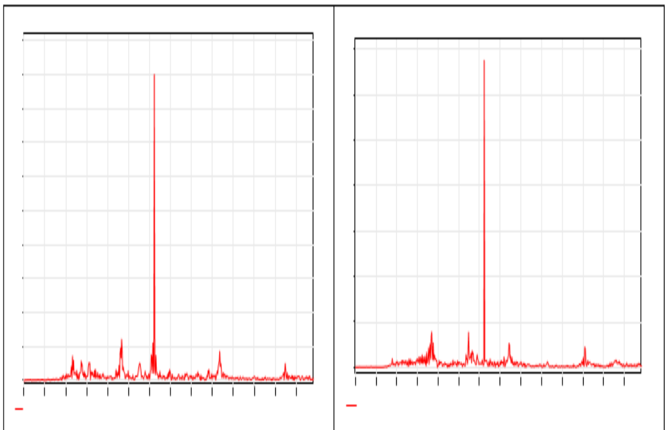
Amplitude with holding to grass trimmer & without holding grass trimmer

Different length used are

- The short length for the shaft is taken as 300mm
- The longer length for shaft is 600mm

TABLE 1
THE RIG WITHOUT ISOLATION MATERIAL

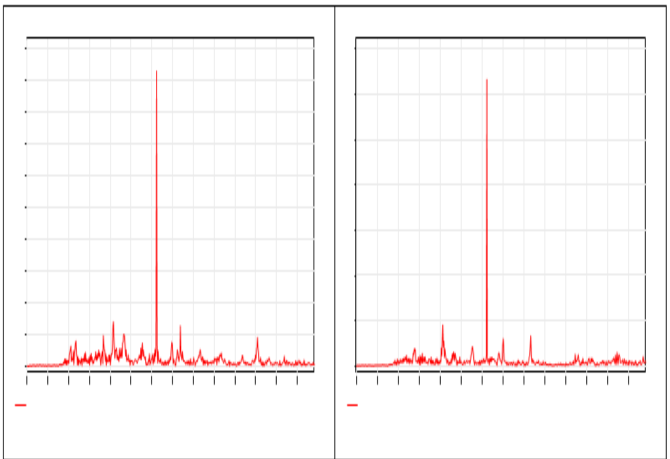
1	The RIG without isolation material			
	Length	Condition of hold trimmer	amplitude (volt)	frequency (Hz)
	short length	with grip	2.20	155.64
	long length	with grip	3.31	155.64



Short length with grip | Long length with grip

TABLE 2: THE RIG ISOLATED WITH FOAM

	The RIG isolated with foam			
2	Length	Condition of hold trimmer	amplitude (volt)	frequency (Hz)
	short length	with grip	2.17	155.64
	long length	With grip	3.11	155.64



Short length with grip | Long length with grip

GRAPH 2 THE RIG ISOLATED WITH FOAM

9.FINITE ELEMENT ANALYSIS

The finite element method is a powerful tool for the numerical procedure to obtain solutions to many of the problems encountered in engineering analysis. Structural, thermal and heat transfer, fluid dynamics, fatigue related problems, electric and magnetic fields, the concepts of finite element methods can be utilized to solve these engineering problems. In this method of analysis, a complex region defining a continuum is discretized into simple geometric shapes called finite elements the domain over which the analysis is studied is divided into a number of finite elements. The material properties and the governing relationship are considered over these elements and expressed in terms of unknown values at element corner .An assembly process, duly considering the loading and constraint, results in set of equation. Solution of these equations gives the approximate behavior of the continuum.

Steps involved in FEM

Step1: Discretization of continuum

The first step in any FEM is to divide the given continuum in to smaller region called element. The type of elements has to be taken depending on type of analysis carried out like one dimensional, two dimensional, and three dimensional.

Step 2: Selection of displacement model

For the continuum discretized in to number of element, displacement variation over each of these element is unknown .Hence a displacement function is assumed for each of the element ,this function is called displacement model.

Step 3: Derivation of elemental stiffness matrix

The equilibrium equation for an element is determined by using the principal of minimum potential energy.

Step 4: Assembly of the element stiffness matrix

This step involves determining of global stiffness matrix. This is done by using the compatibility conditions at the nodes. The displacement of a particular node must be the same for every element connected to it. The externally applied loads must also be balanced by the forces on the elements at these nodes.

Step 5: Apply the boundary conditions

To obtain a unique solution of the problem, some displacement constraints (i.e. boundary conditions) and loading conditions must be prescribed at some of the nodes. This may be of the following forms

1) Elimination method
2) Penalty method
3) Multi constraint method

These boundary conditions are incorporated into the system of linear algebraic equations, which can then be solved to obtain a unique solution for the displacements at each node.

Step 6: To find unknown displacement, strain and stress

After solving the global equations, displacements at all the nodal points are determined. From the displacement values, the element strains can be obtained from the stress-strains relations. In FE formulation only the displacements are the independent variables, that is, forces, strains and stresses are obtained from the displacements.

Static Analysis

Static analysis calculates the effects of steady loading conditions on a structure, while ignoring inertia and damping effects, such as those caused by time-varying loads. A static analysis can, however, include steady inertia loads (such as gravity and rotational velocity), and time-varying loads that can be approximated as static equivalent loads (such as the static equivalent wind and seismic loads commonly defined in many building codes). Static analysis involves both linear and nonlinear analyses. Nonlinearities can include plasticity, stress stiffening, large deflection, large strain, hyper elasticity, contact surfaces, and creep. The FE analysis used for the major part of this work is static analysis which involves both linear and nonlinear structural analysis. Hence more prominence is imparted on Linear and nonlinear analysis in further sections.

Linear Static Analysis

In linear analysis, the behavior of the structure is assumed to be completely reversible; that is, the body returns to its original undeformed state upon the removal of applied loads and solutions for various load cases can be superimposed.

The assumptions in linear analysis are:

1) Displacements are assumed to be linearly dependent on the applied load.
2) A linear relationship is assumed between stress and strain.
3) Changes in geometry due to displacement are assumed to be small and hence ignored.
4) Loading sequence is not important and the final state is not affected by the load history. The load is applied in one go with no iterations.

Non Linear static analysis

In many engineering problems, the behavior of the structure may depend on the load history or may result in large deformations beyond the elastic limit. The assumptions/ features in nonlinear analysis are:

1) The load-displacement relationships are usually nonlinear.
2) In problems involving material non-linearity, the stress-strain relationship is a nonlinear function of stress, strain, and/or time.
3) Displacements may not be small; hence an updated reference state may be needed.
4) The behavior of the structure may depend on the load history; hence the load may have to be applied in small increments with iterations performed to ensure that equilibrium is satisfied at every load increment.

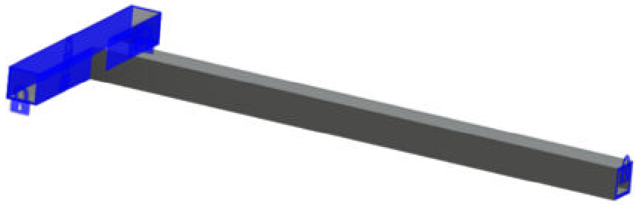
From the above assumptions, the finite element equilibrium equation for static analysis is:

$$[K]\ \{U\} = [F]$$

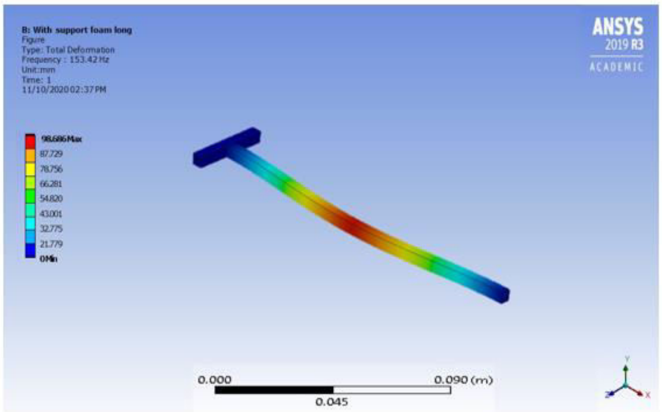
Where $[K]$ is the linear elastic stiffness. When the above assumptions are not valid, one performs nonlinear analysis.

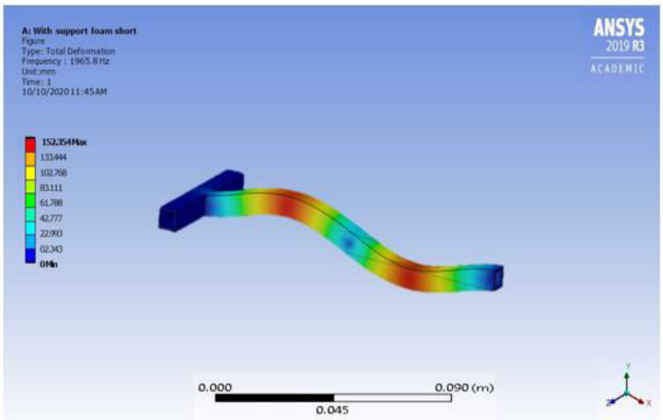
10.FEA RESULTS

Trimmer Handle is modeled on catia

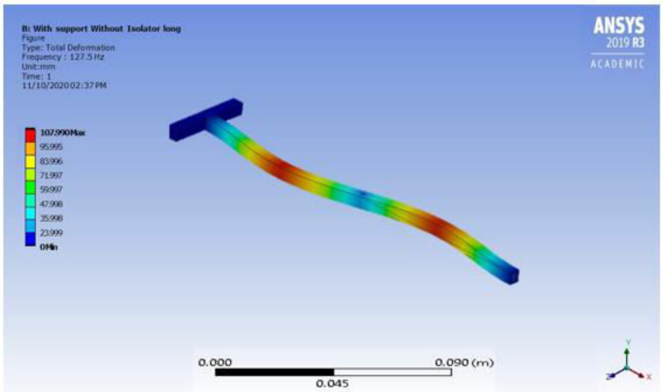


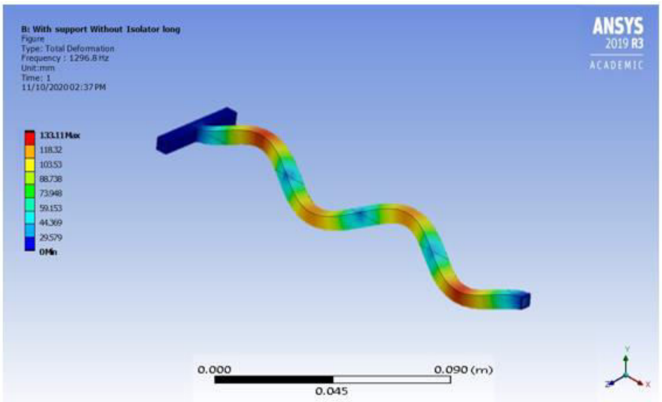
A.With support with Foam Long



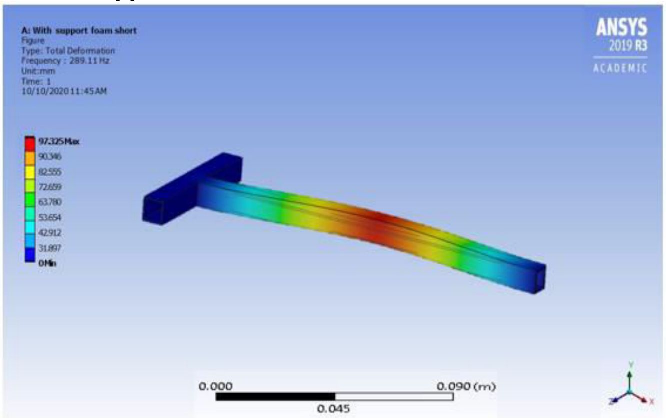


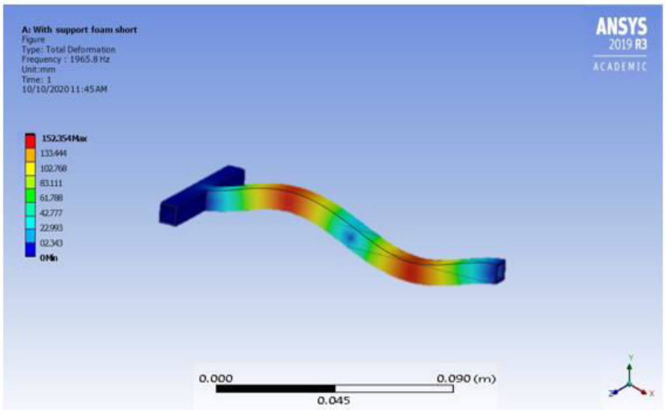
B.With Support Without Isolator



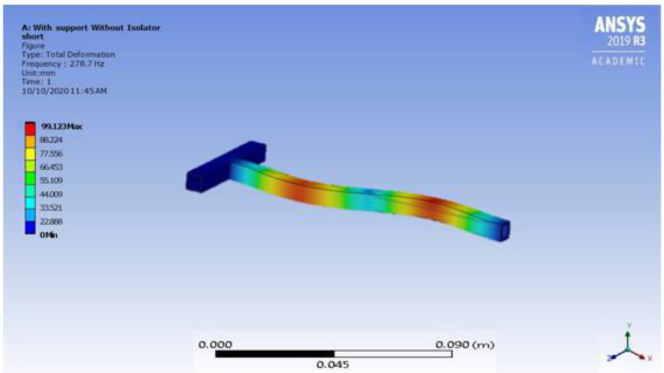


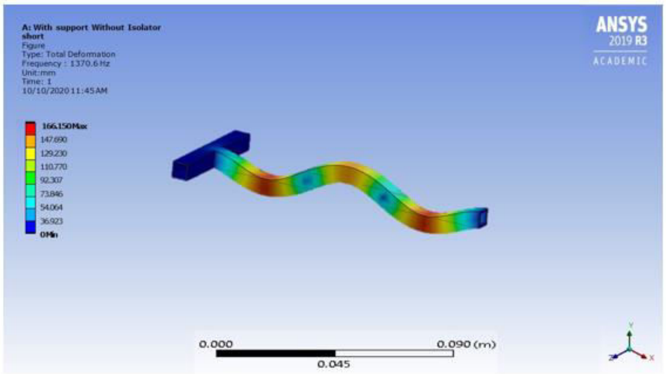
C.With support with foam short





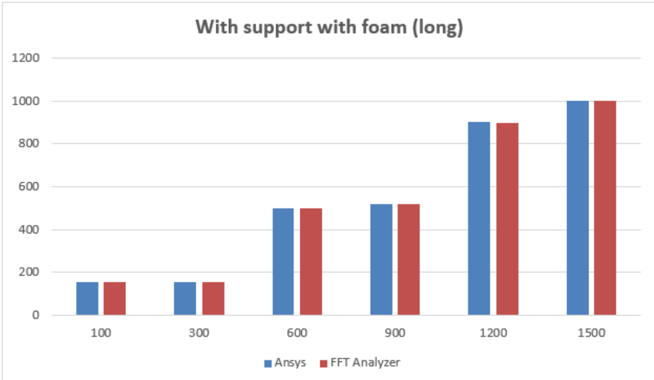
D.With support without isolator

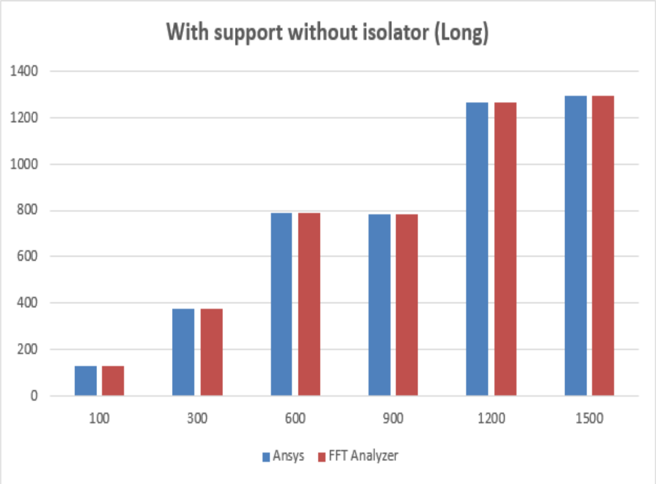


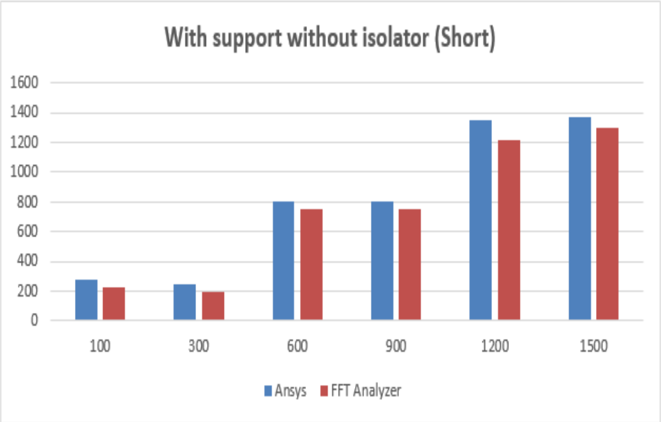


11.CONCLUSION

Mode	Motor RPM	With support with foam long (Ansys) Hz	With support with foam long (FFT) Hz	With support with foam Short (Ansys) Hz	With support with foam Short (FFT) Hz	With support without isolator long (Ansys) Hz	With support without isolator long (FFT) Hz	With support without isolator Short (Ansys) Hz	With support without isolator short (FFT) Hz
1	100	153.42	153.40	298.11	250.3	127.5	127.3	278.7	228.9
2	300	156.6	156.6	300.57	250.68	375.7	374.9	245.6	195.7
3	600	499.4	499.1	945.87	900.72	788.6	788.3	799	748.89
4	900	520.96	520.90	970	920	785.4	783.88	803.55	750.52
5	1200	900.72	900	1997.89	1656.4	1265.9	1265.7	1345.54	1215.63
6	1500	1000	999.9	1965.8	1903.4	1296.8	1296.66	1370.6	1300.99







12. Futureworks

For this, the study was focused more on implantation of DFMA methodology, and finally came out with a new design of grass cutting machine. Actually, there are many ways or phases that this project could be done. So, for future works, I recommended some methods that can be done as follows:

a) Use Morphological Chart method to identify the alternative mechanism and operation system of the grass cutting machine to bedeveloped.

b)Study the overall costing for design grass cutting machine that had been developed.

c)Concept Convergence method to analyze and select the best alternatives based on the quantitative assessment.

d)For student who use DFMA methodology, they sould have collaboration with industry in order to gain more knowledge, information, and the technical requirements regarding DFMAimplementation.

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