UNIVERSITI TEKNIKAL MALAYSIA MELAKA

OIL PALM SEED TRANSPORTER: STRUCTURE ANALYSIS & IMPROVEMENT

Thesis submitted in accordance with the requirements of Universiti Teknikal Malaysia Melaka for the Bachelor's Degree in Manufacturing Engineering (Manufacturing Design) with Honours

By

Muhamad Faidzal Bin Salkah

Faculty of Manufacturing Engineering

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This report is submitted to the Faculty of Manufacturing Engineering of UTeM as a partial fulfillment of the requirements for the degree of Bachelor of Manufacturing Engineering (*Design*). The members of the supervisory committee are as follow:

(...)

En Zolkarnain Bin Marjom

(PSM Supervisor)

ABSTRACT

This project describes about implementation in design and analyzes the structure for new oil palm transporter. Nowadays, there are many type of transporter in the market to transport the FFB from the tree to the FFB piles. But the main problem with the product is the cost for the transporter too high and will not afford to small scale farmer to use it. That's why there are so many worker use wheelbarrow as a main transporter to transport FFB from tree to FFB pile. But using wheelbarrow, a lot of human energy is needed to carry the FFB and the productivity will decrease. So the main purpose of this project is to design a new in-field palm oil seed transporter with low cost. The first step to make a new design is gain all the data from literature review about the existing product and define the problem that occur to the existing product. From this problem, the idea was generate how to make a new design for FFB that can overcome all the problem from existing product. After product design specification had been define, a design need to draw using Computer Aided Design (CAD) software. The CAD software that used in this project is Solidworks. After the drawing of the design had finished, the analysis should be done to know the actual strength of the design. The most important parts that need to analyze is the structure of the design because the structure is the main part of the design. The finite element method will used to analyze the structure of the design. The software that used to analyze the structure is MSC Nastran. Using this software, the load (1000kg) will apply to the structure to know the strength of the structure. From the result of analysis, the maximum stress is 8.00×10^3psi. Then the calculation is done to define the design factor. This design factor must be more than the theory design factor, 2. If less the redesign process need to be done to the design. This step important to make sure the structure can carry the load safety without any crack and fracture.

ABSTRAK

Projek ini menghuraikan tentang perlaksanaan dalam mereka cipta dan menganalisis keadaan struktur untuk jentera pengangkut tandan kelapa sawit yang baru. Pada masa sekarang ini, terdapat pelbagai jenis jentera yang digunakan untuk mengangkut kelapa sawit dari pokok ke tempat pengumpulan kelapa sawit dipasaran. Tetapi masalah utama jentera-jentera ini adalah kos untuk sebuah jentera ini terlalu tinggi dan tidak mampu untuk dimiliki oleh pekebun-pekebun kecil. Oleh sebab ini, kebanyakan pekerja-pekerja ladang menggunakan kereta sorong sebagai pengangkutan yang utama untuk mengangkut tandan sawit ini. Tetapi masalah yang dihadapi menggunakan kereta sorong ini adalah masalah tenaga. Tenaga manusia yang tinggi terpaksa digunakan untuk menolak kereta sorong ini dan hasil pengeluarannya juga amt kurang berbanding menggunakan jentera. Jadi, tujuan utama projek ini adalah untuk menghasilkan satu mesin pengangkut kelapa sawit yang boleh menyelesaikan semua masalah yang dihadapi sekarang ini. Langkah pertama yang harus dilakukan adalah mengumpul segala data tentang mesin-mesin pengangkut yang terdapat dipasaran dan masalah yang dihadapi. Daripada masalah ini akan mencetuskan idea untuk mereka cipta mesin pengangkut kelapa sawit yang boleh menyelesaikan semua masalah ini. Setelah produk spesifikasi dibuat, lukisan tentang mesin ini boleh dilakukan menggunakan Computer Aided Design (CAD). Perisian yang digunakan adalah Solidworks. Setelah lukisan dilakukan, proses analisis perlu dilakukan untuk mengenal pasti tahap kekuatan rekaaan tadi. Finite element method akan digunakan untuk proses analisis ini. Perisian yang digunakan adalah MSC. Nastran. Menggunakn perisisan ini, beban (1000kg) akan dikenakan ke atas struktur rekaan. Daripada keputusan analisis ini, pengiraan secara manual akan dilakukan untuk memastikan tahap kekuatan rekaan terbabit. Sekiranya rekaan terbabit tidak mampu untuk menampung beban yang telah ditetapkan, proses rekaan semula akan dilakukan.

DEDICATION

For my beloved father and mother.

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LIST OF ABBREVIATIONS, SYMBOLS, SPECIALIZED NOMENCLATURE

FFB	-	Fresh Fruit Bunches
CAD	-	Computer-aided Design
MPOB	-	Malaysian Oil Palm Board
MB	-	Mechanical Buffalo
PORIM	-	The Palm Oil Refiners Association of Malaysia
LGP	-	Low Ground Pressure
DFMA	-	Design for Manufacturing and Assembly
DFM	-	Design of Manufacturing
DFA	-	Design for Assembly
QFD	-	Quality Function Deployment
2D	-	2 Dimensions
3D	-	3 Dimensions
CAE	-	Computer-aided Engineering
CAM	-	Computer-aided manufacturing
PLM	-	Product lifecycle management
Catia	-	Computer Aided Three dimensional Interactive Application
NC	-	Non-conventional
FEA	-	Finite Element Analysis
FEM	-	Finite Element Method
P.D.S	-	Product Design Specification
UV	-	Ultraviolet
ATV	-	All-terrain vehicle
N	-	Design Factor

CHAPTER 1
INTRODUCTION

1.1 Background of Problem

The oil palm, Elaeis guineesis Jacques is indigenous to West Africa where the main palm belt ran from Sierra Leone, Liberia, the Ivory Coast, Ghana and Cameroon to the equatorial regions of the Republics of Congo and Zaire, (Hartley, 1955). Around the year, there are many improvement had done to increase the productivity of Oil Palm. But the main problem is about the transporter to carry the fresh it bunches (FFB) to the fresh fruit bunches (FFB) piles. Eventhought there are many type of machine and tractor that had design to solve the problem but it's still cannot to solve this problem fully. The main problem from the existing product is their cost. The cost for one machine or tractor is too high and some of the machine costing above than RM 10 000 and not afford by the small scale farmer. Beside that, the maintenance cost for the machine also high because the complex machine needs high cost maintenance. This product is normally used by the big company.

The previous study had done by Esya Hafiza in 2006 about "Design, Development and Analysis of Palm Oil Seed Transporter using Concurrent Engineering". In this study, she tried to produce the new transporter for FFB. But in the end of the study, it can be seen that the design that had designed is too simple and not suitable to produce it for commercial. Eventhougth the design that had designed produced is low in cost but it's not suitable to use it in plantation especially when the monsoon season where the land and the soil become soft and sometimes become a water pool.

From the analysis that had been done, the frame that is not too strong to carry the FFB more than 500kg. The tyre for the transporter also not suitable to use in soft land and cannot grip to the land because the tyre will become smooth and not grip. This is dangerous and accident would be happened.

So this project will continue the project about the "Design, Development and Analysis of Palm Oil Seen Transporter using Concurrent Engineering". Using the fact that had done by previous study, a new design for the FFB transporter would be done that suitable for all season and all type of land. From the survey that had done by previous study, around 90% of small scale farmer using the wheelbarrow as a main transporter to carry PFB to FFB piles. This is because they are not afforded to buy the new machine or tractor because the machine or tractor is highly cost. So the new design of transporter with low cost is too important to them to carry the FFB. In this study a new design of palm oil seed transporter with the cost below than RM 5000 will produce.

1.2 Problem Identification

Palm oil is one of the commercial value and the primary commodity plant in Malaysia. So, to develop this sector there are many research had done and many tractor and machineries are design to solve all the problem and to increase the productivity.

The main problem here is how to carry the fresh fruit bunches (FFB). Before this, the main transporter to carry the harvested palm oil seed to the fresh fruit bunches (FFB) pile before it was sent to mill for process. So the main problem here is it's not easy to carry the FFB using wheel barrow in a billowy, slimy and copse farm or estate. Beside that the bucket of wheel barrow are too small and only can mange to fill around 4 or 5 bunches of oil palm seed. When the FFB falls from the tree, fruit will bruise and it can reduce the value of the crop. When the process take the longer tie, so it's mean the value of the FFB will also decline. In traditional method, the fruit will handle until 5 times where when the fruit fall from the tree, load into wagon, drop at road, drop at chute, and load into truck and using the advance method, it still involved around three types of handling.

Carrying a bucket of FFB using wheelbarrow requires high effort from human energy. During the monsoon season, the collection of FFB become more difficult where the water pool will exist at the farm and make the soil become soft and it will restrain the fully loaded wheel barrow. So in this case a lot of energy was needed to transport the harvest FFB to the pile. Existing harvest collection method are depends to the transporter system that it's not suitable over the soft ground. This situation becomes more serious during the monsoon season where over any ground becomes a marshy.

The existing machineries and tractors are too highly in cost and not efficient to small-scale palm oil farmer owner. That's why a new design for FFB transporter is needed to overcome this problem with low cost that can be afforded not only for large estate owner but also for small-scale palm oil farmer owner.

1.3 Project objectives

The objectives of this project are:

a) To redesign the new oil palm transporter
b) To study in depth the embodiment and detail design of mechanism
c) To study the structure analysis on mechanism

1.4 Scope of study

The scope of this project involves the problem identification from the existing product in market. Then make the literature view or library research from the existing product. After that, the drawing of the design should be done first using Computer Aided Design (CAD) before make the analysis. After the design best design had been drawn, the structure analysis of the design should be done. The software that used for analysis process is MSC Nastran Patran. In analysis process, all the component and structure must be analyzed using the actual loads. Redesign process will be done to the old design if the design cannot support the load.

CHAPTER 2
LITERATURE REVIEW

This chapter discuss about the origin of oil palm, the over view about the oil palm industry, mechanization in oil palm industry, type of existing product, problem related on existing product and also the conclusion for this chapter.

2.1 Origin of Oil Palm

It is generally agreed that the Oil Palm (Elaeis guineensis) originated in the tropical rain forest region of West Africa. The African oil palm is native to tropical/Africa, from Sierra Leone in the west through the Democratic Republic of Congo in the east. It was domesticated in its native range, probably in Nigeria, and moved throughout tropical Africa by humans who practiced shifting agriculture at least 5000, years ago. European explorers discovered the palm in the late 1400's, and distributed it throughout the world during the slave trade period. In the early 1800s, the slave de ended but British began trading with West Africans in ivory, lumber, and palm oil. The oil palm was introduced to the Americas hundreds of years ago, where it became naturalized and associated with slave plantations, but did not become and industry of its own until the 1960s. The first plantations were established on Sumatra in 1911 and in 1917 in Malaysia. Oil palm plantations were established in tropical America and West Africa about this time, and in 2003, palm oil production equaled that of soybean, which had been the number one oil crop for many years. (Anonymous, 2007)

Palm oil is rich in carotenoids, (pigments found in plants and animals) from which it derives its deep red colour, and the major component of its glycerides is the saturated fatty acid palmitic; hence it is a viscous semi-solid, even at tropical ambient, and a solid fat in temperate climates. (Anon, 2007)

Because of its economic importance as an high-yielding source of edible and technical oils, the oil palm is now grown as a plantation crop in most countries with high rainfall (minimum 1 600 mm/yr) in tropical climates within 10° of the equator. The palm bears its fruit in bunches varying in weight from 10 to 40 kg. The individual fruit, ranging from 6 to 20 gm, are made up of an outer skin (the exocarp), a pulp (mesocarp) containing the palm oil in a fibrouhatrix; a central nut consisting of a shell (endocarp); and the kernel, which itself contains an oil, quite different to palm oil, resembling coconut oil.

The extensive development of oil palm industries in many countries in the (tropics) has been motivated by its extremely high potential productivity. The oil palm gives the highest yield of oil per unit area compared to any other crop and produces two distinct oils - palm oil and palm kernel oil - both of which are important in world trade.

Modern high-yielding varieties developed by breeding programs, under ideal climatic conditions and good management, are capable of producing in excess of 20 tonnes of bunches/ha/yr, with palm oil in bunch content of 25 percent. This is equivalent to a yield of 5 tonnes oil/ha/yr (excluding the palm kernel oil), which far outstrips any other source of edible oil.

Table 2.1 : Ideal composition of palm fruit bunch

Bunch weight	23-27 kg
Fruit/bunch	60-65%
Oil/bunch	21-23%
Kernel/bunch	5-7%
Mesocaip/bunch	44-46%
Mesocarp/fruit	71-76%
Kernel/fruit	21-22
Shell/fruit	10-11

Sources: www.etawau.com/OilPalm/PalmOil.htm

Figure 2.2 : Oil Palm fresh fruit bunch

Sources : http://en.wikipedia.org/wiki/Oil_palm"

2.2 Mechanization in Palm Oil Industry

Oil palm in Malaysia is most important crop where it was the largest cultivation area in Malaysia (total area of about 4 million hectares). It was produced about 45% of the total world oil palm production and exported a total of 29% of the total global oil and fats (MPOB, 2006). Oil palm remains as the 'golden crop' that would continue significantly contribute to the increase in the global oils and fats trade.

Despite being an important crop, the availability of work force and low productivity of the current force are the most important and challenging problems for oil palm plantations sector for Malaysia. Mechanization becomes an important input that can help to accelerate the process of transforming the plantation sector to be more efficient, modern, sustainable, and globally competitive. Even tough some improvements has been implemented to mechanize various field operations, however, introduction of new and innovative technology to reduce the labor dependency and also at the same time able to increase the labor productivity are still low. (Darius & Azmi, 2007).

Advancement of mechanization in the oil palm plantation sector is hindered by the availability of suitable prime movers to suit the local terrain conditions. Consequently, tractors have been widely used as prime mover for various agricultural field operations in the plantation throughout Malaysia without other options.

Moreover, mechanization in Malaysia is still depending on imported tractors due to unavailability of local agricultural machinery manufacturing company to produce its own local design and made tractors. In addition, Malaysia in the same position with other non manufacturing tractors countries to accept any imported product than can compromise on the specifications and affordable to own. (Darius & Azmi, 2007b).

Research and development should make a special effort to expedite mechanization of certain field operations. With the aim of achieving the status of the developed nation the Malaysian government has embarked on an aggressive industrialization program as means of achieving the national goal. Increasingly the plantation sector relies on foreign workers to fill the void. It is estimated that foreign workers account for some 65% and 90% of the plantation labor in Peninsular Malaysia and Sabah.

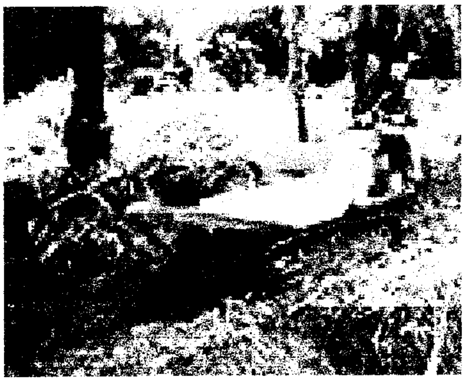
Figure 2.3 : Oil palm plantation in Malaysia

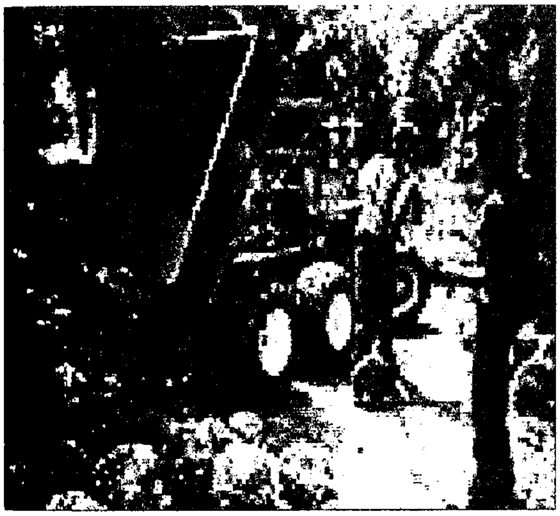
Sources : www.etawau.com/OilPalm/PalmOil.htm

2.3 Existing product

Type	Description
Wheelbarrow 	a) Wheelbarrow is the standard transporter that used in past in transporting palm bases to collection road. b) Wheelbarrow is the simple transporter with low cost. c) The current prices for a standard wheelbarrow are around RM 80. d) With the single tyre, wheelbarrow can to push in the narrow pathway and carry the load balanced on the head.
Mechanical Buffalo 	a) A 'mechanical buffalo' is the simple 3-wheel carrier with 400kg payload and dump bin. b) Mechanical buffalo (badang) was manufactured by EPA Management Sdn. Bhd. c) The price around RM 6500 in 1990 was and was increase in 1999 and the actual price around RM 11600. d) Once the year, the machine has been improved from 4hp to 6hp engine to provide more power in stepper terrain. (MPOB 2006).

	e) Right now MB was installed with 9hp engine with a high lift for direct unloading of crop.
The grabber 	a) Equipped with 25hp engine and hydraulic grabber (a device like a small boom crane mounted on the back of the tractor) towing a scissor lift trailer. b) Was developed by Wan Ishak Wan Ismail from Department of Biological & Agricultural Engineering, University Putra Malaysia. c) The price is around RM 65,000 d) The driver will drives down the palm rows and using the grabber to pick up the fruit around him. When the trailer is full, it's driven to a large over-the-road trailer (or a large bin that is power loaded onto a trailer or at the FFB pile), that is placed in the field at a convenient location.

Super Crawler	
	a) Super crawler was designed by MPOB to overcome the problem of FFB transportation in area which the soil was wet and soft. b) The low ground pressure characteristic of this machine enables it to maneuver effectively under this condition. c) One driver and two loader are needed and the average of collection is around 18-22 tonnes per day. d) The current price for super crawler is around RM 15, 000. e) Specification for Super Crawler: • Engine : air cool, diesel • Engine power: 30 hp • Speed : 10 km/hr • Track : metal, 30 cm wide • Transmission : hydrostatic • Performance : 18-22 t/d (PORIM 2006)

Wakfoot	
Wakfoot 	a) Wakfoot is the six single chassis machine with six wheel-drive vehicle. The system enables the machine to pull out of difficult areas. b) The productivity of this product is around 22-25 tonnes per day depends on the crop level and palm age. c) This product was designed by PORIM for FFB infield transportation. d) Specification for wakfoot: • Diesel engine 23hp • Six low ground tyres • Six wheel drive • Fuel consumption 1.2 l/h

	Manual	Wakfoot
Average daily productivity	22	20
Mechanical worker	-	3
Productivity for harvester	1.47	2.22
No of harvester	15	9
No of worker	15	12
Labor reduce	-	3
Feet / day	20-23	20-22

Taltrac 	a) This product was invented by MPOB. b) Specification for Taltrac : • Double chassis FFB infield transportation with 10 low ground pressure (LGP) tyres, suitable for peat and soft areas. • 18hp diesel power • Carrying capacity : 0.5-1 tonnes • Productivity : 18-25 (mt/dy)

	Manual	Taltrac
Average daily productivity	22	20
Mechanical worker	-	3
Productivity for harvester	1.47	2.22
No of harvester	15	9
No of worker	15	12
Labor reduce	-	3
Feet / day	20-23	22-23

Table 2.2 : Characteristic of existing product

2.4 Problem related on existing product.

Even the existing product can use as a transporter for FFB, but there a lot of problem using the existing product.

Even wheelbarrow is cheap, but it does require more energy to transport harvested palm-oil seed to the collecting pile. It also reduces the amount of FFB collected because the bucket for wheelbarrow is too small. Wheelbarrow only fit for 4 to 5 bunches of oil-palm seed and it's not efficient for large-scale plantation.

For mechanical buffalo, it is restricted used to collect the FFB only but not suitable to collect the loose fruit. Eventhough, MB still special compare to other small tractor because the price still low and adaptation with oil-palm estate condition, harvester's productivity and maintenance. Based on the comparative study between the mechanical buffalo and mini tractor, some company has adopted the former as a standard vehicle for infield palm-oil collection because:

1. Mechanical buffalo (MB) is useable in almost all terrains, and easy to operate and maintain.
2. Harvester's productivity in MB system is comparable to mini-tractor system.
3. MB is cheaper than mini-tractor and hence it involves a lower capital outlay.

For manual collecting such as haul on shoulder and carried the basket fully loaded of FFB on the head are not suitable for large-scale plantation furthermore it requires more labors, energy and waste the collection time. The productivity of FFB collection using this method, are low compare to other and it's not efficient for in plantation areas whether for large-scale plantation or small-large plantation.

The mini tractor that equipped with the hydraulic grabber for easy pick up of palm-oil bunches is very high cost and can't be supported by small-scale plantation owners. Beside that, these tractor also high maintenance and require peripheral cost for machine breakdown and others. Although it will reduce labor but its still cannot collect the loose fruit.

The use of big tractor with the trailer need a high cost and not very useable in all terrains. Althought these tractors can carry until 6 to 7 tonnes but its still can use on soft grounds or on raining day. These heavy loaded tractors also are not for hilly ground because the hilly condition will make it unstable and difficult to operate. Beside that, these tractors also need the highly maintenance and caution to avoid damage or loss.

2.5 Related study

To finish do this study there a lot of study that must be considered. Start from the conceptualization until finish makes the mockup. The study that need to consider such as Finite element analysis (FEA), CAD & CAM, Rapid Prototyping and many more.

2.5.1 Pugh method

This is a method for concept selection using a scoring matrix called the Pugh Matrix. It is implemented by establishing an evaluation team, and setting up a matrix of evaluation criteria versus alternative embodiments. This is the scoring matrix usually associated with the QFD method and is a form of prioritization matrix. Usually, the options are scored relative to criteria using a symbolic approach (one symbol for better than, another for neutral, and another for worse than baseline). These get converted into scores and combined in the matrix to yield scores for each option. (Wikipedia 2007c).

a) Effective for comparing alternative concepts
b) Scores concepts relative to one another
c) Iterative evaluation method
d) Most effective if each member of a design team performs it independently and results are compared.

Comparison of the scores generated gives insight into the best alternatives

2.5.1.1 Steps to Use/Construct Pugh matrix

1. Choose or develop the criteria for comparison.
   Examine customer requirements to do this.
   Generate a set of engineering requirements and targets.

2. Select the Alternatives to be compared.
   The alternatives are the different ideas developed during concept generation. All concepts should be compared at the same level of generalization and in similar language.

3. Generate Scores.
   Usually designers will have a favorite design, by the time it comes to pick one. This concept can be used as datum, with all the other being compared to it as measured by each of the customer requirements. If the problem is to redesign an existing product, then the existing product can be used as the datum.

   For each comparison the product should be evaluated as being better (+), the same (S), or worse (-). Alternatively, if the matrix is developed with a spreadsheet like Excel, use +1, 0, and —1 for the ratings.
   If it is impossible to make a comparison, more information should be developed.

4. Compute the total score

Four scores will be generated, the number of plus scores, minus scores, the overall total and the weighted total.

The overall total is the number of plus scores- the number of minus scores.

The weighted total is the scores times their respective weighting factors, added up.

The totals should not be treated as absolute in the decision making process but as guidance only.

If the two top scores are very close or very similar, then they should be examined more closely to make a more informed decision.

Table 2.3 : General Format for a Pugh Matrix:

		Concepts
Criterion	Wt	(Step 2)
(Step 1)	:	Generate score (step 3)
.		.
:		.
Total +		
Total -		
Overall Total		Generate totals (step 4)
Weighted Total		

(Sources : www.enge.vt.edu/terpenny/Smart/Virtual_econ/Module2/pugh_method.htm)

2.5.2 Computer-aided Design (CAD)

Computer-aided design (CAD) is use of a wide range of computer based tools that assist engineers, architects and other design professions in their design activities. It is the main geometry authoring tool within the Product Lifecycle Management process and involves both software and sometimes special-purpose hardware. Current packages range from 2D vector base drafting systems to 3D solid and surface modelers.

There are many producers of the lower-end 2D systems, including a number of free and open source programs. These provide an approach to the drawing process without all the fuss over scale and placement on the drawing sheet that accompanied hand drafting, since these can be adjusted as required during the creation of the final draft. (Wikipedia, 2008)

3D wireframe is basically an extension of 2D drafting. Each line has to be manually inserted into the drawing. The final product has no mass properties associated with it and cannot have features directly added to it, such as holes. The operator approaches these in a similar fashion to the 2D systems, although many 3D systems allow using the wireframe model to make the final engineering drawing views.

3D parametric solid modeling (programs incorporating this technology include Alibre Design, TopSolid, SolidWorks, and Solid Edge) require the operator to use what is referred to as "design intent". The objects and features created are adjustable. Any future modifications will be simple, difficult, or nearly impossible, depending on how the original part was created. One must think of this as being a "perfect world" representation of the component.

If a feature was intended to be located from the center of the part, the operator needs to locate it from the center of the model, not, perhaps, from a more convenient edge or an arbitrary point, as he could when using "dumb" solids. Parametric solids require the operator to consider the consequences of his actions carefully. What may be simplest today could be worst case tomorrow.

Some software packages provide the ability to edit parametric and non-parametric geometry without the need to understand or undo the design intent history of the geometry by use of direct modeling functionality.Draft views are able to be generated easily from the models. Assemblies usually incorporate tools to represent the motions of components, set their limits, and identify interference. The tool kits available for these systems are ever increasing, including 3D piping and injection mold designing packages.

Mid range software was integrating parametric solids more easily to the end user: integrating more intuitive functions (SketchUp), going to the best of both worlds with 3D dumb solids with parametric characteristics (VectorWorks) or making very real-view scenes in relative few steps (Cinema4D).

Top end systems offer the capabilities to incorporate more organic, aesthetics and ergonomic features into designs. Freeform surface modelling is often combined with solids to allow the designer to create products that fit the human form and visual requirements as well as they interface with the machine.

The CAD operator's ultimate goal should be to make future work on the current project as simple as possible. This requires a solid understanding of the system being used. A little extra time spent now could mean a great savings later.Another consequence had been that since the latest advances were often quite expensive, small and even mid-size firms often could not compete against large firms who could use their computational edge for competitive purposes. Today, however, hardware and software costs have come down. Even high-end packages work on less expensive platforms and some even support multiple platforms.

The costs associated with CAD implementation now are more heavily weighted to the costs of training in the use of these high level tools, the cost of integrating a CAD/CAM/CAE PLM using enterprise across multi-CAD and multi-platform environments and the costs of modifying design workflows to exploit the full advantage of CAD tools. CAD vendors have been effective in providing tools to lower these costs. (Anonymous, 2007)

2.5.2.1 SolidWorks

SolidWorks recently emerged as one of the 3D product design software for Windows, providing one of the most powerful and intuitive mechanical design solutions in its class. In SolidWorks, building a base feature creates parts and adding other features such as bosses, cuts, holes, fillets, or shells. The base feature may be an extrusion, revolution, swept profile, or loft. To create a base feature, sketch a two-dimensional geometric profile and move the profile through space to create a volume.

Geometry can be sketched on construction planes or on planar surfaces of parts. Feature-based solid-modeling programs are making two-dimensional design techniques obsolete. However, Unix-based solid-modeling software is expensive. With the introduction of SolidWorks for Microsoft Windows, the cost is less than the price of earlier dimension driven solid-modeling programs. (Anonymous, 2007b)

2.5.3 Finite Element Analysis (FEA)

Finite Element Analysis (FEA) was first developed in 1943 by R. Courant, who utilized the Ritz method of numerical analysis and minimization of variational calculus to obtain approximate solutions to vibration systems. Shortly thereafter, a paper published in 1956 by M. J. Turner, R. W. Clough, H. C. Martin, and L. J. Topp established a broader definition of numerical analysis. The paper centered on the "stiffness and deflection of complex structures".

By the early 70's, FEA was limited to expensive mainframe computers generally owned by the aeronautics, automotive, defense, and nuclear industries. Since the rapid decline in the cost of computers and the phenomenal increase in computing power, FEA has been developed to an incredible precision. Present day supercomputers are now able to produce accurate results for all kinds of parameters.

FEA consists of a computer model of a material or design that is stressed and analyzed for specific results. It is used in new product design, and existing product refinement. A company is able to verify a proposed design will be able to perform to the client's specifications prior to manufacturing or construction. Modifying an existing product or structure is utilized to qualify the product or structure for a new service condition. In case of structural failure, FEA may be used to help determine the design modifications to meet the new condition.

There are generally two types of analysis that are used in industry: 2-D modeling, and 3-D modeling. While 2-D modeling conserves simplicity and allows the analysis to be run on a relatively normal computer, it tends to yield less accurate results. 3-D modeling, however, produces more accurate results while sacrificing the ability to run on all but the fastest computers effectively. Within each of these modeling schemes, the programmer can insert numerous algorithms (functions) which may make the system behave linearly or non-linearly. Linear systems are far less complex and generally do not take into account plastic deformation. Non-linear systems do account for plastic deformation, and many also are capable of testing a material all the way to fracture.

FEA uses a complex system of points called nodes which make a grid called a mesh (Figure 2). This mesh is programmed to contain the material and structural properties which define how the structure will react to certain loading conditions. Nodes are assigned at a certain density throughout the material depending on the anticipated stress levels of a particular area. Regions which will receive large amounts of stress usually have a higher node density than those which experience little or no stress. Points of interest may consist of: fracture point of previously tested material, fillets, corners, complex detail, and high stress areas. The mesh acts like a spider web in that from each node, there extends a mesh element to each of the adjacent nodes. This web of vectors is what carries the material properties to the object, creating many elements. (Peter Widas, 1997)

A wide range of objective functions (variables within the system) are available for minimization or maximization:

- Mass, volume, temperature
- Strain energy, stress strain
- Force, displacement, velocity, acceleration
- Synthetic (User defined)

There are multiple loading conditions which may be applied to a system. Next to Figure 3, some examples are shown:

- Point, pressure, thermal, gravity, and centrifugal static loads
- Thermal loads from solution of heat transfer analysis
- Enforced displacements
- Heat flux and convection
- Point, pressure and gravity dynamic loads

Each FEA program may come with an element library, or one is constructed over time. Some sample elements are:

- Rod elements
- Beam elements
- Plate/Shell/Composite elements
- Shear panel
- Solid elements
- Spring elements
- Mass elements
- Rigid elements
- Viscous damping elements

Many FEA programs also are equipped with the capability to use multiple materials within the structure such as:

- Isotropic, identical throughout
- Orthotropic, identical at 90 degrees
- General anisotropic, different throughout

2.5.3.1 MSC. Nastran

MSC.Nastran is the premium computer aided engineering (CAE) tool that major manufacturers worldwide rely on for their critical engineering computing needs to produce safe, reliable, faster and optimized designs.

For over 30 years, MSC.Nastran has been the analysis solution of choice in almost every industry including aerospace, automotive, medical, heavy machinery, electronic devices, and consumer products. When engineers think of computer-aided stress, vibration, heat-transfer, acoustic, and aeroelasticity analysis, they think of MSC.Nastran.

Flexible, easy-to-use, and powerful, MSC.Nastran provides engineers the tools they need to analyze and improve designs of everything from simple components to complex structures and systems. The results from MSC.Nastran are so trusted that airplane manufacturers use the results to get FAA certification. It is the most tested FEA tool available based on real life usage by engineers worldwide. Other FEA vendors use MSC.Nastran results to validate their own programs.

MSC.Nastran helps manufacturers simulate reality, which reduces the need to do physical prototype testing and allows them to consider various design alternatives, thus saving millions of dollars. Using MSC.Nastran, engineers can identify the design flaws earlier in their manufacturing cycles, reducing the time-to-market of their products and warranty costs, while at the same time saving on material costs without reducing the integrity of their products. (Anonymous 2008)