DESIGN AND DEVELOPMENT OF 1-SEATED URBAN CAR CHASSIS USING ALUMINIUM

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BORANG PENGESAHAN STATUS TESIS ♦

JUDUL: DESIGN AND DEVELOPMENT OF 1-SEATED URBAN CAR CHASSIS USING ALUMINIUM

SESI PENGAJIAN: 2010/2011

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DESIGN AND DEVELOPMENT OF 1-SEATED URBAN CAR CHASSIS USING ALUMINIUM

FAZLIANA BINTI FAUZUN

Report submitted in partial fulfillment of the requirements
for the award of the degree of
Bachelor of Mechanical Engineering

Faculty of Mechanical Engineering
UNIVERSITI MALAYSIA PAHANG

DECEMBER 2010

STUDENT'S DECLARATION

I hereby declare that the work in this project is my own except for quotations and summaries which have been duly acknowledged. The project has not been accepted for any degree and is not concurrently submitted for award of other degree.

Name: FAZLIANA BINTI FAUZUN

ID Number: MA 07063

Date: 6 DECEMBER 2010

Dedicated to my parents

Mr. Fauzun bin Yahya and Mrs. Shahriah binti Hamzah

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ABSTRACT

This thesis deals with the design and development of the 1-seated urban car chassis using aluminium. The objective of this thesis is to develop the general procedures of analyzing the existing design of Shell Eco-marathon car chassis and designing a new chassis with several enhancements using aluminium as material. The thesis describes finite element analysis techniques to predict the displacement magnitude and identify the worst stress locates in the structures. Stainless steel AISI type 304 and aluminium alloy T6 6063 were studied in this thesis which commonly used for a chassis structure in industry. The structural of three-dimensional solid modeling of the chassis was developed using Solidworks software. The strategy of validation of finite element model was developed. The finite element analysis was then performed using ALGOR Fempro. Both chassis structure was analyzed using the static stress with linear material models approaches. Finally, the displacement magnitude of the structure and worst stress are obtained. From the results, it is observed that the displacement magnitude of new chassis is decreasing about 40% compared to the existing design. The existing design which used the stainless steel as material selection also is found to have higher worst stress compared with the aluminium chassis. Besides, comparing both designs founds the overall chassis weight of aluminium chassis is reduced about 30%. The obtained results indicate that using aluminium gives the chassis structure higher stiffness and light in weight. It also found that the rectangular tubes aluminium gives stiffer structure compared to aluminium pipes. The results conclude that using aluminium with larger cross sectional tubes area gives higher stiffness chassis structure. Therefore, using rectangular tubes aluminium promising higher stiffness structure and weight saving. The durability assessment results are significant to improve the chassis design at the developing stage. The results can also significantly reduce the cost and time in fabricating the chassis during the events, and improve reliability and user confidence.

ABSTRAK

Tesis ini membincangkan tentang reka bentuk dan pembangunan casis kereta bandar satu tempat duduk dari bahan aluminium. Objektif tesis ini adalah untuk membangunkan prosedur umum dalam menganalisis reka bentuk casis kereta Shell Eco-marathon yang sedia ada dan mereka bentuk satu reka bentuk casis yang baharu dengan beberapa tambahan dengan menggunakan bahan aluminium. Tesis ini juga menjelaskan teknik analisis elemen terhad untuk meramalkan perubahan magnitud dan mengenal pasti kedudukan tekanan terburuk dalam struktur. Besi tahan karat AISI 304 dan aloy aluminium T6 6063 dikaji dalam tesis ini yang kebiasaannya digunakan untuk struktur casis dalam industri. Penstrukturan model padu tiga dimensi casis telah dibangunkan menggunakan perisian Solidworks. Strategi juga mengenal pasti model elemen terhad telah dibangunkan. Analisis elemen terhad pula telah dilakukan menggunakan ALGOR Fempro. Kedua-dua struktur casis telah dianalisis menggunakan tekanan statik dengan pendekatan model material mendatar. Akhirnya, perubahan magnitud struktur dan tekanan terburuk diperolehi. Dari keputusan yang diperoleh, perubahan magnitud casis yang baharu diperhatikan mengalami perubahan lebih kecil berbanding reka bentuk yang sedia ada. Reka bentuk sedia ada yang menggunakan besi tahan karat sebagai bahan pilihan telah didapati mempunyai tekanan terburuk yang lebih tinggi berbanding casis aluminium. Selain itu juga, dengan membandingkan kedua-dua reka bentuk mendapati bahawa berat casis keseluruhan bagi aluminium casis telah dikurangkan. Keputusan yang diperoleh menunjukkan bahawa menggunakan aluminium memberikan struktur casis kepegunan yang lebih tinggi dan ringan. Keputusan ini juga mendapati bahawa tiub aluminium sesegi empat sama menghasilkan lebih kepegunan berbanding dengan paip aluminium. Keputusan merangkumkan bahawa menggunakan aluminium dengan luas keratan rentas yang lebih besar menghasilkan struktur casis yang lebih pegun. Oleh yang demikian, menggunakan tiub aluminium sesegi empat sama menjanjikan struktur yang tinggi kepegunan dan ringan. Keputusan penilaian ketahanan adalah penting dalam mempertingkatkan reka bentuk casis pada fasa pembangunan. Hasil keputusan juga dengan nyata sekali mengurangkan kos dan masa membina casis semasa hari acara dan meningkatkan kepercayaan pengguna.

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LIST OF SYMBOLS

F	Forces
P	Pressure
σ	True stress, local stress
δ	Displacement magnitude
ρ	Material density
v	Material volume
A	Cross sectional Area
D	Diameter of the pipes material
t	Thickness

LIST OF ABBREVIATIONS

AA	Aluminium alloy
FEA	Finite Element Analysis
SEM	Shell Eco-marathon
FYP	Final Year Project

CHAPTER 1

INTRODUCTION

1.1 PROJECT BACKGROUND

This chapter basically discuss about the urban car chassis and the best material used. Currently, urban areas suffer heavily from problems caused by the excessive use of the private car which also cause the congestion to air and noise pollution. Urban transport is not only a significant contributor to climate change, but also the main source of fine particulate matters. The pollutant may cause many cities in the world to exceed the thresholds given in the world air quality directive.

One of the solutions that can be made is using an urban concept car. The urban concept car is a car designed to be used in city traffic. It is normally small in size and not very powerful, but very fuel efficient.

Urban cars are often hailed as the answer to the escalating levels of air pollution and traffic congestion that result from increases in numbers of larger personal vehicles. They are intended for use exclusively in or near cities and towns, but they are not suited to long journeys or fast travel on highways. They are very light, pollute little, take up a fraction of the space required by most vehicles, cost much less than most cars and trucks, and can be effectively recycled (Erdmenger and Fuhr, 2005).

As for this studies, the chassis design that been proposed is for one-seated urban car. Most of the current modern cars use monocoque chassis since it is a single piece of framework that gives shape to the car. However for this study, tubular space frame

APPENDIX E

GANTT CHART / PROJECT SCHEDULE FOR FYP 1

PROJECT ACTIVITIES	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12	W13	W14	W15	W16
Receive the FYP title																
Discussion with supervisor about the project																
Do the research in gaining project information																
Collecting data																
Gathering data																
Gathering information																
Prepare the report by chapter																
Submit the report with logbook to supervisor																
Arrangement for presentation																
FYP 1 presentation																

Figure 6.3: Project planning for FYP 1

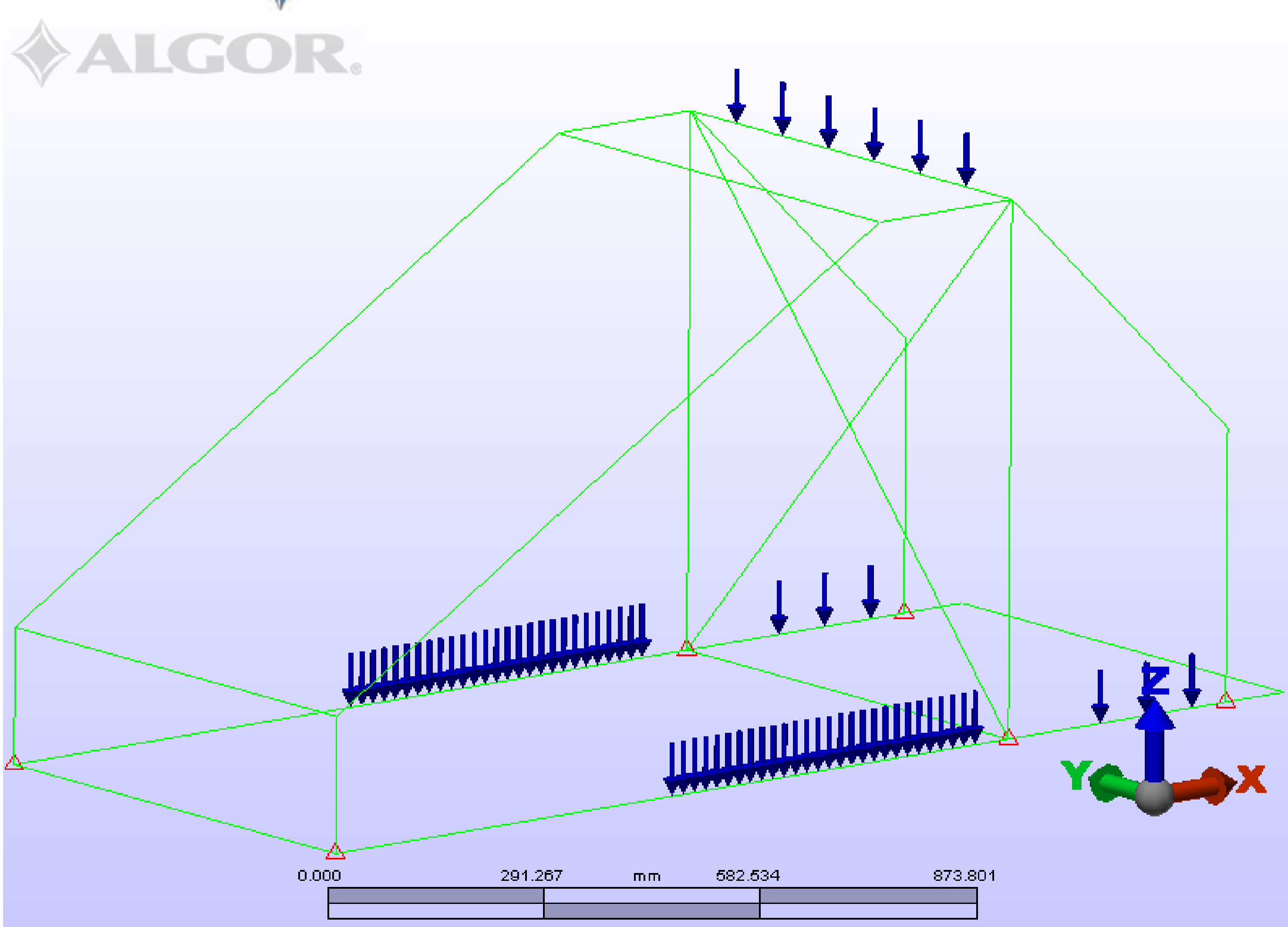
APPENDIX F

GANTT CHART / PROJECT SCHEDULE FOR FYP 2

PROJECT ACTIVITIES	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12	W13	W14	W15	W16
Material testing																
Analysis of existing design																
Proposing a new design with enhancement																
Gathering result and data																
Discussion and Conclusion																
Recommendation																
Complete report for FYP 2																
Submit the report with logbook to supervisor																
Arrangement for presentation																
FYP 2 presentation																

Figure 6.4: Project planning for FYP 2

APPENDIX D



Design Analysis
Project Title Here

Created by
Author:
Department:
Created Date: 11/3/2010

Reviewed by
Reviewer:
Department:
Model Created Date: 11/3/2010
Reviewer Comments:

Executive Summary

This is where to put your Executive summary. So, replace this text with your overall Project Description.

Summary

Model Information
Analysis Type - Static Stress with Linear Material Models
Units - Custom - (N, mm, s, deg C, deg C, V, ohm, A, J)
Model location - C:\Documents and Settings\User\Desktop\TAHUN 4\analysis\new chassis\design 2.fem
Design scenario description - Design Scenario # 1

Analysis Parameters Information

Load Case Multipliers

Static Stress with Linear Material Models may have multiple load cases. This allows a model to be analyzed

with multiple loads while solving the equations a single time. The following is a list of load case multipliers that were analyzed with this model.

Load Case	Pressure/Surface Forces	Acceleration/Gravity	Rotation	Angular Acceleration	Displaced Boundary	Thermal	Voltage
1	1	0	0	0	0		

Multiphysics Information

Default Nodal Temperature	0 °C
Source of Initial Nodal Temperatures	None
Time step from Heat Transfer Analysis	Last

Processor Information

Type of Solver	Automatic
Disable Calculation and Output of Strains	No
Calculate Reaction Forces	Yes
Invoke Banded Solver	Yes
Avoid Bandwidth Minimization	No
Stop After Stiffness Calculations	No
Displacement Data in Output File	No
Stress Data in Output File	No
Equation Numbers Data in Output File	No
Element Input Data in Output File	No
Nodal Input Data in Output File	No
Centrifugal Load Data in Output File	No

Part Information

Part ID	Part Name	Element Type	Material Name
1	Part 1	Beam	Aluminum 6063-T6

Element Information

Element Properties used for:

- Part 1

Element Type	Beam
Stress Free Reference Temperature	0 °C
Layer 1 - Area	133.486
Layer 1 - SA2	33.3715
Layer 1 - SA3	33.3715
Layer 1 - J1	30804.7
Layer 1 - I2	15402.3

Layer 1 - I3	15402.3
Layer 1 - S2	970.226
Layer 1 - S3	970.226

Material Information

Aluminum 6063-T6 -Beam

Material Model	Standard
Material Source	ALGOR Material Library
Material Source File	C:\Program Files\ALGOR\22.00\matlibs\algormat.mlb
Date Last Updated	2004/10/28-16:02:00
Material Description	None
Mass Density	0.0000000027 N·s²/mm/mm³
Modulus of Elasticity	68900 N/mm²
Poisson's Ratio	0.33
Thermal Coefficient of Expansion	2.340000E-005 1/°C

Loads

FEA Object Group 16: Nodal Forces

Nodal Force

ID	Description	Vertex ID	Node Number	Vx	Vy	Vz	Magnitude	Multiplier Table ID
117	Unnamed	500	46	0.000000	0.000000	-1.000000	12.730000	1
118	Unnamed	502	47	0.000000	0.000000	-1.000000	12.730000	1
119	Unnamed	504	48	0.000000	0.000000	-1.000000	12.730000	1
120	Unnamed	506	49	0.000000	0.000000	-1.000000	12.730000	1
121	Unnamed	508	50	0.000000	0.000000	-1.000000	12.730000	1
122	Unnamed	510	51	0.000000	0.000000	-1.000000	12.730000	1
123	Unnamed	512	52	0.000000	0.000000	-1.000000	12.730000	1
124	Unnamed	514	53	0.000000	0.000000	-1.000000	12.730000	1
125	Unnamed	516	54	0.000000	0.000000	-1.000000	12.730000	1
126	Unnamed	526	59	0.000000	0.000000	-1.000000	12.730000	1
127	Unnamed	528	60	0.000000	0.000000	-1.000000	12.730000	1
128	Unnamed	530	61	0.000000	0.000000	-1.000000	12.730000	1
129	Unnamed	532	62	0.000000	0.000000	-1.000000	12.730000	1
130	Unnamed	534	63	0.000000	0.000000	-1.000000	12.730000	1
131	Unnamed	536	64	0.000000	0.000000	-1.000000	12.730000	1
132	Unnamed	538	65	0.000000	0.000000	-1.000000	12.730000	1
133	Unnamed	540	66	0.000000	0.000000	-1.000000	12.730000	1
134	Unnamed	542	67	0.000000	0.000000	-1.000000	12.730000	1
135	Unnamed	544	68	0.000000	0.000000	-1.000000	12.730000	1
136	Unnamed	546	69	0.000000	0.000000	-1.000000	12.730000	1
137	Unnamed	548	70	0.000000	0.000000	-1.000000	12.730000	1
138	Unnamed	550	71	0.000000	0.000000	-1.000000	12.730000	1

139	Unnamed	552	72	0.000000	0.000000	-1.000000	12.730000	1
140	Unnamed	518	55	0.000000	0.000000	-1.000000	12.730000	1
141	Unnamed	520	56	0.000000	0.000000	-1.000000	12.730000	1
142	Unnamed	522	57	0.000000	0.000000	-1.000000	12.730000	1
143	Unnamed	524	58	0.000000	0.000000	-1.000000	12.730000	1
144	Unnamed	619	105	0.000000	0.000000	-1.000000	12.730000	1
145	Unnamed	621	106	0.000000	0.000000	-1.000000	12.730000	1
146	Unnamed	623	107	0.000000	0.000000	-1.000000	12.730000	1
147	Unnamed	625	108	0.000000	0.000000	-1.000000	12.730000	1
148	Unnamed	627	109	0.000000	0.000000	-1.000000	12.730000	1
149	Unnamed	629	110	0.000000	0.000000	-1.000000	12.730000	1
150	Unnamed	631	111	0.000000	0.000000	-1.000000	12.730000	1
151	Unnamed	633	112	0.000000	0.000000	-1.000000	12.730000	1
152	Unnamed	635	113	0.000000	0.000000	-1.000000	12.730000	1
153	Unnamed	637	114	0.000000	0.000000	-1.000000	12.730000	1
154	Unnamed	639	115	0.000000	0.000000	-1.000000	12.730000	1
155	Unnamed	641	116	0.000000	0.000000	-1.000000	12.730000	1
156	Unnamed	643	117	0.000000	0.000000	-1.000000	12.730000	1
157	Unnamed	645	118	0.000000	0.000000	-1.000000	12.730000	1
158	Unnamed	647	119	0.000000	0.000000	-1.000000	12.730000	1
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160	Unnamed	651	121	0.000000	0.000000	-1.000000	12.730000	1
161	Unnamed	653	122	0.000000	0.000000	-1.000000	12.730000	1
162	Unnamed	655	123	0.000000	0.000000	-1.000000	12.730000	1
163	Unnamed	657	124	0.000000	0.000000	-1.000000	12.730000	1
164	Unnamed	659	125	0.000000	0.000000	-1.000000	12.730000	1
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166	Unnamed	663	127	0.000000	0.000000	-1.000000	12.730000	1
167	Unnamed	665	128	0.000000	0.000000	-1.000000	12.730000	1
168	Unnamed	667	129	0.000000	0.000000	-1.000000	12.730000	1
169	Unnamed	669	130	0.000000	0.000000	-1.000000	12.730000	1
170	Unnamed	671	131	0.000000	0.000000	-1.000000	12.730000	1
171	Unnamed	673	132	0.000000	0.000000	-1.000000	12.730000	1

FEA Object Group 17: Nodal Forces

Nodal Force

ID	Description	Vertex ID	Node Number	Vx	Vy	Vz	Magnitude	Multiplier Table ID
172	Unnamed	686	138	0.000000	0.000000	-1.000000	56.670000	1
173	Unnamed	682	136	0.000000	0.000000	-1.000000	56.670000	1
174	Unnamed	693	141	0.000000	0.000000	-1.000000	56.670000	1
175	Unnamed	695	142	0.000000	0.000000	-1.000000	56.670000	1
176	Unnamed	697	143	0.000000	0.000000	-1.000000	56.670000	1
177	Unnamed	684	137	0.000000	0.000000	-1.000000	56.670000	1

FEA Object Group 18: Nodal Forces

Nodal Force

ID	Description	Vertex ID	Node Number	Vx	Vy	Vz	Magnitude	Multiplier Table ID

178	Unnamed	702	145	0.000000	0.000000	-1.000000	116.670000	1
179	Unnamed	704	146	0.000000	0.000000	-1.000000	116.670000	1
180	Unnamed	706	147	0.000000	0.000000	-1.000000	116.670000	1
181	Unnamed	708	148	0.000000	0.000000	-1.000000	116.670000	1
182	Unnamed	710	149	0.000000	0.000000	-1.000000	116.670000	1
183	Unnamed	712	150	0.000000	0.000000	-1.000000	116.670000	1

Constraints

FEA Object Group 7: Nodal Boundary Conditions

Nodal Boundary Condition

ID	Description	Vertex ID	Node Number	Tx	Ty	Tz	Rx	Ry	Rz
9	Unnamed	425	12	Yes	Yes	Yes	Yes	Yes	Yes
10	Unnamed	421	11	Yes	Yes	Yes	Yes	Yes	Yes

FEA Object Group 9: Nodal Boundary Conditions

Nodal Boundary Condition

ID	Description	Vertex ID	Node Number	Tx	Ty	Tz	Rx	Ry	Rz
13	Unnamed	410	9	Yes	Yes	Yes	Yes	Yes	Yes
14	Unnamed	414	10	Yes	Yes	Yes	Yes	Yes	Yes

FEA Object Group 15: Nodal Boundary Conditions

Nodal Boundary Condition

ID	Description	Vertex ID	Node Number	Tx	Ty	Tz	Rx	Ry	Rz
21	Unnamed	187	3	Yes	Yes	Yes	Yes	Yes	Yes
22	Unnamed	189	4	Yes	Yes	Yes	Yes	Yes	Yes

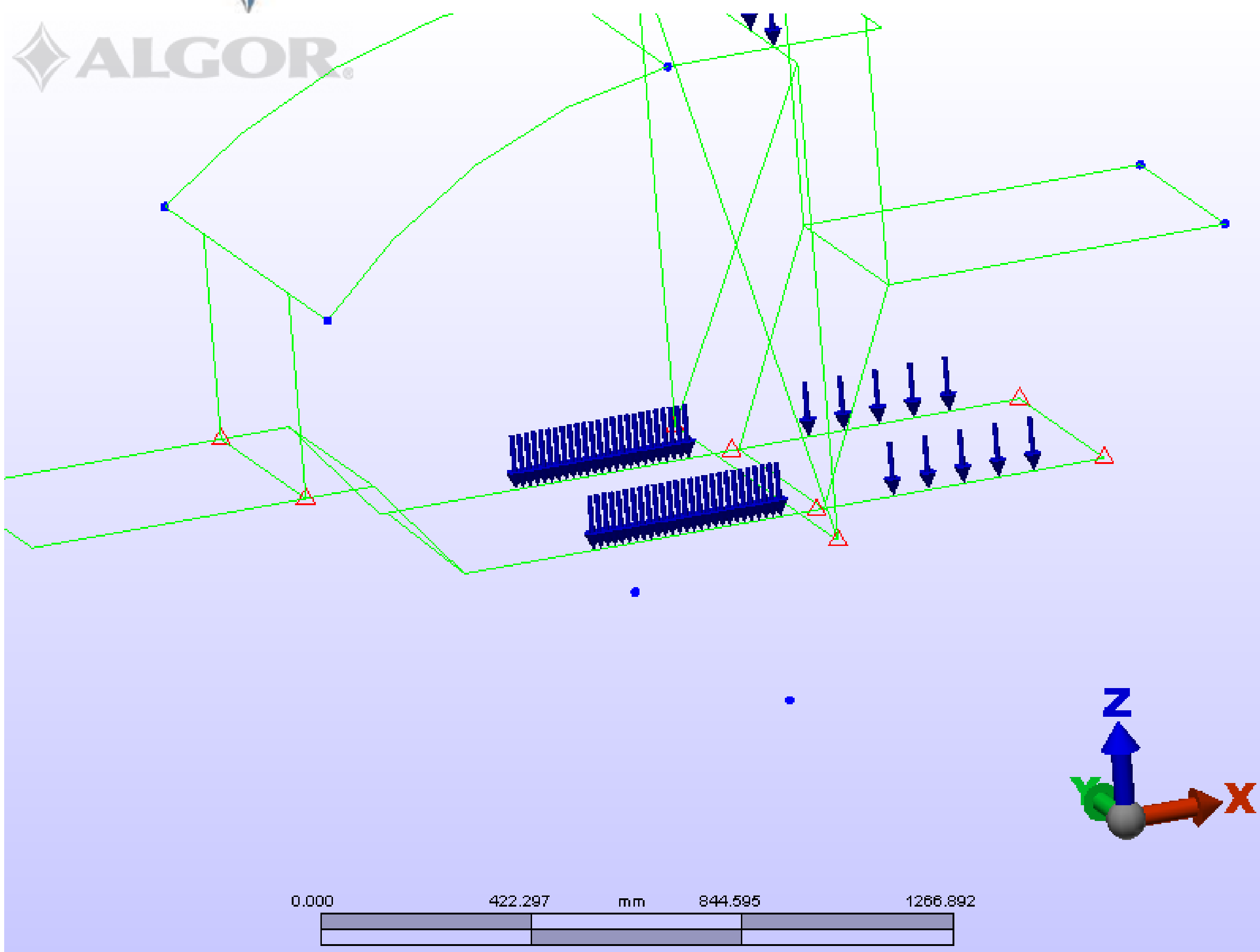
Probes

Probe data was requested, but no probes were detected.

Results Presentation Images

No Results Images available.

APPENDIX C



Design Analysis
Project Title Here

Created by
Author:
Department:
Created Date: 10/22/2010

Reviewed by
Reviewer:
Department:
Model Created Date: 10/22/2010
Reviewer Comments:

Executive Summary

This is where to put your Executive summary. So, replace this text with your overall Project Description.

Summary

Model Information
Analysis Type - Static Stress with Linear Material Models
Units - Custom - (N, mm, s, deg C, deg C, V, ohm, A, J)
Model location - C:\Documents and Settings\User\Desktop\TAHUN 4\analysis\existing chassis\design 1.fem
Design scenario description - Design Scenario # 1

Analysis Parameters Information

Load Case Multipliers

Static Stress with Linear Material Models may have multiple load cases. This allows a model to be analyzed with multiple loads while solving the equations a single time. The following is a list of load case multipliers that were analyzed with this model.

Load Case	Pressure/Surface Forces	Acceleration/Gravity	Rotation	Angular Acceleration	Displaced Boundary	Thermal	Voltage
1	1	0	0	0	0		

Multiphysics Information

Default Nodal Temperature	0 °C
Source of Initial Nodal Temperatures	None
Time step from Heat Transfer Analysis	Last

Processor Information

Type of Solver	Automatic
Disable Calculation and Output of Strains	No
Calculate Reaction Forces	Yes
Invoke Banded Solver	Yes
Avoid Bandwidth Minimization	No
Stop After Stiffness Calculations	No
Displacement Data in Output File	No
Stress Data in Output File	No
Equation Numbers Data in Output File	No
Element Input Data in Output File	No
Nodal Input Data in Output File	No
Centrifugal Load Data in Output File	No

Part Information

Part ID	Part Name	Element Type	Material Name
1	Part 1	Beam	AISI Type 304 Stainless Steel

Element Information

Element Properties used for:

- Part 1

Element Type	Beam
Stress Free Reference Temperature	0 °C
Layer 1 - Area	133.486
Layer 1 - SA2	33.3715
Layer 1 - SA3	33.3715
Layer 1 - J1	30804.7
Layer 1 - I2	15402.3
Layer 1 - I3	15402.3

Layer 1 - S2	970.226
Layer 1 - S3	970.226

Material Information

AISI Type 304 Stainless Steel -Beam

Material Model	Standard
Material Source	ALGOR Material Library
Material Source File	C:\Program Files\ALGOR\22.00\matlibs\algormat.mlb
Date Last Updated	2004/10/28-16:02:00
Material Description	None
Mass Density	0.000000008 N·s²/mm/mm³
Modulus of Elasticity	193000 N/mm²
Poisson's Ratio	0.29
Thermal Coefficient of Expansion	1.730000E-005 1/°C

Loads

FEA Object Group 11: Nodal Forces

Nodal Force

ID	Description	Vertex ID	Node Number	Vx	Vy	Vz	Magnitude	Multiplier Table ID
102	Unnamed	363	100	0.000000	0.000000	-1.000000	13.460000	1
103	Unnamed	365	101	0.000000	0.000000	-1.000000	13.460000	1
104	Unnamed	367	102	0.000000	0.000000	-1.000000	13.460000	1
105	Unnamed	369	103	0.000000	0.000000	-1.000000	13.460000	1
106	Unnamed	371	104	0.000000	0.000000	-1.000000	13.460000	1
107	Unnamed	373	105	0.000000	0.000000	-1.000000	13.460000	1
108	Unnamed	375	106	0.000000	0.000000	-1.000000	13.460000	1
109	Unnamed	377	107	0.000000	0.000000	-1.000000	13.460000	1
110	Unnamed	379	108	0.000000	0.000000	-1.000000	13.460000	1
111	Unnamed	381	109	0.000000	0.000000	-1.000000	13.460000	1
112	Unnamed	383	110	0.000000	0.000000	-1.000000	13.460000	1
113	Unnamed	385	111	0.000000	0.000000	-1.000000	13.460000	1
114	Unnamed	387	112	0.000000	0.000000	-1.000000	13.460000	1
115	Unnamed	389	113	0.000000	0.000000	-1.000000	13.460000	1
116	Unnamed	391	114	0.000000	0.000000	-1.000000	13.460000	1
117	Unnamed	393	115	0.000000	0.000000	-1.000000	13.460000	1
118	Unnamed	395	116	0.000000	0.000000	-1.000000	13.460000	1
67	Unnamed	270	54	0.000000	0.000000	-1.000000	13.460000	1
68	Unnamed	272	55	0.000000	0.000000	-1.000000	13.460000	1
69	Unnamed	274	56	0.000000	0.000000	-1.000000	13.460000	1
70	Unnamed	276	57	0.000000	0.000000	-1.000000	13.460000	1
71	Unnamed	278	58	0.000000	0.000000	-1.000000	13.460000	1
72	Unnamed	280	59	0.000000	0.000000	-1.000000	13.460000	1
73	Unnamed	282	60	0.000000	0.000000	-1.000000	13.460000	1

74	Unnamed	284	61	0.000000	0.000000	-1.000000	13.460000	1
75	Unnamed	286	62	0.000000	0.000000	-1.000000	13.460000	1
76	Unnamed	288	63	0.000000	0.000000	-1.000000	13.460000	1
77	Unnamed	290	64	0.000000	0.000000	-1.000000	13.460000	1
78	Unnamed	292	65	0.000000	0.000000	-1.000000	13.460000	1
79	Unnamed	294	66	0.000000	0.000000	-1.000000	13.460000	1
80	Unnamed	296	67	0.000000	0.000000	-1.000000	13.460000	1
81	Unnamed	298	68	0.000000	0.000000	-1.000000	13.460000	1
82	Unnamed	300	69	0.000000	0.000000	-1.000000	13.460000	1
83	Unnamed	302	70	0.000000	0.000000	-1.000000	13.460000	1
84	Unnamed	304	71	0.000000	0.000000	-1.000000	13.460000	1
85	Unnamed	306	72	0.000000	0.000000	-1.000000	13.460000	1
86	Unnamed	308	73	0.000000	0.000000	-1.000000	13.460000	1
87	Unnamed	310	74	0.000000	0.000000	-1.000000	13.460000	1
88	Unnamed	312	75	0.000000	0.000000	-1.000000	13.460000	1
89	Unnamed	314	76	0.000000	0.000000	-1.000000	13.460000	1
90	Unnamed	316	77	0.000000	0.000000	-1.000000	13.460000	1
91	Unnamed	318	78	0.000000	0.000000	-1.000000	13.460000	1
92	Unnamed	320	79	0.000000	0.000000	-1.000000	13.460000	1
93	Unnamed	322	80	0.000000	0.000000	-1.000000	13.460000	1
94	Unnamed	347	92	0.000000	0.000000	-1.000000	13.460000	1
95	Unnamed	349	93	0.000000	0.000000	-1.000000	13.460000	1
96	Unnamed	351	94	0.000000	0.000000	-1.000000	13.460000	1
97	Unnamed	353	95	0.000000	0.000000	-1.000000	13.460000	1
98	Unnamed	355	96	0.000000	0.000000	-1.000000	13.460000	1
99	Unnamed	357	97	0.000000	0.000000	-1.000000	13.460000	1
100	Unnamed	359	98	0.000000	0.000000	-1.000000	13.460000	1
101	Unnamed	361	99	0.000000	0.000000	-1.000000	13.460000	1

FEA Object Group 13: Nodal Forces

Nodal Force

ID	Description	Vertex ID	Node Number	Vx	Vy	Vz	Magnitude	Multiplier Table ID
119	Unnamed	435	135	0.000000	0.000000	-1.000000	116.670000	1
120	Unnamed	437	136	0.000000	0.000000	-1.000000	116.670000	1
121	Unnamed	439	137	0.000000	0.000000	-1.000000	116.670000	1
122	Unnamed	441	138	0.000000	0.000000	-1.000000	116.670000	1
123	Unnamed	443	139	0.000000	0.000000	-1.000000	116.670000	1
124	Unnamed	445	140	0.000000	0.000000	-1.000000	116.670000	1

FEA Object Group 17: Nodal Forces

Nodal Force

ID	Description	Vertex ID	Node Number	Vx	Vy	Vz	Magnitude	Multiplier Table ID
125	Unnamed	647	151	0.000000	0.000000	-1.000000	34.000000	1
126	Unnamed	649	152	0.000000	0.000000	-1.000000	34.000000	1
127	Unnamed	651	153	0.000000	0.000000	-1.000000	34.000000	1
128	Unnamed	638	147	0.000000	0.000000	-1.000000	34.000000	1
129	Unnamed	640	148	0.000000	0.000000	-1.000000	34.000000	1

130	Unnamed	634	145	0.000000	0.000000	-1.000000	34.000000	1
131	Unnamed	653	154	0.000000	0.000000	-1.000000	34.000000	1
132	Unnamed	655	155	0.000000	0.000000	-1.000000	34.000000	1
133	Unnamed	632	144	0.000000	0.000000	-1.000000	34.000000	1
134	Unnamed	636	146	0.000000	0.000000	-1.000000	34.000000	1

Constraints

FEA Object Group 2: Nodal Boundary Conditions

Nodal Boundary Condition

ID	Description	Vertex ID	Node Number	Tx	Ty	Tz	Rx	Ry	Rz
1	Unnamed	58	13	Yes	Yes	Yes	Yes	Yes	Yes
2	Unnamed	60	14	Yes	Yes	Yes	Yes	Yes	Yes

FEA Object Group 12: Nodal Boundary Conditions

Nodal Boundary Condition

ID	Description	Vertex ID	Node Number	Tx	Ty	Tz	Rx	Ry	Rz
15	Unnamed	332	85	Yes	Yes	Yes	Yes	Yes	Yes
16	Unnamed	335	86	Yes	Yes	Yes	Yes	Yes	Yes

FEA Object Group 16: Nodal Boundary Conditions

Nodal Boundary Condition

ID	Description	Vertex ID	Node Number	Tx	Ty	Tz	Rx	Ry	Rz
22	Unnamed	110	30	Yes	Yes	Yes	Yes	Yes	Yes
21	Unnamed	107	29	Yes	Yes	Yes	Yes	Yes	Yes

FEA Object Group 18: Nodal Boundary Conditions

Nodal Boundary Condition

ID	Description	Vertex ID	Node Number	Tx	Ty	Tz	Rx	Ry	Rz
24	Unnamed	627	142	Yes	Yes	Yes	Yes	Yes	Yes
23	Unnamed	625	141	Yes	Yes	Yes	Yes	Yes	Yes

Probes

Probe data was requested, but no probes were detected.

Results Presentation Images

No Results Images available.

APPENDIX A

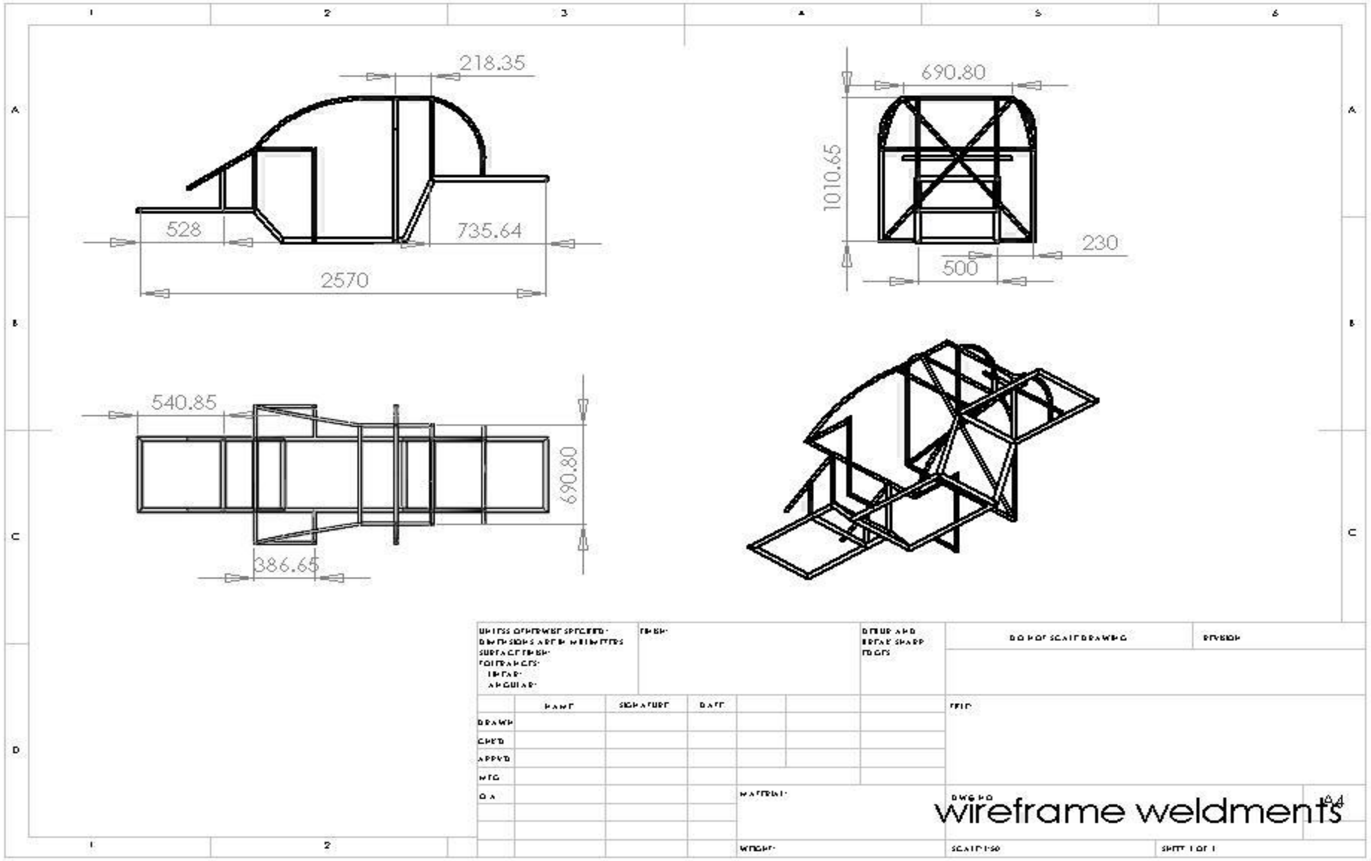


Figure 6.1: The drawing of the existing chassis design

APPENDIX B

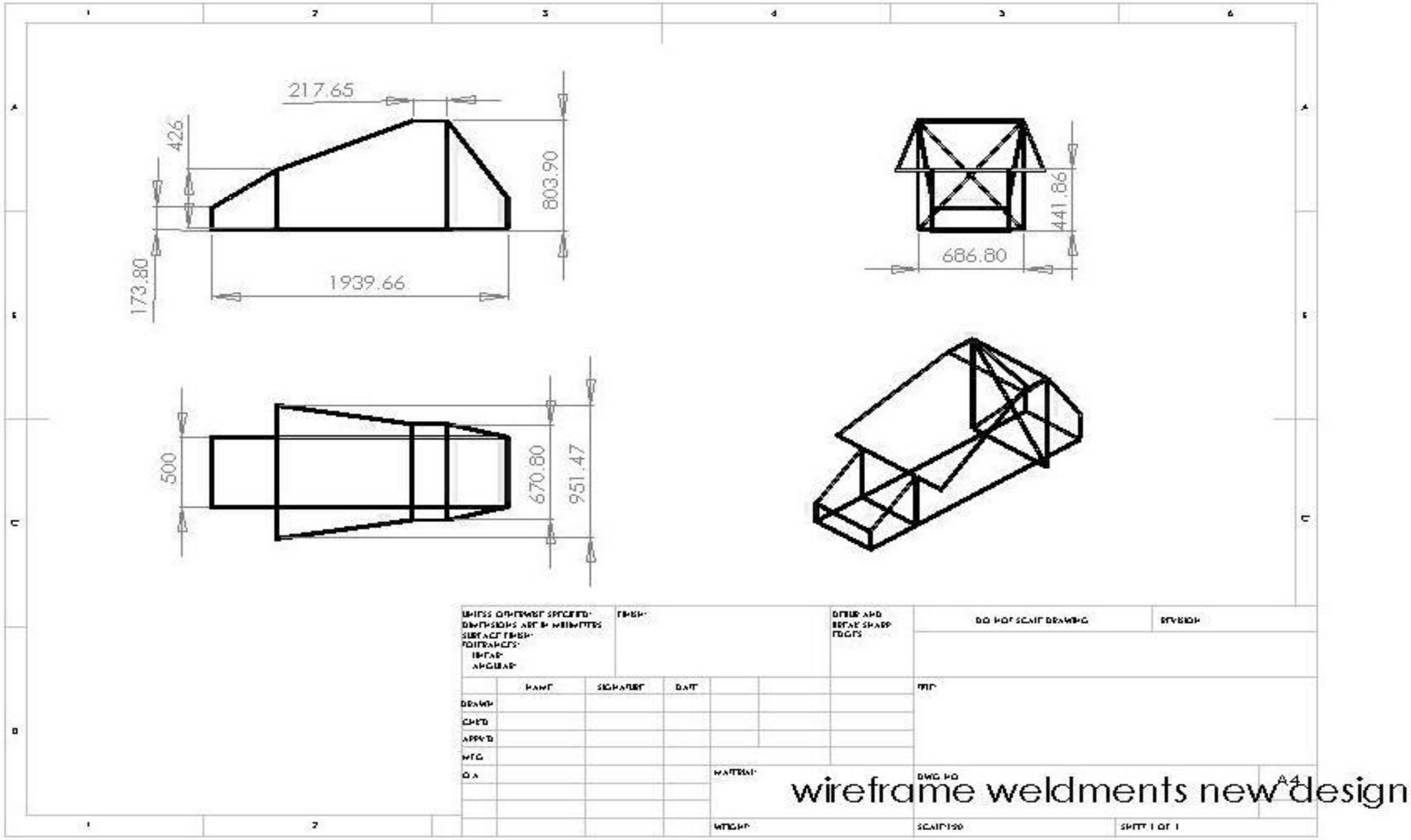


Figure 6.2: The drawing of the new chassis design

chassis is chosen since it is strong enough and have the ability in providing supports for smaller sports car.

As for material, aluminium is chosen as the best material for the car chassis. It is because of the material properties itself which can be melted, light in weight, cast, formed and machined much like these metals and it conducts electric current. According to the European Aluminium Association (EAA, 2009), aluminium physically, chemically and mechanically it is a metal like steel, brass, copper, zinc, lead or titanium. It is in fact often the same equipment and fabrication methods are used as for steel. So, aluminium will be the best solution in making the chassis framework.

Besides, aluminium is a very light metal with a specific weight of 2.7 g/cm^3, about a third that of steel. For example, the use of aluminium in vehicles reduces dead-weight and energy consumption while increasing load capacity. Its strength can be adapted to the application required by modifying the composition of its alloys. This property is essential in order to make a chassis for a light weight and fuel consumption urban car (Anonymous, 2009).

Others property for aluminium is it naturally generate a protective oxide coating and are highly corrosion resistant. Different types of surface treatment such as anodising, painting or lacquering can further improve this property. It is particularly useful for applications where protection and conservation are required (Anonymous, 2009).

In terms of Electrical and Thermal Conductivity, aluminium is an excellent heat and electricity conductor and in relation to its weight is almost twice as good a conductor as copper. This has made aluminium the most commonly used material in major power transmission lines (Anonymous, 2009).

Aluminium also a good reflector of visible light as well as heat and together with its low weight makes it an ideal material for reflectors in for example, light fittings or rescue blankets. Aluminium is ductile and has a low melting point and density. In a molten condition it can be processed in a number of ways. Its ductility allows products of aluminium to be basically formed close to the end of the product’s design (Anonymous, 2009).

Aluminium also is 100 percent recyclable with no downgrading of its qualities. The re-melting of aluminium requires little energy: only about 5 percent of the energy required to produce the primary metal initially is needed in the recycling process. The Table 1.1 below are listed the materials properties of the materials used in this study (Anonymous, 2009).

Table 1.1: The material properties of aluminium

Materials properties	
Density	2600-2800 kg/m^3
Melting Point	660 °C
Poisson's Ratio	0.33
Tensile Strength	230-570 MPa
Yield Strength	215-505 MPa
Percent Elongation	10-25%
Elastic Modulus	70-79 GPa

Source: Anonymous (2010)

1.2 PROBLEM STATEMENT

Urban city nowadays suffered from heavy traffic jams by excessive use of private car. These heavy traffics jams could lead to the air congestion and noise pollution. The used of an urban car could reduce the traffic problems since it is small in size. Regarding to the air and noise pollution, using of urban car is recommended since it is fuel consumption with environmental friendly.

There is a new hydrogen car unveiled in London, UK by Riversimple. This Riversimple Urban Car (RUC) is powered by fuel cells. These fuels cells combine hydrogen with oxygen from the air to release energy. What come out from the exhaust pipe are not toxic fumes but water. Even using hydrogen fuel from source to car’s fuel tank, its carbon emissions for urban driving are only 30 grams/km. The weight of this hydrogen car is 772 pounds. We can travel 186 miles on just 2.2 pounds of liquid hydrogen. The Riversimple Urban Car is powered by a cheap, 6-kilowatt fuel. The car’s top speed is 50 miles per hour (80.4672 kilometres per hour) and it can be accelerated from 0 to 30 mph (48 km/h) in 5.5 seconds. This hydrogen car should be commercialized around the world as one of ways in supporting fuel consumption and environment friendly.

Currently, automobile sector faced problems regarding reducing vehicle weight. The used of aluminium throughout the chassis could helped to reduce the overall vehicle weight, hereby reduce the fuel consumption and emission generations. This is due to the properties of aluminium which light in weight compared to another metals.

Besides, since the demand for more fuel-efficient vehicles increasing and the cost of steel is rising, aluminium will be the best choices to continue play an important strategic role in reducing vehicle weight. For example, aluminium extrusions offer one of the lowest investment options for getting aluminium into the vehicle.

1.3 OBJECTIVE OF THE PROJECT

There are several objectives to be achieved in this study;

1.3.1 To design and develop a chassis for an urban car

1.3.2 To analyze the chassis structure

1.3.3 To propose a new concept of chassis design

1.4 PROJECT SCOPES

This project is focusing on a development of 1-seated urban car chassis using aluminium and it consists of studying and designing of a 1-seated urban car. This focus area is done based on the following aspects:

1.4.1 Based on Shell Eco-marathon Asia 2010 rules and regulations

1.4.2 Design a 1-seated urban car chassis using aluminium

1.4.3 Study the used of aluminium as material for the chassis

1.4.4 Analyze the displacement and stress for aluminium as material for the chassis using ALGOR Fempro

1.4.5 Come out with a general blueprint and specifications of the urban car

1.5 PROJECT METHODOLOGY

The research methodology in the form of flow chart is graphically shown in the Figure 1.1. The research methodology of this project can be classified as follows:

- Analysis of existing chassis design of Shell Eco-marathon (SEM) Asia 2010
- Development of chassis design with different material used.
- Comparison of the analysis result between the current design and the new design.

Initially, there are various aspect need to be considered to fulfil the design requirements. The existing chassis was design according to the Shell Eco-marathon rules and regulation which include the size of the chassis, the driver’s position in the chassis, the material used and spectator safety. The existing chassis of SEM use tubular stainless steel which assumed to be rigid and heavy.

There are few parameters need to be considered to analyze the chassis structure. There are stress, displacement magnitude and rotational magnitude. All of these parameters were applied under same load of 700 N on the roll bar and driver position as stated in the SEM rules. The stress and strength of the chassis is obtained by analysis and used to develop the new chassis design.

The new chassis design come out with several enhancement includes the weight of the chassis, type of element and material used. The new chassis design aims light in weight with high strength of structure. This is why aluminium rectangular tube been used replacing the t stainless steel pipes. The aluminium is chosen by the experiment in Algor to obtain the material properties.

The analyses are also done on the different type of element which is tubular space frame and hollow rectangular space frame. Each of these two elements has different displacement magnitude and stress under certain load applied. The result of the analysis will be used to obtain the most high strength structure of the chassis. The analysis is done on different size of tubes.

After done analyzing both existing and new design of the chassis, there are several comparisons to be made to ensure that the development of new chassis has fulfilled the design requirement such as light in weight. Finally, the discussion upon all analyses results is made and some recommendations are proposed.

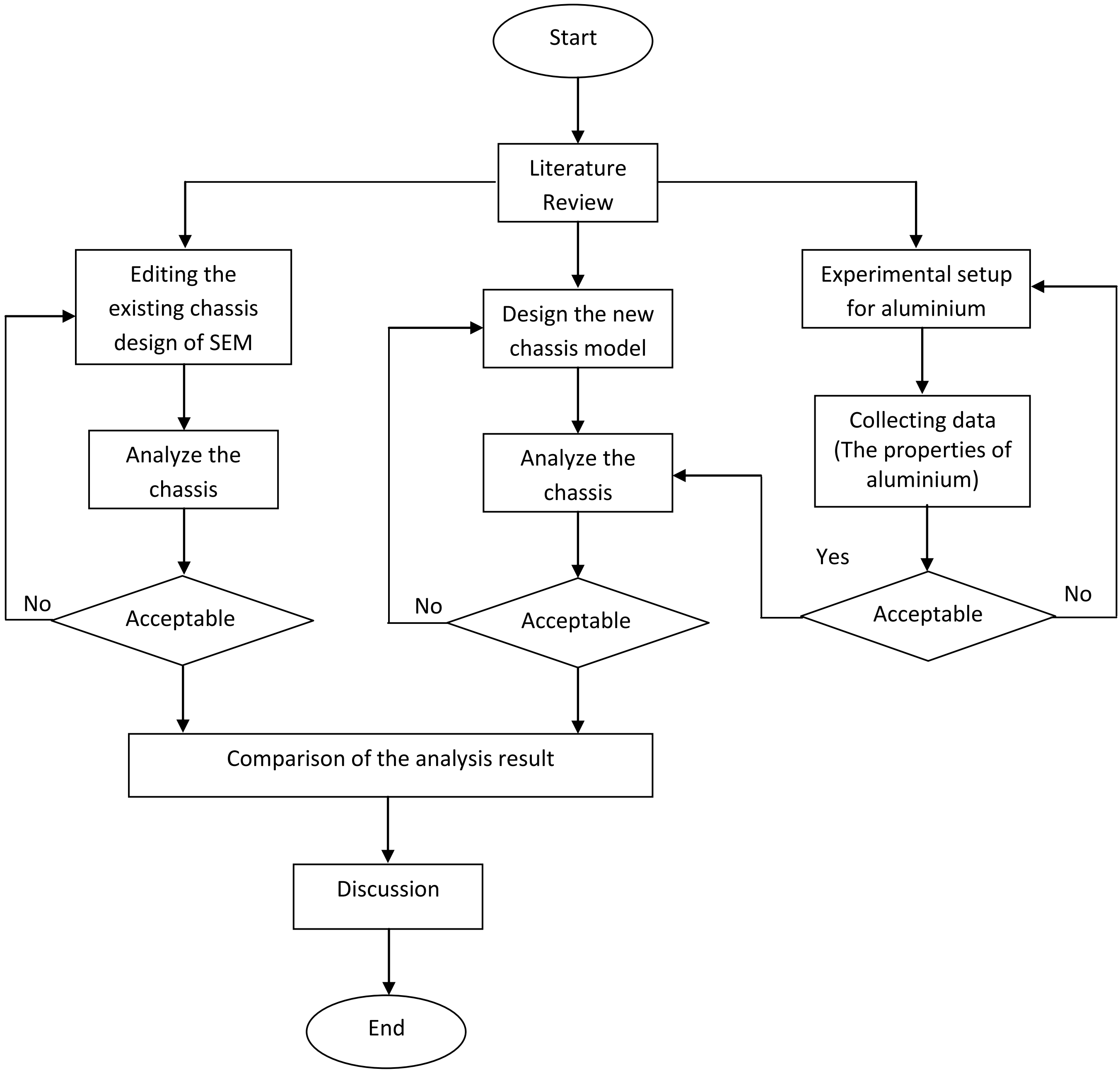


Figure 1.1: The research methodology in flowchart

1.6 STRUCTURE OF THESIS

Chapter 1 introduced the overall view of this study upon chassis development. The overviews begin with the project's background which clarifies the concept and main concern of this study. For the problem statement section, there are sort of discussion about current industrial problems upon the design of chassis and material used for chassis. Besides, the objectives and scopes are also being clarified in this chapter and it is important to construct the flow of the process done in this study. The project's methodology proposed the flow chart and discussing the method used for analyzing the chassis.

The main concern in chapter 2 is the literature review. Basically, literature review give readers the detailed explanation involving scopes of this project. Since the design is based on the rules and regulation of SEM, there are several overviews upon what it is all about and the main concern in designing the vehicle during competition. Other than that, the advantages and disadvantages of using aluminium for a chassis also have been discussed in this chapter. Both advantages and disadvantages are based on the current technologies use in industries.

As for the chapter 3, there will some explanations about Finite Element Analysis and parameters involved in this study. The result of analyses on the existing chassis design also is shown in this chapter. Considering aluminium as the material for new chassis, there will be a material experiment using Algor to determine the properties of aluminium. Besides, the type of aluminium used which is Aluminium Alloy T6 also clarified in this chapter.

The new chassis design proposed in this study will be shown in chapter 4. The full analyses of the chassis are made same as the existing chassis in chapter 3. However, there will be three readings for the result data according to different sizes of the pipes. The displacement magnitude and worst stress of the chassis is observed after load is applied. Besides that, the weight of the chassis also consider in the analysis result.

The chapter 5 will be the final chapter in this thesis. Overall conclusion upon this study will be clarified here. The assumption made before also to be discussed in this chapter. Besides, there is also the project recommendation which is proposed few recommendations and ideas improving this study.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

Chapter 2 consists of few sections which are the section (2.2), Introduction of Shell Eco-marathon Asia 2010 and the type of Chassis of an Urban Car and Current Design (2.3). For section (2.4), there are advantages and disadvantages of using aluminium for a chassis including (2.4.1), the advantages and section (2.4.2) the disadvantages. The final section will be the summary of the chapter 2 (2.5).

The chronology of this chapter has been properly organized according to the sequence of this study. In this chapter, the readers will get chances to understand the idea on how aluminium would be the best aluminium for chassis and also the concept of the chassis design. The introduction of Shell Eco-marathon Asia 2010 in the section (2.2) clarifies the concept of the competition, rules and regulations need to be follow by the participant in designing the vehicle. Section (2.3) gives explanation upon chassis types and current chassis used in industry. This section also clarified the type of chassis used in this study. The section (2.4) will elaborate the advantages and disadvantages of using aluminium as chassis based on the research from current automotive industry. This section also indicates the reasons of choosing aluminium as chassis. As for summary section, there will be an overall overview of what have been discussed in this chapter.

2.2 INTRODUCTION OF SHELL ECO-MARATHON ASIA 2010

Shell Eco-marathon challenges high school and college student teams from around the world to design, build and test energy efficient vehicles. With annual events in the Americas, Europe and Asia, the winner is the team that goes furthers distance using the least amount of energy. This event also affords an outstanding engagement opportunity for current and future leaders who are passionate about finding sustainable solutions to the world's energy challenge.

There are two categories contested; urban category and prototype category. For this year, Malaysia is the host for this challenge for Asia stages. In order to support this event, Universiti Malaysia Pahang has sent two teams to participate which include both categories. For this project, the chassis design is based on the design of SAE-UMP Chapter Team Urban Concept. Since we participating this event, the design of the chassis is based on the rules and regulation state by Shell Asia which include design and safety part.

Basically, this challenge is about fuel consumption which needs further distance with less fuel. So, we need to do a lot of weight reduction to the vehicle which for this project; urban car. Due to this problem, choosing material and design become important for this project. According to the Shell Eco-marathon Official Website (2010), here is the latest record in Shell Eco-marathon. The NTNU Team, Norges Tekiske og Naturvitenskapelige Universitet, Norway is 1,246km/l (2,930.77 mpg) and the best overall Urban Concept fuel consumption is 848km/l (1, 994.62 mpg) in 2008.

Designing the chassis of urban category, the entire car should fulfill the rules and regulation needs. One of the rules is that the vehicle must be equipped with an effective roll bar that extends 5cm around driver's helmet when seated in normal driving position with safety belts fastened. Any roll bar must be capable of withstanding a static vertical and horizontal load of 700N (~70 kg) without deforming as stated in the Shell Eco Marathon Asia Official Rules 2010-Chapter 1). The Figure 2.1 shows the picture during the event of Shell Eco-marathon Asia 2010 which held in Sepang International Circuit on 9th July until 11th July 2010.

Figure 2.1: The Shell Eco-marathon participant for prototype category (left side) and urban

category (right side).

Source: Shell Eco-marathon Asia (2010)

2.3 TYPE OF CHASSIS AND CURRENT ALUMINIUM CHASSIS DESIGN

Chassis is considered to be one of the significant structures of an automobile. It is usually made of a steel frame, which holds the body and motor of an automotive vehicle. To be precise, car chassis or automobile chassis is a skeletal frame which bolts various mechanical parts like engine, tires, brakes, steering and axle assemblies. Chassis usually made of light a metal or composite plastic which provides strength needed for supporting vehicle components and load into it. Here I listed several different types of automotive chassis which include ladder chassis, backbone chassis, monocoque chassis and tubular space frame chassis.

Ladder chassis is considered to be one of the oldest forms of automotive chassis or automobile chassis that is still been used by most of the SUVs till today. It is also resembles a shape of a ladder which having two longitudinal rails inter linked by several lateral and cross braces. The lateral and cross members provide rigidity to the structure.

The other type of chassis is backbone chassis which has a rectangular tube like backbone and simple in structure. It usually made up of glass fiber that is used for joining front and rear axle together and responsible for most of the mechanical strength of the framework. The space within the structure is used for positioning the drive shaft in case a rear-wheel drive. Furthermore, the drivetrain, engine and suspensions are all connected to each of the ends of the chassis. This type of chassis is strong enough to provide support smaller sports car besides it is easy to make and cost effective.

As for monocoque chassis, most modern cars nowadays use this type of chassis. A monocoque chassis is a single piece of framework that gives shape to the car. A one-piece chassis is built by welding several pieces together. It is different from the ladder and backbone chassis as unlike them incorporated with the body in a single piece, where as the former only support the stress members. The demanding of a monocoque chassis highly increased since it is cost effective and suitable for robotized production.

In this study, it is decided that tubular space frame chassis is used for the urban car. Since ladder chassis is not strong enough, motor racing engineers have developed a 3-dimensional design which known as tubular space frame. Tubular space frame chassis employs dozens of circular-section tubes (some may use square-section tubes for easier connection to the body panels though circular section provides the maximum strength), position in different directions to provide mechanical strength against forces from anywhere. These tubes are welded together and form a complex structure. For higher strength required by high performance sports cars, tubular space frame chassis usually incorporate a strong structure under both doors. Tubular space frame chassis also very strong in any direction compared with ladder chassis and monocoque chassis of the same weight.

There are several disadvantages of tubular space frame which it is very complex, costly and time consuming to be built. It also impossible for robotized production and it engages a lot of space and raise the door sill. Tubular space frame leads the result in difficult access to the cabin. However, some of the disadvantages stated before are true only for a big production. Regarding to the concept of Shell Eco-marathon, there will be no problem using tubular space frame as chassis in fact the vehicle is build only by the team members. The Figure 2.2 below showed the sample tubular space frame chassis of TVR Tuscan.

Figure 2.2: An example of chassis of TVR Tuscan

Source: Mark Wan (2000)

Discussing the current chassis design, there is several existing design of aluminium chassis that had been used by automobile company around the world. Lotus Engineering as the example has been building cars with aluminium chassis for many years. Lotus succeeds to introduce that none of the chassis are welded since the strength of aluminium is decrease once it is welded. They have decided that the chassis are held together only with screws and adhesive. When Lotus first introduced the method on the low-volume Elise in 1996, company leaders were worried about the market acceptance for what is essentially a glued-together car, but the technique proved so successful (over 23,000 cars produced with no reported failures) that it has become the basis of a new higher volume venture that may help to bring aluminium-intensive vehicles more into the mainstream (Whitfield, 2004).

2.4 THE ADVANTAGES AND DISADVANTAGES OF USING ALUMINIUM FOR A CHASSIS

2.4.1 The advantages

Corresponding to this project, it is been proposed that aluminium used as a material for the new chassis design as in the project of Shell Eco-marathon Asia 2010. To ensure it is the correct decisions, there were researches made from current aluminium chassis in the industry. In term of corrosion resistances, we all believe that aluminium has excellent corrosion resistances. This is due to our experience with very weak sheet materials used for body or anodized parts. The high strength heat treatable alloys do not like to anodize. Even if we could anodized a complete chassis after fabrication it would not be successful and could not successfully weld after anodizing. Anodizing produces a relatively thick oxide layer on the surface of aluminium and it is the oxide which seals the surface and gives aluminium it excellent corrosion resistance.

Existing urban vehicle currently used aluminium as material for their chassis. To support the details, Jaguar's Lightweight Vehicle Technology is the most suitable example. Jaguar's industry leading and riveted aluminium monocoque body structure, introduced their latest model. The aluminium body incorporates the latest thinking in epoxy bonding and riveting techniques to produce a chassis that is very safe, as well as very light. In fact, the new model, XK's aluminium chassis is significantly lighter and stiffer yet impressive 50 percent stiffer respectively. Jaguar's Lightweight Vehicle Technology is unique in the industry as a complete aluminium monocoque body structure as distinct from an aluminium spaceframe with separate aluminium panels. Its strength and light weight come from the way the shell is constructed, using new jointing technologies developed by Jaguar and its suppliers (Surrey, 2010).

Besides, safety is another major benefit of this very strong construction method. That is partly inherent in aluminium as a material, which absorbs significantly more energy per kilogram of material weight than steel when it is deformed. But the strength advantage doesn't only apply to high-speed impacts; it also means lower-speed accident repair costs are kept to a minimum. The reduction in the number of joints in the all-new XK further increases strength, and the front of the body is protected by easily replaced ‘crush cans’ that absorb the energy in impacts up to just over 9mph (15kph).

The new XK’s all-aluminium doors are each over 13 lbs (6 kg) lighter than an equivalent steel door and their mountings are significantly stiffer, which allows smaller gaps. Mounting the window glass rails directly to the aluminium castings at the front and rear of the door gives better sealing from the frameless layout and an impressively solid sound and feel when closed. Figure 2.3 below shows the chassis of the new XK model (Surrey, 2010).

Figure 2.3: The chassis of the new XK model

Source: Surrey (2010)

2.4.2 The disadvantages

However, there are some disadvantages of using aluminium as chassis. This can be observed is in term of strength, stiffness and weight by copying the steel chassis in aluminium (to an identical design) the weight will be reduced to one third. This seems good but as a proportion of the complete car is quite small. As the G and E of aluminium is also one third of steel all of the chassis deflections and deformations will increase by a factor of three. All moments used in stiffness and deformation calculations are effectively multiplied by E (the Young's Modulus of the material), this could result in dodgy or uncomfortable handling. The only way to really use aluminium is to re-design the chassis to suit the different characteristic (Flavell, 2003).

Besides, the main problem with aluminium is that it has relatively low fatigue strength and unlike most terrific a steel which does not have endurance limit. The endurance limit is the stress at which fatigue failure will never occur. Aluminium will always fatigue even if stresses are very low. In practices it may take millions of cycles for this to occur and it may not be of any practical significance but we would need to consider the fatigue loading of every critical chassis joint and pick-up point to be confident. Practically, the best solution is to run analysis of the structure of the chassis.

Most cars build with aluminium chassis are not welded since the yield strength of aluminium goes down by half once it is welded. Another big disadvantage of welding aluminium is that stresses are localized along a point or a line, which can lead to material fatigue. Stresses are distributed over a wide part-mating when bonding is used. To gain full merits of using adhesive, Lotus for example had come up with ways to optimize its properties. This included determining the optimum bond gap between parts and to maintain that gap uniformly over the bonded surface (Whitfield, 2004).

2.5 SUMMARY OF THE CHAPTER

Overall of this chapter is clarified the concept of the study on chassis design. It is found that the rules and regulation of the existing chassis design is based on the Shell Eco-marathon terms. The concept of the competition also being introduced so that the new chassis is designed according to the specification set by the organizer.

Furthermore, there is sort of discussion about the advantages and disadvantages of using aluminium for a chassis. The types of chassis also have been discussed and it is decided that the tubular space frame is the most suitable type of chassis used in this study. It is important to determine those research and properties in order to decide the best type of chassis since there are many things to be considered to achieve the longest distance with less fuel consumption for a car.

All the specification discussed in this chapter will be used to design a new chassis with several enhancements from the existing design of Shell Eco-marathon Asia 2010.

CHAPTER 3

ANALYSIS OF EXISTING DESIGN AND PROPOSED A NEW CONCEPT OF THE CHASSIS OF AN URBAN CAR

3.1 INTRODUCTION

Overall view of this chapter will be clarified here. Firstly, these chapters contain several sections and these sections were organized according to this project process flow or procedure. The first section (3.2) will be the parameter selection continued by the existing design of Shell Eco-marathon Asia 2010 (3.3). This section also includes the Finite Element Analysis using Algor (3.3.1) and discussion (3.3.2). Besides, there will be the properties of Aluminium based on experiment (3.4) and the final section is the summary of this chapter (3.5).

Parameter selection in the section (3.2) will discuss upon parameter responsible in this study. Parameter listed in this chapter includes both used in analyzing the chassis and also in designing process. There will be several important parameters to be considered such as beam element, material selection and weight saving. The existing design of Shell Eco-marathon Asia 2010 in the section (3.3) will discuss about the analysis of the chassis. This analysis used the method of Finite Element Analysis (FEA) by using Algor continued with the discussion on how chassis structure being analyzed and result properties. There are two parameters to be tested which include the displacement and the worst stress applied on the chassis. The properties of aluminium based on experiment explain the material's properties and its composition. The experiment is done using Algor Software.

3.2 PARAMETER SELECTION

The analysis of both materials and chassis structure consist numerous number of parameter attached to it. Clarification of the parameter selected for this analysis is important to fulfill the scope of the study. However, not all of them involved in determining the result though all of them are related to each other, thus they can be consider as important as the parameter that must rely on each other in order to do the analysis. Several parameters that genuinely involved in this research will be as Table 3.1 follows;

Table 3.1: List of parameters involved

Analysis	**Description**
Force, F	Load applied on the selected part in the chassis structure
Stress, σ	Determined after the analysis
Displacement magnitude, δ	Determined after the analysis
Material density, ρ	Calculated by the software
Material volume, v	Calculated by the software
Mass, m	Calculated by the software
Diameter of the pipes material, D	Standard dimension available in the market
Thickness, t	Standard dimension available in the market

The force value applied into the chassis structure is chosen according to the rules by Shell Eco-marathon organizer. The analysis is run after applying forces to selected parts. The result of analysis is observed in the terms of displacement magnitude and worst stress. The constant parameters are selected by the properties of existing design of Shell Eco-marathon. However, the material for the new chassis design will be different and the properties will be obtained by the existing market prospect.

3.3 EXISTING DESIGN OF SHELL ECO-MARATHON ASIA 2010

The existing design of Shell Eco-marathon Asia 2010 urban concept is done by one of the team member himself, Mr. Noor Akmal bin Zolkifli. The urban concept car is designed by the rules and regulation state by the organizer. This urban car is design with two parts which are body parts and the chassis part. The chassis type chosen is the tubular space frame. The chassis is made of stainless steel AISI T403 pipes with the diameters of 31.75 mm and the thickness is 1.4 mm. The overall chassis weight is calculated as 48.88 kg using Solidwork Software. However, this value might be larger than the real one since there is difference value of beam element states by the software itself. Thus, the true value of chassis weight will be measured using Algor after the analysis is done. Figure 3 below is the design sketching of the existing chassis.

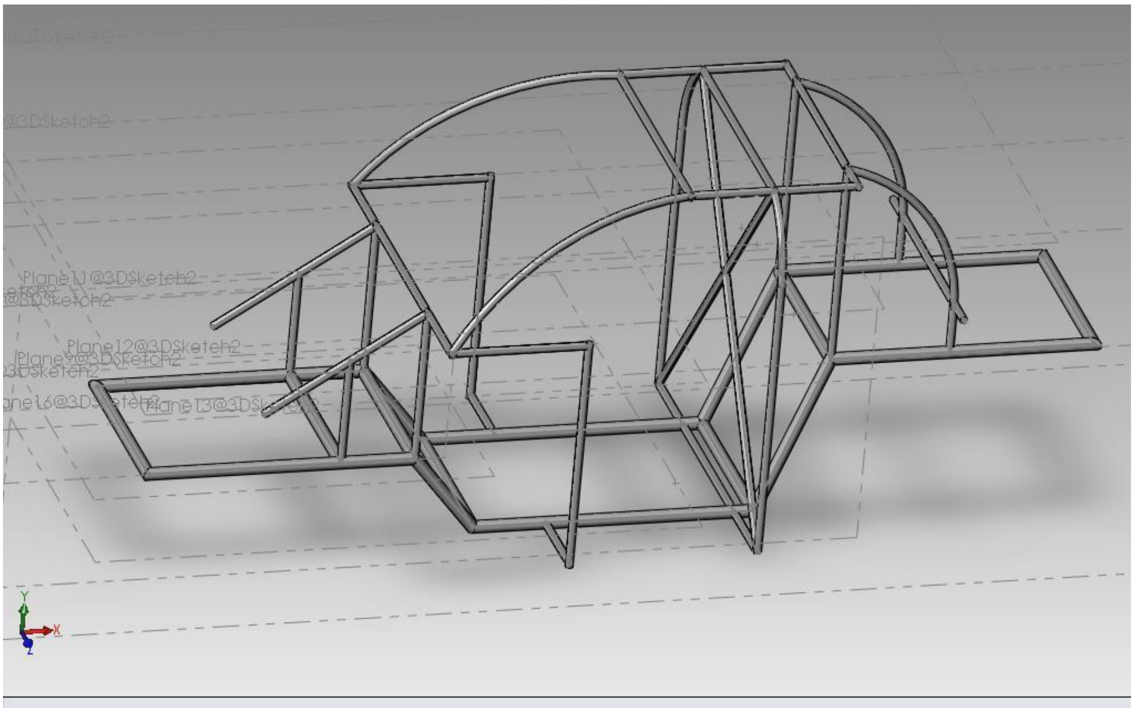


Figure 3.1: The chassis structure of the existing chassis for urban car.

The chassis structure have been drawn in Solidwork Software. After defined the type of material used, few of the chassis properties can be obtained which calculated by the software itself as shown in Figure 3.2 below. However, the value might be not exact as theoritical calculation but it can be assumed as the true value. Besides, the properties of both chassis and stainless steel 304 also can be determined in the Solidwork Software as stated in Figure 3.3 and Table 3.1 below.

Mass properties of wireframe weldments (Part Configuration - Default<As Machined>)

Output coordinate System: -- default --

Density = 0.01 grams per cubic millimeter

Mass = 48883.95 grams

Volume = 6110493.22 cubic millimeters

Surface area = 4063946.42 millimeters^2

Center of mass: (millimeters)
X = 1320.88
Y = 378.76
Z = 250.07

Principal axes of inertia and principal moments of inertia: (grams * square millimeters)
Taken at the center of mass.
Ix = (0.99, 0.16, 0.00) Px = 7866026662.13
Iy = (-0.16, 0.99, 0.00) Py = 25192048890.43
Iz = (0.00, -0.00, 1.00) Pz = 25853961645.46

Moments of inertia: (grams * square millimeters)
Taken at the center of mass and aligned with the output coordinate system.
Lxx = 8325438670.43 Lxy = 2783653420.00 Lxz = 449007.44
Lyx = 2783653420.00 Lyy = 24732645079.02 Lyz = 2429259.24
Lzx = 449007.44 Lzy = 2429259.24 Lzz = 25853953448.58

Moments of inertia: (grams * square millimeters)
Taken at the output coordinate system.
Ixx = 18395284862.54 Ixy = 27240349519.72 Ixz = 16147247205.65
Iyx = 27240349519.72 Iyy = 113078723163.82 Iyz = 4632527318.08
Izx = 16147247205.65 Izy = 4632527318.08 Izz = 118156111688.64

Figure 3.2: The properties of chassis structure from the Solidwork.

Table 3.2: The properties of Stainless steel AISI 304

Property	Value	Units
Elastic Modulus	190000	N/mm^2
Poissons Ratio	0.29	
Shear Modulus	75000	N/mm^2
Thermal Expansion Coefficient	1.8 E-05	
Density	0.008	g/mm^2
Thermal Conductiity	16	W/mK
Specific Heat	500	J/kg K
Tensile Strength	517.017	N/mm^2
Yield Strength	206.807	N/mm^2

Source: Anonymous (2010)

3.3.1 Finite Element Analysis (FEA) using Algor

Finite Element Analysis (FEA) Finite Element Analysis (FEA) was first developed by R. Courant in 1943, who utilized the Ritz method of numerical analysis and minimization of variation calculus to obtain approximate solutions to vibration systems. 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 (Widas, 1997).

The FEA analysis of the chassis structure is done in Algor software to obtain the displacement magnitude and stress under certain load. The analyses begin with the process of drawing the chassis continued by applying forces on certain part in the structure. In this study, there two parts of the chassis that being analyze which is the roll bar, the driver’s position and the engine position. The result of analyses is shown in Table 3.3 as follow;

Table 3.3: The analyses result of existing chassis of Shell Eco-marathon.

On the roll bar	Displacement magnitude, δ	1.229 mm
	Worst stress, σ	50.755 N/mm^2
Driver and engine position	Displacement magnitude, δ	2.514 mm
	Worst stress, σ	83.647 N/mm^2
Overall chassis weight	243 N	
Outer diameter	31.75 mm	
Thickness	1.4 mm	

The chassis structure is drawn in the Algor in the form of wireframes. It is important to draw the sketching in this form since Algor cannot analyze a 3-Dimensional hollow structure. Note that, the Solidwork drawing which converted into *.igs* format could not simply import into Algor. Otherwise, the analyses will be wrong as the force only exerted in the surface of the beam and there will be no displacement magnitude is seen. The Figure 3.3 below shows the wireframes chassis and forces applied at the roll bar.

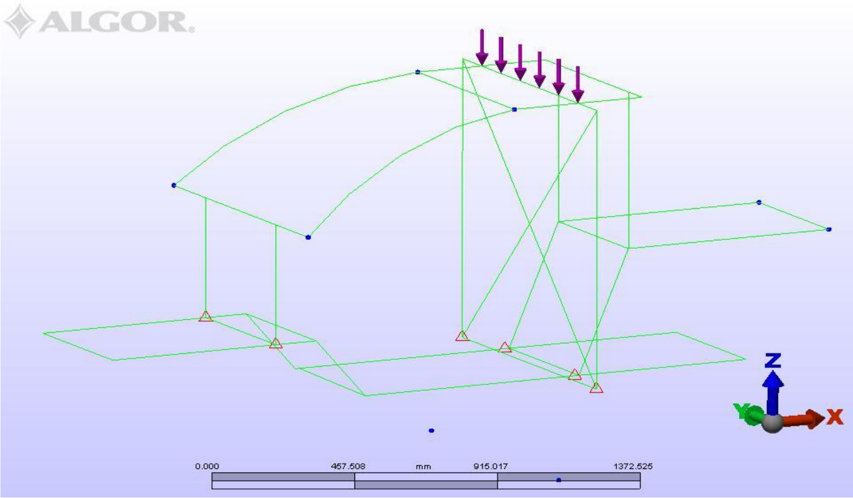


Figure 3.3: The analysis of existing chassis applying load on the roll bar

After run the analysis, the roll bar is found to be deflected with 1.223 mm displacement magnitude as shown in the Figure 3.4 below. However, it seen that the other structure is not affected by the force and it shows that the structure stiffness is high or it might be over design.

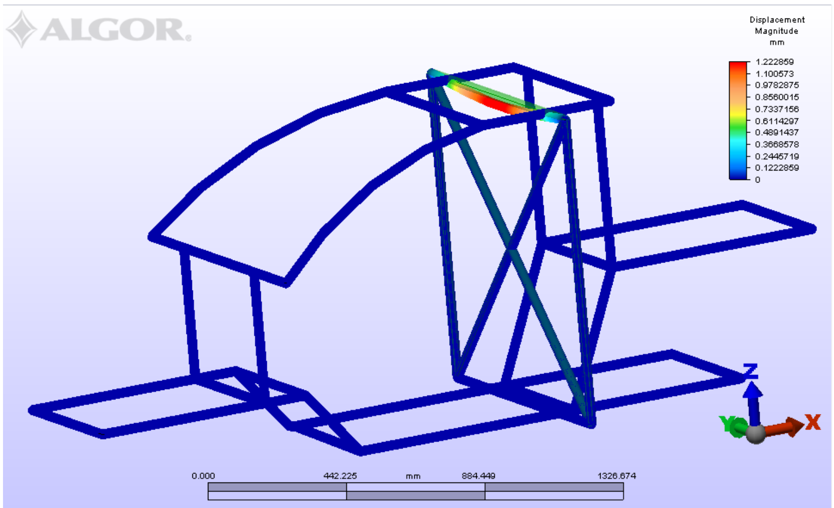


Figure 3.4: The result of displacement on the roll bar

The Figure 3.5 below shows the displaced model of the roll bar with 3% of scale factor in Algor. This model is important to show the reader on how the roll bar is deformed after applied load.

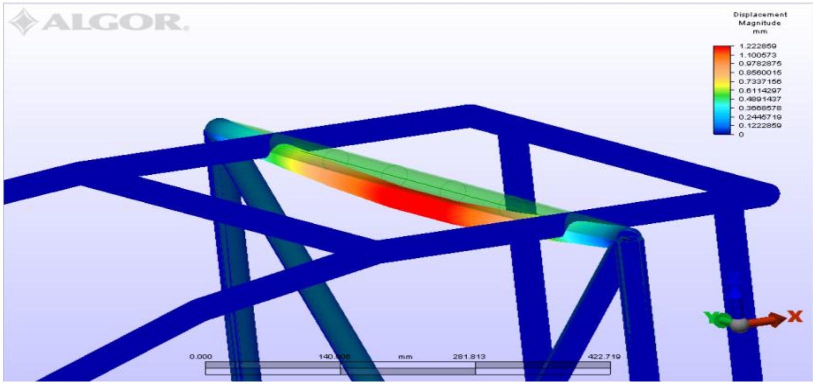


Figure 3.5: The deformed shaped of the roll bar after applied load

The other parameter to be tested is the worst stress applied on the structure. It is found that the value of worst stress is 50.755 N/mm^2 as shown in the Figure 3.6 below. The worst stress after applied load is found to be small. Note that yield occurs when largest stress exceeds the tensile yield strength. Thus, considering the yield strength of stainless steel which is 275 MPa, it means that the chassis structure is stiff.

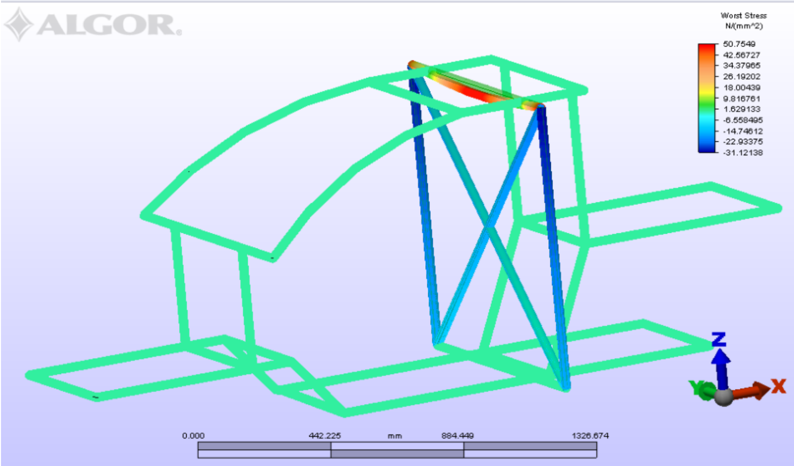


Figure 3.6: The result of worst stress on the roll bar.

The analysis of the chassis is continued by applying load on the driver's position and engine compartment. The load applied on the driver's position is 700 N while load on the engine compartment is 340 N. It shows that there are several loads applied on the diver position. This is because; the force is distributed along the pipes which supports the lower position of the driver. As for the engine compartment, the load is assumed distributed along the rear structure. The position of the load applied on driver's position and engine compartment is shown in the Figure 3.7 as follows;

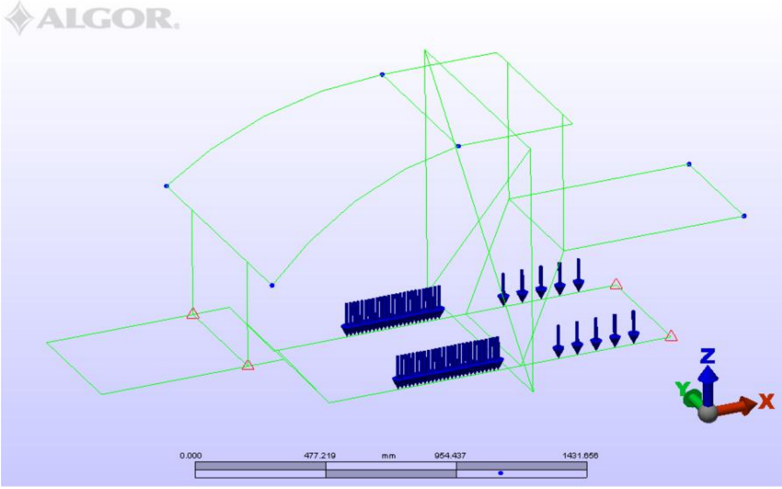


Figure 3.7: The position of load applied on the driver and engine position.

It is found that the lower structure is bent after subjected loads. The maximum value of displacement magnitude is 2.514 mm as shown in the Figure 3.8 below. From the observations, there are several parts of the chassis that looks like broken and it is because the figure is taken by 3% scale factor of displaced model. In the real situation, the chassis is displaced on a very small amount.

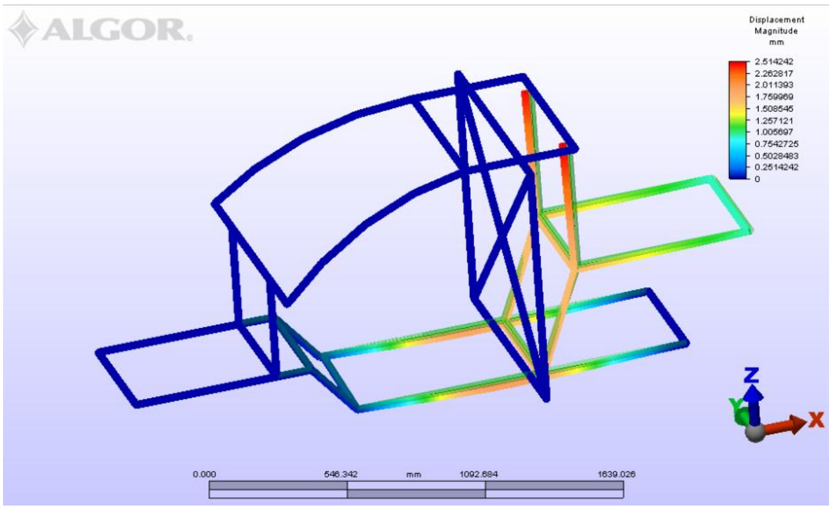


Figure 3.8: The result of displacement magnitude on driver and engine position.

Here, also attached is the vector plot of the displacement magnitude in the driver's position and engine compartment. This is an important model for the readers to see and understand the direction of deflected model when subjected to load.

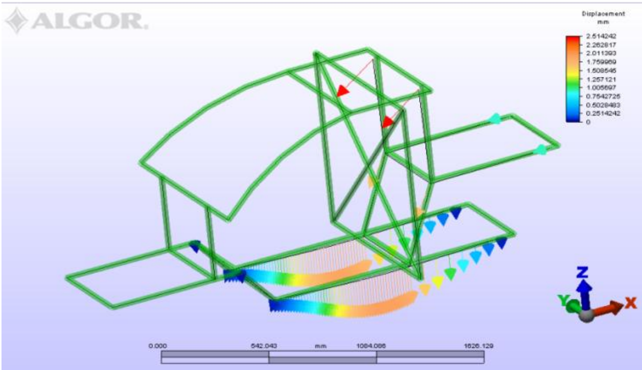


Figure 3.9: The vector plot of displacement result in the driver's position and engine compartment

With the same position of applied load as discussed above, the worst stress also being determined. From the analysis, it is found that the maximum value of the worst stress is 83.647 N/mm^2 while the minimum value is -0.802 N/mm^2. The minimum value is too small which means that the other structure is not affected by the applied load. Figure 3.10 shows the result of worst stress under same position and loads.

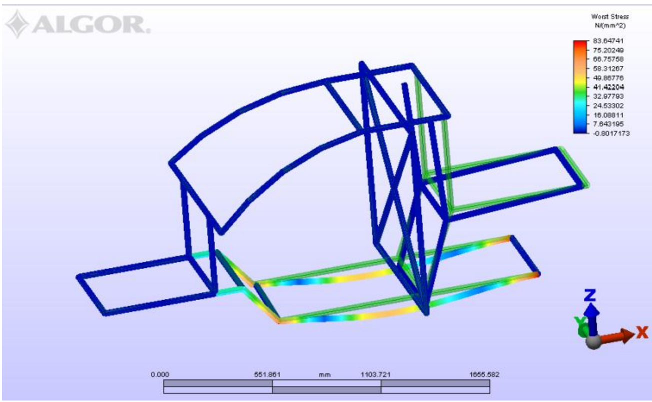


Figure 3.10: The worst stress result in the driver's position and engine compartment

3.3.2 Discussion

From the result, it showed clearly how the structure displaced after applying load. The variety of colors contour are represent the magnitude of displacement occurred. The result value observed is small and it shows that the structure is strong enough to stand the load apply on itself. However, noted that the deformed shape seems large but actually it is observed under certain scale for the readers ease. In reality situation, the structure would not bend as shown in the figures since the value of displacement is very low.

Because of all materials have a finite modulus of elasticity and plasticity; plastic deformation always is followed by some elastic recovery when the load is removed. In bending, this recovery is called springback, which can be observed easily by bending and then releasing a piece of sheet metal or wire. Springback occurs not only in flat sheets and plates, but also in solid or hollow bars and tubes of any cross-section. Springback also gives advantages of the chassis structure since it can represent the 'suspension' to the structure itself. The Table 3.3 shows the Mechanical properties of the stainless steel AISI T304 (Kalpakjian and Schmid, 2006).

Table 3.4: The mechanical properties of stainless steel AISI Type 304

Properties		Conditions	
		T (°C)	**Treatment**
Density (×1000 kg/m^3)	7.7-8.03	25	
Poisson's Ratio	0.27-0.30	25	
Elastic Modulus (GPa)	190-210	25	
Tensile Strength (Mpa)	485	25	annealed, hot finished (wire) more
Yield Strength (Mpa)	275		
Elongation (%)	20		
Reduction in Area (%)	45		
Hardness (HRB)	88 (max)	25	annealed (plate, sheet, strip)

Source: Kalpakjian and Schmid (2006)

Thus, it is important to ensure that the displacement of the structures not exceed the yield strength of the material otherwise the structure tend to crack. As discussed before, the worst stress of the structure has a very small value compare with the material yield strength; 275 MPa. However in this case, the structure is found to have high stiffness otherwise, it might be over designed.

3.4 Properties of Aluminium based on experiment

As stated in the Chapter 1, the scope of this study is proposing a new design which is light in weight and using different material. It has been decided that the new design is using aluminium T6 6063. Further discussion upon the material selection will be done in the next subchapter of 3.4.1. However in this section, the experiment using Fempro software is made to the Aluminium Pipe T6 6063 with 38.1 mm diameter and 460 mm long. The force is applied to the center of the pipe which is at 300mm coordinate length as shown in the Figure 3.11 below. The magnitude of displacement is observed to be 0.489 mm under subjected loading of 700 N.

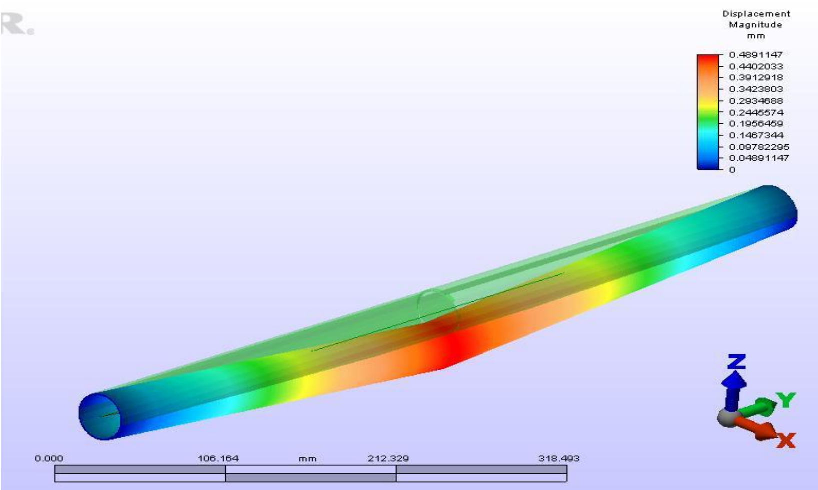


Figure 3.11: The result of Aluminium Pipes T6 6063 displacement analysis.

After running the analysis, the properties of material used is obtained by the software itself. Figure 3.12 below shows the properties of aluminium Pipes T6 6063 in Algor.

Aluminum 6063-T6	
Material model	Standard
Unit System	Metric mks (SI)
General Properties	
Mass density (kg/m³)	2700
Damping (s)	0
Elastic Properties	
Modulus of Elasticity (N/m²)	68900000000
Poisson's Ratio	0.33
Shear Modulus of Elasticity (N/m²)	25800000000
Thermal Coefficient of Expansion (1/°C)	0.0000234
Thermal Properties	
Thermal conductivity (J/(s*m*°C))	200
Specific heat (J/(kg*°C))	900
Electrical Properties	
Electrical Conductivity (A/(V*m))	30120480
Dielectric Constant	0
Plastic Properties	
Yield Strength (N/m²)	214000000
Strain Hardening Modulus (N/m²)	0
Ultimate Strength (N/m²)	241000000
Elongation at 2 in. (%)	12
Stress vs. strain data	No data available (Click to view/edit)

Figure 3.12: The properties of Aluminium Pipes T6 6063 in Algor

3.4.1 Properties of Aluminium Alloy T6 6063

Pure aluminum, primarily seen in the 1xxx series of wrought aluminum alloys, has little strength, but possesses high electrical conductivity, reflectivity, and corrosion resistance. For this reason, a wide variety of aluminum alloys have been developed.

Aluminium Alloy is a medium strength alloy commonly referred to as an architectural alloy. It is normally used in intricate extrusions. It has a good surface finish and high corrosion resistance which is readily suited to welding. It also can be easily anodized. Most commonly available as T6 temper and for the T4 condition, it has good formability.

Aluminium alloy 6063 is typically used in architectural applications such as extrusions, window frames, doors, shop fittings and irrigation tubing. The aluminium 6063 finding applications in hydroformed tube for chassis. Observing the aluminium 6063 weldability, it is found that 6063 suitable for all conventional welding methods. Here are the properties of Aluminium Alloy T6 6063 as shown in the Table 3.4, Table 3.5, Table 3.6 and Table 3.7 (Aalco, 2005).

Table 3.5: Typical chemical composition for aluminium alloy 6063

Element	**6063** **% Present**	**6063A** **% Present**
Si	0.2 to 0.6	0.3 to 0.6
Fe	0.35 max	0.15 to 0.35
Cu	0.1 max	0.1
Mn	0.1 max	0.15
Mg	0.45 to 0.9	0.6 to 0.9
Zn	0.1 max	0.15
Ti	0.1 max	0.1
Cr	0.1 max	0.05
Al	Balance	Balance

Source: Aalco (2005)

Table 3.6: Typical mechanical properties for aluminium alloy 6063

Temper	**O**	**T4**	**T6**
MinimumProof Stress 0.2% (MPa)	50	65	160
Minimum Tensile Strength (MPa)	100	130	195
Shear Strength (MPa)	70	110	150
Elongation A5 (%)	27	21	14
Hardness Vickers (HV)	25	50	80

Source: Aalco (2005)

Table 3.7: Typical physical properties for aluminium alloy 6063.

Property	**Value**
Density	2.70 g/cm^3
Melting Point	600°C
Modulus of Elasticity	69.5 GPa
Electrical Resistivity	0.035x10^{-6} O.m
Thermal Conductivity	200 W/m.K
Thermal Expansion	23.5 x 10^{-6} /K

Source: Aalco (2005)

Table 3.8: The fabrication of 6063 Aluminium

Process	Rating
Workability	Cold Average
Machinability	Average
Weldability	Gas excellent
Weldability	Arc Excellent
Weldability	Resistant Excellent
Brazability	Excellent
Solderability	Good

Source: Aalco (2005)

3.5 Summary

Overall chapter 3 discusses the existing chassis of Shell Eco-marathon Asia 2010. From the analysis result, we can see the capability of the structure to withstand the load applied. The result of displacement and worst stress is observed and found that it have a small value. Those results will be compared with the new chassis in the next chapter. There are also some discussion upon properties of aluminium alloy T6 6063 which will be used for the new chassis design in the chapter 4.

CHAPTER 4

DETAIL DESIGN OF PROPOSED SELECTED DESIGN

4.1 INTRODUCTION

Chapter 4 contains several main sections and these sections were organized continuing the previous chapter. The first section (4.2) will be the analysis of the new design which includes brainstorming session, the sketching in Solidwork, the finite element analysis using Algor and the analysis comparison results. The next section will be the analysis of materials (4.3) which includes the comparison between aluminium pipes and hollow rectangular aluminium. The final section is the result discussion (4.4) of the analyses in previous sections.

The new design is done by the development from existing chassis of Shell Eco-marathon Asia in the previous chapter. This new design is proposed with different material, Aluminium Alloy T6 6063 rectangular tubes. However, the analyses done are same with the existing design considering the displacement magnitude and stress on the chassis.

This chapter also discusses the analysis of the beam element comparing both materials used in this study. The analyses are done between the aluminium pipes and rectangular tube aluminium. Increasing the chassis stiffness required bigger area cross section. However, the shapes of area also influence the ability of the structure to withstand load applied. Therefore, the analyses are carried out so that the stiffer chassis is obtained. Finally, there will be discussion session explaining the result and corresponding matters.

4.2 ANALYSIS OF THE NEW DESIGN

4.2.1 Design Sketching

The new chassis design proposing structure with few trusses in order to reduce overall chassis weight. It is found that the existing design in the previous chapter might be over design, thus the new design considered only the critical part. Correspond to the urban concept car during the competition, the vehicle must have overall maximum weight of 160 kg including the driver. Thus, as a major structure of the vehicle, the chassis need to be light in weight. Other than that, this chassis will be covered with carbon fiber as a body, so it is function as support structure to the vehicle and must be strong.

It is assumed that the used of aluminium rectangular tube will increase the chassis stiffness and light in weight. However, the analyses will be done to obtain the result in the next subchapter of (3.4). The new chassis sketching is done using Solidwork as shown in the Figure 4.1 below.

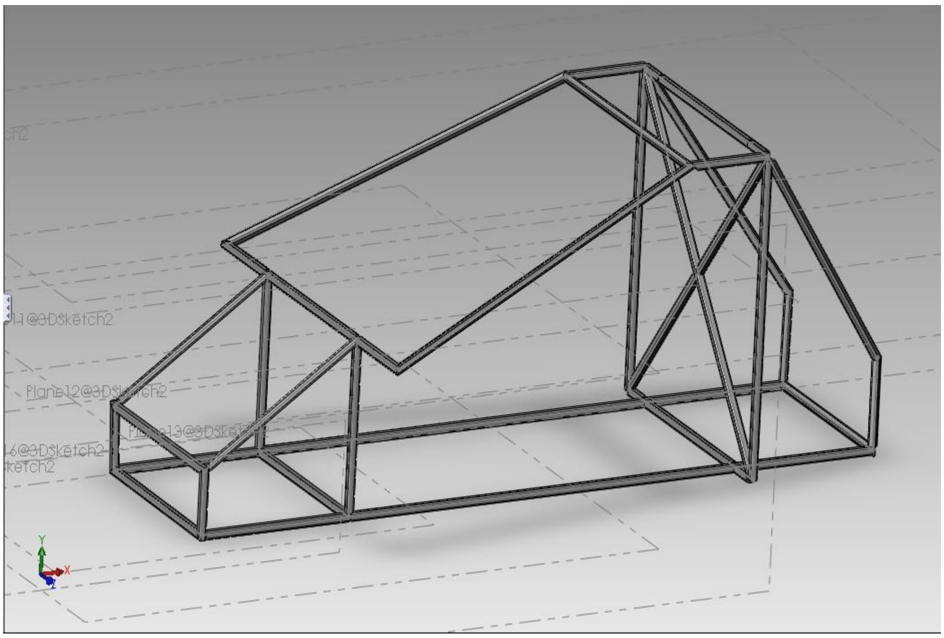


Figure 4.1: The new chassis design sketching in Solidwork

4.2.2 Finite Element Analysis (FEA) using Algor

The new chassis developed in structures which aim the result of light in weight and high stiffness. The analysis procedure and parameters involves of the new design is mainly the same with the existing chassis design in previous chapter. As stated before, this chassis will be analyzed in two different types of material element which are pipes and rectangular tubes of Aluminium Alloy T6 6063.

However, in the section (4.22), the new chassis will be analyses in pipes. The result then is compared with the existing design in the previous chapter. For this section, the chassis stiffness and weight will be differentiating in terms of material selection. The analyses results on the roll bar using aluminium pipes are shown in the Figure 4.2 below.

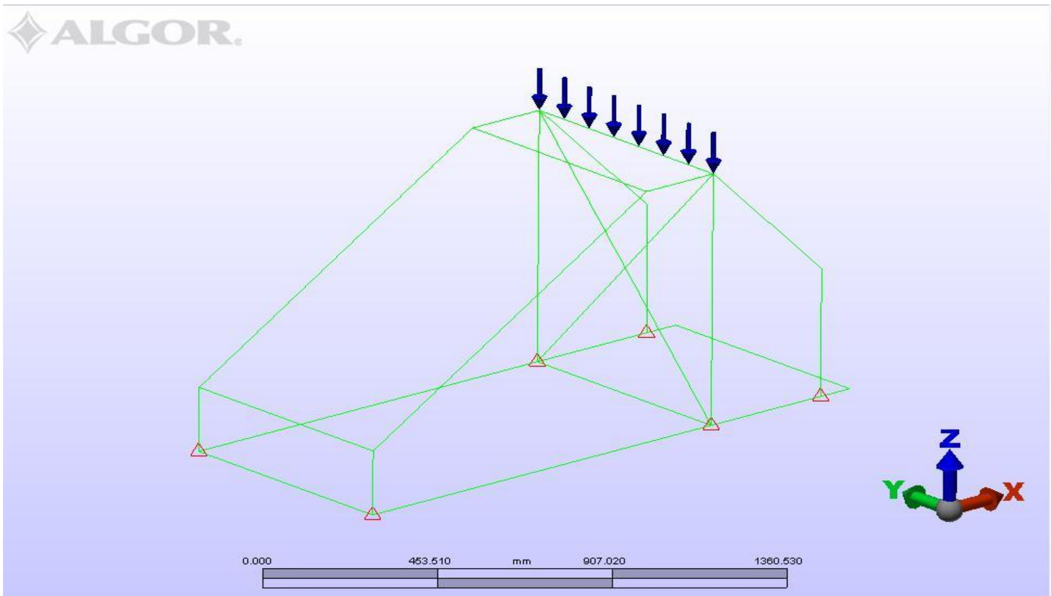


Figure 4.2: The forces of 700 N are applied on the roll bar of the chassis.

As stated in previous chapter, there are displacement occurred in the roll bar when subjected to load of 700 N. Note that, the Figure 4.3 as follows is the displaced model with 3% scale factor. From the observation, it is found that the displacement magnitude of this aluminium chassis is 1.181 mm.

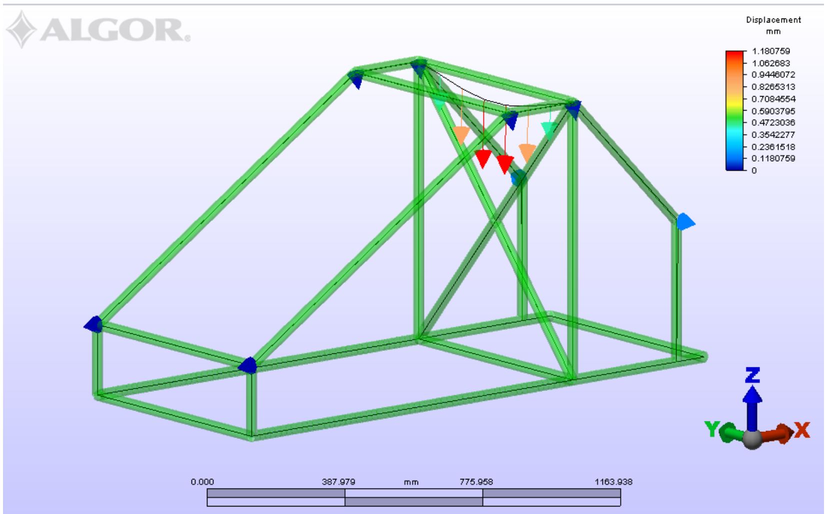


Figure 4.3: The displacement model of applied forced on the roll bar.

The result of worst stress also taken under the same load of 700 N. From the result shown on the Figure 4.4, it seen that the value of maximum worst stress is 39.897 N/mm^2 while the minimum value is -16.483 N/mm^2.

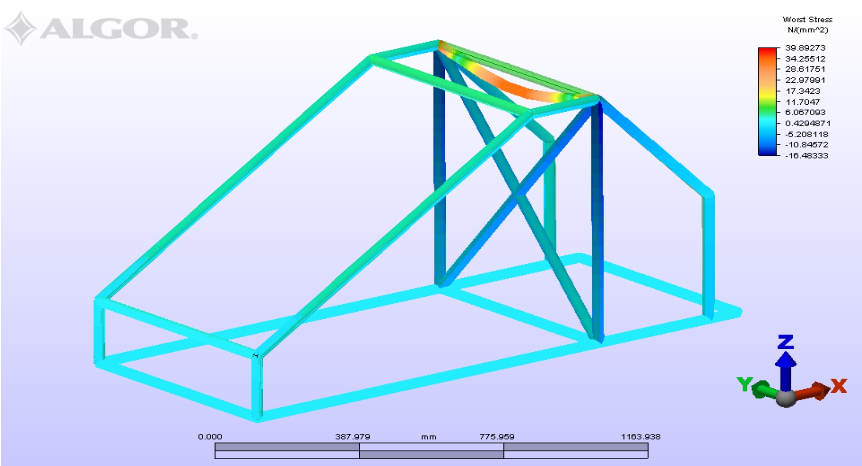


Figure 4.4: The worst stress of applied forced on the roll bar.

The analysis of the chassis is continued by applying load on the driver's position and engine compartment. The load applied on the driver's position is 700 N while load on the engine compartment is 340 N same as stated in the previous chapter. It shows that there are several loads applied on the diver position. This is because; the force is distributed along the pipes which supports the lower position of the driver. As for the engine compartment, the load is assumed distributed along the rear structure. The position of the load applied on driver’s position and engine compartment is shown in the Figure 4.5 as follows;

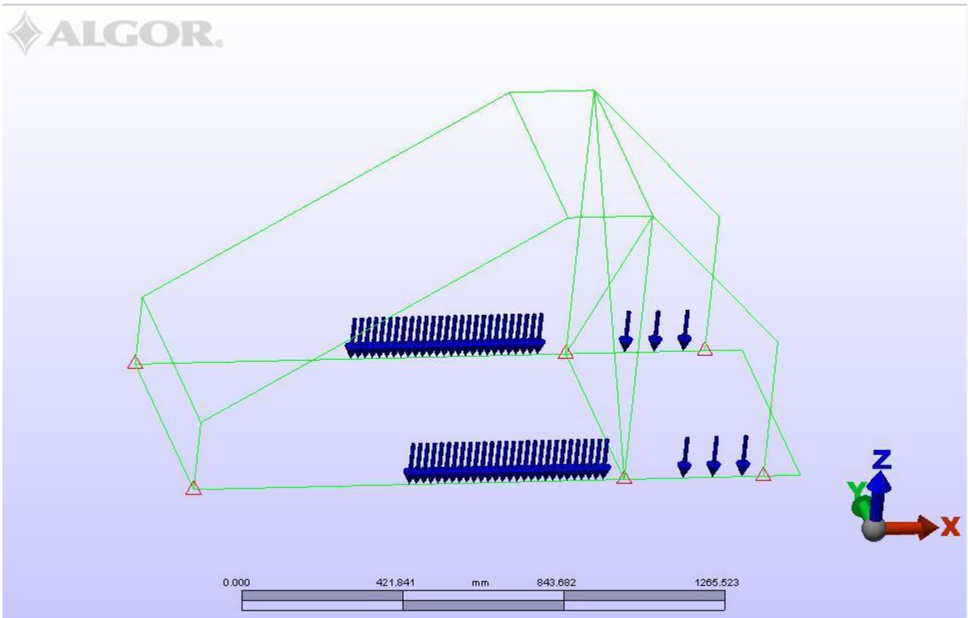


Figure 4.5: The forces apply on the roll bar of the new chassis structure.

It is found that the lower structure is bent after subjected loads. The maximum value of displacement magnitude is 1.963 mm as shown in the Figure 4.6 below. From the observations, there are wireframe structures that looks like broken and it is because the figure is taken by 3% scale factor of displaced model. In the real situation, the chassis is displaced on a very small amount.

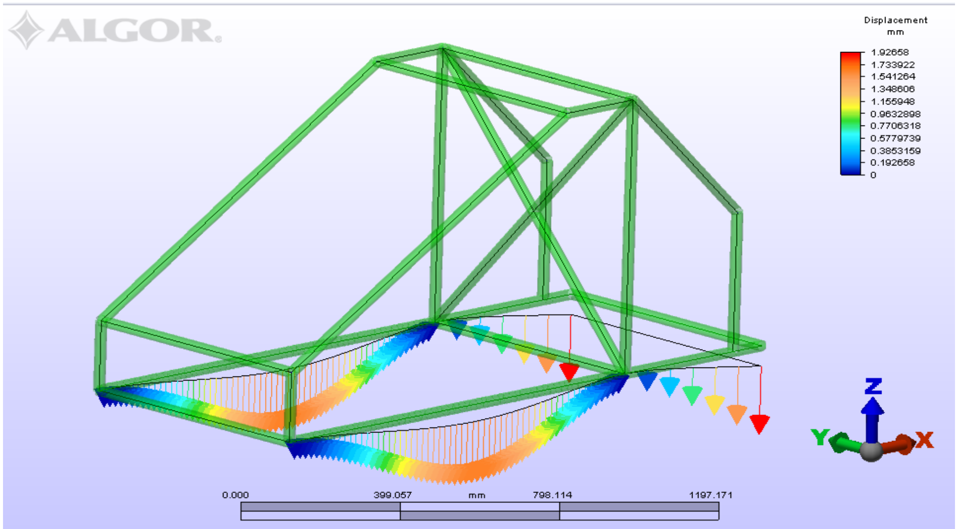


Figure 4.6: The worst stress of applied forced on the driver and engine position.

With the same position of applied load as discussed above, the worst stress also being determined. From the analysis, it is found that the maximum value of the worst stress is 52.555 N/mm^2 while the minimum value is zero. The minimum value is observed to be zero which means that the other structure is not affected by the applied load. Figure 4.7 shows the result of worst stress under same position and loads.

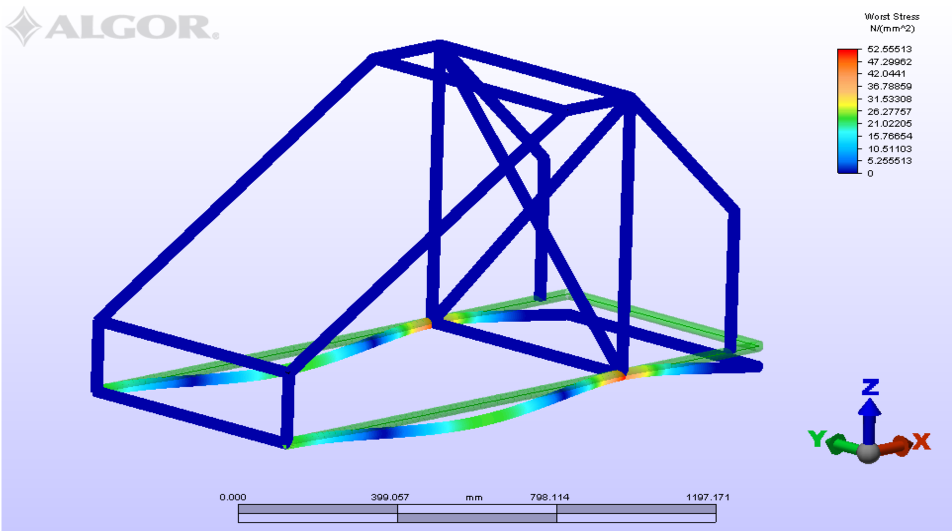


Figure 4.7: The displacement of applied forced on the driver and engine position.

4.2.3 Analysis Comparison Result

In this section, overall result comparing the existing design with the new design is discussed. The result is measure with the same pipe size but in different material which for this case, aluminium is used. Compared to the existing design, it is shown that the displacement magnitude and worst stress of the aluminium structure is smaller than existing design in chapter 3. Besides, the weight of aluminium structure also reducing about 20 % compared to the previous chassis which used stainless steel.

Comparing both designs, the result shows that the early assumption is correct due to the lower value of displacement magnitude, worst stress and the weight saving. The new design, which is designed by aluminium that has high stiffness, has confirmed the early assumption. This can proven by the properties of aluminium stated in the previous chapter. Here are the comparison results of both designs as stated in the Table 4.1 below.

Table 4.1: The comparison results between the existing design and the new design.

	Existing design using Stainless Steel T304	**New design using Aluminium T6 6063**
On the roll bar		
Displacement magnitude, δ	1.229 mm	0.604 mm
Worst stress, σ	50.755 N/mm^2	23.480 N/mm^2
Driver's position and engine position		
Displacement magnitude, δ	2.514 mm	1.266 mm
Worst stress, σ	83.647 N/mm^2	40.928 N/mm^2
Overall chassis weight	243 N	59 N
Outer diameter	31.75 mm	31.75 mm
Thickness	1.4 mm	1.4 mm

4.3 ANALYSIS OF THE MATERIALS

4.3.1 Comparison of Finite Element Analysis between aluminium pipes and rectangular tube aluminium.

Note that, the new chassis also analyzed using rectangular tube aluminium alloy. The analyses are done in different size of cross section areas. Assume that, the bigger cross section area influences the stiffness. Here is the example result of the aluminium rectangular tube analysis on the roll bar and driver's position including the engine compartment. Overall results figures shows the same displaced model after applied load, thus only one size of cross area is taken. The worst stress on the roll bar in the Figure 4.8 is observed to be 40.679N/mm^2.

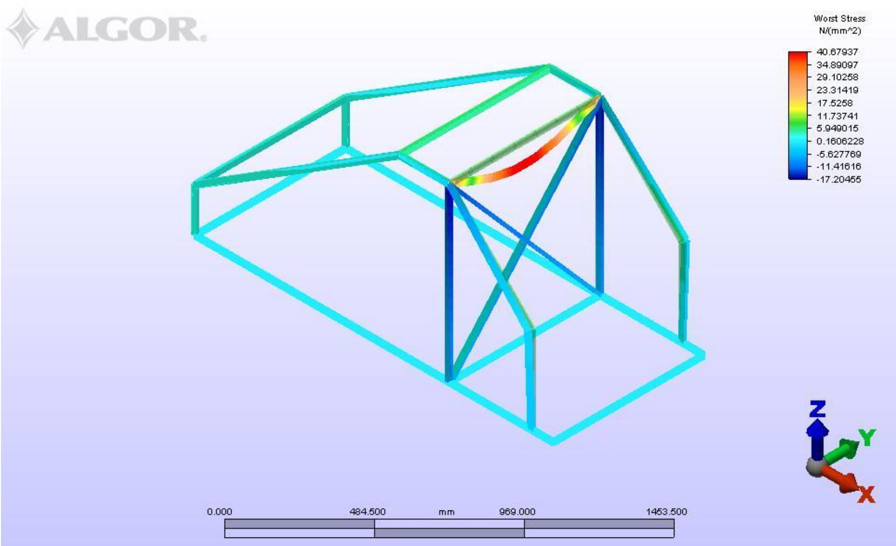


Figure 4.8: The worst stress of applied forced on the roll bar.

As stated above, the analyses are also done on the driver's position and engine compartment. The Figure 4.9 shows the deformed structure after subjected load of 700 N on the diver's position while 340 N on the engine compartment. The value of worst stress is 18.769 N/mm^2.

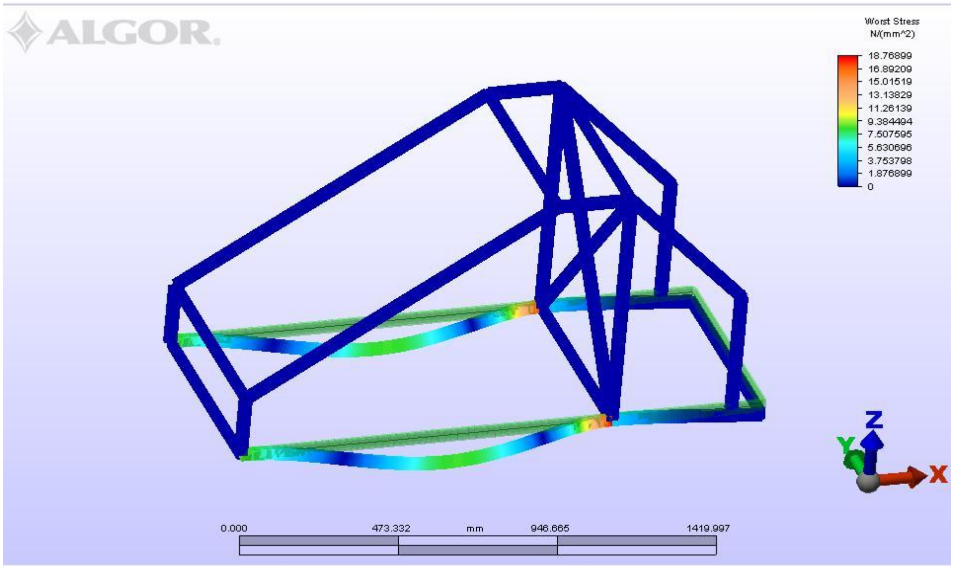


Figure 4.9: The worst stress of applied forced on the driver and engine position.

From the results shown before, readers could see how the structure is deformed after applying loads at different part of different materials. Here is the complete result data taken from the analyses of both aluminium alloy T6 6063 pipes and rectangular tubes. The Table 4.2 and Table 4.3 below shows the result data of aluminium pipes after subjected loads on the structures.

Table 4.2: The result data of the force applied on the roll bar.

Size of diameter (mm)	Thickness (mm)	Displacement magnitude (mm)	Worst Stress (N/mm^2)	Weight (N)
25.40	1.0	2.322	64.759	32.55
31.75	1.4	0.891	30.069	56.69
38.10	1.2	0.604	23.479	59.08

From the data shown above, it is found that the values of displacement magnitude are decrease due to increasing cross section area of the pipes. The worst stress also decreasing while the overall weight chassis is increasing. Considering the vehicle weight, the optimum result should be 59.08 N with 0.604 mm displacement and 23.479 N/mm^2 worst stresses. It is because, the chassis should not too light in weight otherwise it will affect the vehicle balance. The result data of applied load on the driver's position and engine compartment are stated in the Table 4.3 as follows;

Table 4.3: The result data of the force applied on the driver's position and engine compartment.

Size of diameter (mm)	Thickness (mm)	Displacement magnitude (mm)	Worst Stress (N/mm^2)	Weight (N)
25.40	1.0	5.148	113.441	32.55
31.75	1.4	1.927	52.555	56.69
38.10	1.2	1.266	40.928	59.08

The result data of aluminium pipes for both parts have the same patterns. The values of displacement magnitude and worst stress are decrease due to increasing cross section area of the pipes. However, the overall weight chassis is increase. Thus, it shows that the early assumption of bigger area increase the chassis stiffness is accepted. The optimum result of the data above should be one with weight of 59.08 N, 1.266 mm displacement magnitude and 40.928 N/mm^2 worst stresses. This result is chosen considering the weight balances and the lowest value of displacement magnitude.

The analysis is continued with the same steps as before but with different material element which is the rectangular tube aluminium. There are also three different sizes to be considered to obtain the most optimum result as stated in the Figure 4.4 and Figure 4.5. The Figure 4.3 shows the result data of the force applied on the roll bar of the chassis.

Table 4.4: The result data of the force applied on the roll bar for rectangular tubes.

Height (mm)	Width (mm)	Thickness (mm)	Displacement magnitude (mm)	Worst Stress (N/mm^2)	Weight (N)
12.70	25.4	3	1.955	40.679	81.80
19.05	38.1	3	0.502	15.410	130.30
25.40	38.1	3	0.350	11.177	146.52

Obviously, the result pattern is same as previous data. However, it found that the overall chassis weight of rectangular tube aluminium is larger compared with the pipes. The optimum result of the data above found to be the one with weight of 81.80 N. As for the displacement value; the optimum result is 1.955 mm while the worst stress is 40.679 N/mm^2. Further discussion upon chassis weight will be continued in the discussion section (4.4). The Table 4.5 shows the result data of the force applied on the driver's position and engine compartment.

Table 4.5: The result data of the force applied on the driver and engine position for rectangular tubes.

Height (mm)	Width (mm)	Thickness (mm)	Displacement magnitude (mm)	Worst Stress (N/mm^2)	Weight (N)
12.70	25.4	3	2.193	48.926	81.80
19.05	38.1	3	0.565	18.769	130.30
25.40	38.1	3	0.462	15.292	146.52

As for results in Table 4.5, the optimum result of chassis weight is 81.80 N same as Table 4.4. The reason of taking this result also is the same. It seen that the displacement magnitude value is the largest compared to the others. However, this value will not affect the chassis stiffness since it is small value.

4.4 DISCUSSION

From the results shown in the figures, we can see that the new chassis design is build with a simple structure compared with the existing design. The decision of proposing a simple design is made after considering the rule and regulation during competition. The chassis of an urban concept are not suggested to use suspension since the vehicle accelerates less than 50 km/hour. The vehicle only needs to consider the weight in order to increase the acceleration and decrease the fuel consumption.

Weight saving is important particularly for aircraft and aerospace structures, for automotive bodies and components, and for other products where energy consumption and power limitations are major criteria. Substitution of materials for the sake of weight saving and economy is a major factor in the design both of advanced equipment and machinery of consumer products such as automobiles.

The results above show that the overall weight for rectangular tubes is higher than the pipes. The aim for this study is to design a chassis which light in weight thus, it found that aluminium pipes are the lightest. However, overall chassis weight influence the vehicle stability. Comparing the aluminium pipes and rectangular tubes, the weight values of rectangular tube is more accepted.

Due to the magnitude displacement and worse stress of both structures, it shows that the values of rectangular tubes are lower than pipes. The decision of using rectangular tubes aluminium to develop the existing design is found to be correct. Thus, the new chassis stiffness is higher than the existing design.

Besides that, others matters that can be considered in this study is the strength to weight ratios. A significant role that density plays is in the strength-to-weight ratio (specific strength) of materials and structures. The Table 4.6 shows the ratio of maximum yield stress to density for a variety of metal alloys. Note that titanium and aluminium are at the top of the list, they are among the most commonly used metals for aircraft and aerospace applications (Kalpakjian and Schmid, 2006).

Table 4.6: The ratio of Maximum Yield Stress to Density for Assorted Metals

Alloy	Maximum yield stress/density (m x 10^3)
Titanium	32
Aluminum	20
Steels	19
Magnesium	17
Nickel	14
Copper	13
Tantalum	10
Molybdenum	5.5
Lead	0.13

Source: Kalpakjian and Schmid (2006)

From the data shown in the previous tables, we can see there is slightly different of result between pipes and rectangular pipes. Observing the result of displacement magnitude, it shows that aluminium rectangular tubes have lower displacement value compared to the pipes. The area of force applied on rectangular tube is larger than pipe. It is because of the cross sectional area that proportional to the forced applied is larger for rectangular tube as Eq. (4.1). Thus, the force distribution will be larger and less pressure exerted on the structure. This is why rectangular tube deformed smaller compared to the pipes.

$$P = \frac{F}{A} \quad \text{Or} \quad P = \frac{dF_n}{dA} \qquad \text{Eq. (4.1)}$$

Where: *P* is the pressure,
F is the normal force,
A is the area.

Besides, the thickness of rectangular tube available in the market is found to be 3mm, thicker than pipes. With larger size of thickness, the structure is stronger because the path of the material to crack will be larger. However, larger thickness of rectangular tube causing the increasing in chassis weight. This is why the chassis weight using pipe lighter than rectangular tube. Comparing with the existing chassis which use stainless steel as material, the aluminium chassis is lighter in weight. This is corresponding to the different material density of both materials.

As for worst stress, it is observed that the value of rectangular pipes is smaller compared to pipe. Note that stress is the average amount of force exerted per unit area. It is the internal resistance a material offers to being deformed and is measured in terms of the applied load. It is the same reasons with the previous discussion of displacement magnitude above.

CHAPTER 5

CONCLUSSION AND RECOMMENDATIONS

5.1 CONCLUSION

Existing chassis of Shell Eco-marathon Asia is found to be heavy in weight which did not meet the rules and regulation of the competition. Clarify that the material used is stainless steel type 304 which have large density of 7.7-8.03 (x 1000 kg/m^3). The vehicle performance is constantly relying on the overall vehicle weight including the driver. Note that Shell Eco-marathon challenge the urban concept car with fuel consumption which needs the chassis; the major structure of the vehicle is light in weight.

Using aluminium could be one of the methods of developing the chassis other than the structure itself. Using aluminium T6 6063, the chassis weight is reduce about 30% from existing design. Besides, considering the element type of structure; it is found to be that chassis with aluminium rectangular tube is stronger that aluminium pipe. The rectangular shape offer smaller displacement magnitude and stress of the structure.

Observing the new chassis structure, it has fewer trusses compared to the existing design. The design was proposed to ensure that the new structure reducing in weight and yet stronger than the previous one. From the result data, the optimum weight of aluminium pipes is 59.08 N while for the rectangular tubes is 81.80 N. Both values taken based on the rules of SEM which also consider several safety aspects as discussed in the previous chapters.

As for the displacement magnitude, the result obtain for stainless steel pipes applying forces on the roll bar is 1.229 mm while on the driver's position is 2.514 mm.

For rectangular tube, the optimum value applying force on roll bar is 1.955 mm while for driver's position is 2.193 mm. The reasons of those result is chosen have discussed in the previous chapters.

All of those results are leads to the conclusion that the used of rectangular tube of aluminium T6 6063 could reduce the chassis weight and also the strength of the structure itself.

5.1 RECOMMENDATIONS

There are few recommendations to be made in this study. Firstly, the proposed material which is Aluminium T6 6063 should done the tensile test of its structural member so that the yield strength of the rectangular tube used is obtain. For most structural materials, the difficulty in finding compressive strength can be overcome by substituting the tensile strength value for compressive strength. This substitution is a safe assumption since the nominal compression strength is always greater than the nominal tensile strength because the effective cross section increases in compression and decreases in tension. For current analysis, the yield strength is obtained from the properties of aluminium itself, thus the value of yield strength of the structure is not accurate. It is important to get the accurate result since we are identifying the stress at which plastic deformation begins.

Besides, the ultimate tensile strength of the chassis structure also needs to be obtained. The ultimate tensile strength (UTS) is the maximum resistance to fracture. It is equivalent to the maximum load that can be carried by one square inch of cross-sectional area when the load is applied as simple tension. UTS are expressed in pounds per square inch. When a force is applied to metal's layers of atoms, the crystal structure is moving in relation to adjacent layers of atoms. This process is referred to as *slip*. Grain boundaries tend to prevent slip. The smaller the grain size will larger the grain boundary area. (Nuclear Power Fundamental)

Other than that, improving the strength of the chassis could be done by integrated the structural tube with layer of fiber. The thin layer of fiber on the metal structure will decrease the displacement of the structure after load is applied. The decreasing of displacement will delay the plastic deformation of the structure.

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DESIGN AND DEVELOPMENT OF 1-SEATED URBAN CAR CHASSIS USING ALUMINIUM

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Report submitted in partial fulfillment of the requirements
for the award of the degree of
Bachelor of Mechanical Engineering

Faculty of Mechanical Engineering
UNIVERSITI MALAYSIA PAHANG

DECEMBER 2010

STUDENT'S DECLARATION

I hereby declare that the work in this project is my own except for quotations and summaries which have been duly acknowledged. The project has not been accepted for any degree and is not concurrently submitted for award of other degree.

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Dedicated to my parents

Mr. Fauzun bin Yahya and Mrs. Shahriah binti Hamzah

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ABSTRACT

This thesis deals with the design and development of the 1-seated urban car chassis using aluminium. The objective of this thesis is to develop the general procedures of analyzing the existing design of Shell Eco-marathon car chassis and designing a new chassis with several enhancements using aluminium as material. The thesis describes finite element analysis techniques to predict the displacement magnitude and identify the worst stress locates in the structures. Stainless steel AISI type 304 and aluminium alloy T6 6063 were studied in this thesis which commonly used for a chassis structure in industry. The structural of three-dimensional solid modeling of the chassis was developed using Solidworks software. The strategy of validation of finite element model was developed. The finite element analysis was then performed using ALGOR Fempro. Both chassis structure was analyzed using the static stress with linear material models approaches. Finally, the displacement magnitude of the structure and worst stress are obtained. From the results, it is observed that the displacement magnitude of new chassis is decreasing about 40% compared to the existing design. The existing design which used the stainless steel as material selection also is found to have higher worst stress compared with the aluminium chassis. Besides, comparing both designs founds the overall chassis weight of aluminium chassis is reduced about 30%. The obtained results indicate that using aluminium gives the chassis structure higher stiffness and light in weight. It also found that the rectangular tubes aluminium gives stiffer structure compared to aluminium pipes. The results conclude that using aluminium with larger cross sectional tubes area gives higher stiffness chassis structure. Therefore, using rectangular tubes aluminium promising higher stiffness structure and weight saving. The durability assessment results are significant to improve the chassis design at the developing stage. The results can also significantly reduce the cost and time in fabricating the chassis during the events, and improve reliability and user confidence.

ABSTRAK

Tesis ini membincangkan tentang reka bentuk dan pembangunan casis kereta bandar satu tempat duduk dari bahan aluminium. Objektif tesis ini adalah untuk membangunkan prosedur umum dalam menganalisis reka bentuk casis kereta Shell Eco-marathon yang sedia ada dan mereka bentuk satu reka bentuk casis yang baharu dengan beberapa tambahan dengan menggunakan bahan aluminium. Tesis ini juga menjelaskan teknik analisis elemen terhad untuk meramalkan perubahan magnitud dan mengenal pasti kedudukan tekanan terburuk dalam struktur. Besi tahan karat AISI 304 dan aloy aluminium T6 6063 dikaji dalam tesis ini yang kebiasaannya digunakan untuk struktur casis dalam industri. Penstrukturan model padu tiga dimensi casis telah dibangunkan menggunakan perisian Solidworks. Strategi juga mengenal pasti model elemen terhad telah dibangunkan. Analisis elemen terhad pula telah dilakukan menggunakan ALGOR Fempro. Kedua-dua struktur casis telah dianalisis menggunakan tekanan statik dengan pendekatan model material mendatar. Akhirnya, perubahan magnitud struktur dan tekanan terburuk diperolehi. Dari keputusan yang diperoleh, perubahan magnitud casis yang baharu diperhatikan mengalami perubahan lebih kecil berbanding reka bentuk yang sedia ada. Reka bentuk sedia ada yang menggunakan besi tahan karat sebagai bahan pilihan telah didapati mempunyai tekanan terburuk yang lebih tinggi berbanding casis aluminium. Selain itu juga, dengan membandingkan kedua-dua reka bentuk mendapati bahawa berat casis keseluruhan bagi aluminium casis telah dikurangkan. Keputusan yang diperoleh menunjukkan bahawa menggunakan aluminium memberikan struktur casis kepegunan yang lebih tinggi dan ringan. Keputusan ini juga mendapati bahawa tiub aluminium sesegi empat sama menghasilkan lebih kepegunan berbanding dengan paip aluminium. Keputusan merangkumkan bahawa menggunakan aluminium dengan luas keratan rentas yang lebih besar menghasilkan struktur casis yang lebih pegun. Oleh yang demikian, menggunakan tiub aluminium sesegi empat sama menjanjikan struktur yang tinggi kepegunan dan ringan. Keputusan penilaian ketahanan adalah penting dalam mempertingkatkan reka bentuk casis pada fasa pembangunan. Hasil keputusan juga dengan nyata sekali mengurangkan kos dan masa membina casis semasa hari acara dan meningkatkan kepercayaan pengguna.

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LIST OF SYMBOLS

F	Forces
P	Pressure
σ	True stress, local stress
δ	Displacement magnitude
ρ	Material density
v	Material volume
A	Cross sectional Area
D	Diameter of the pipes material
t	Thickness

LIST OF ABBREVIATIONS

AA	Aluminium alloy
FEA	Finite Element Analysis
SEM	Shell Eco-marathon
FYP	Final Year Project