

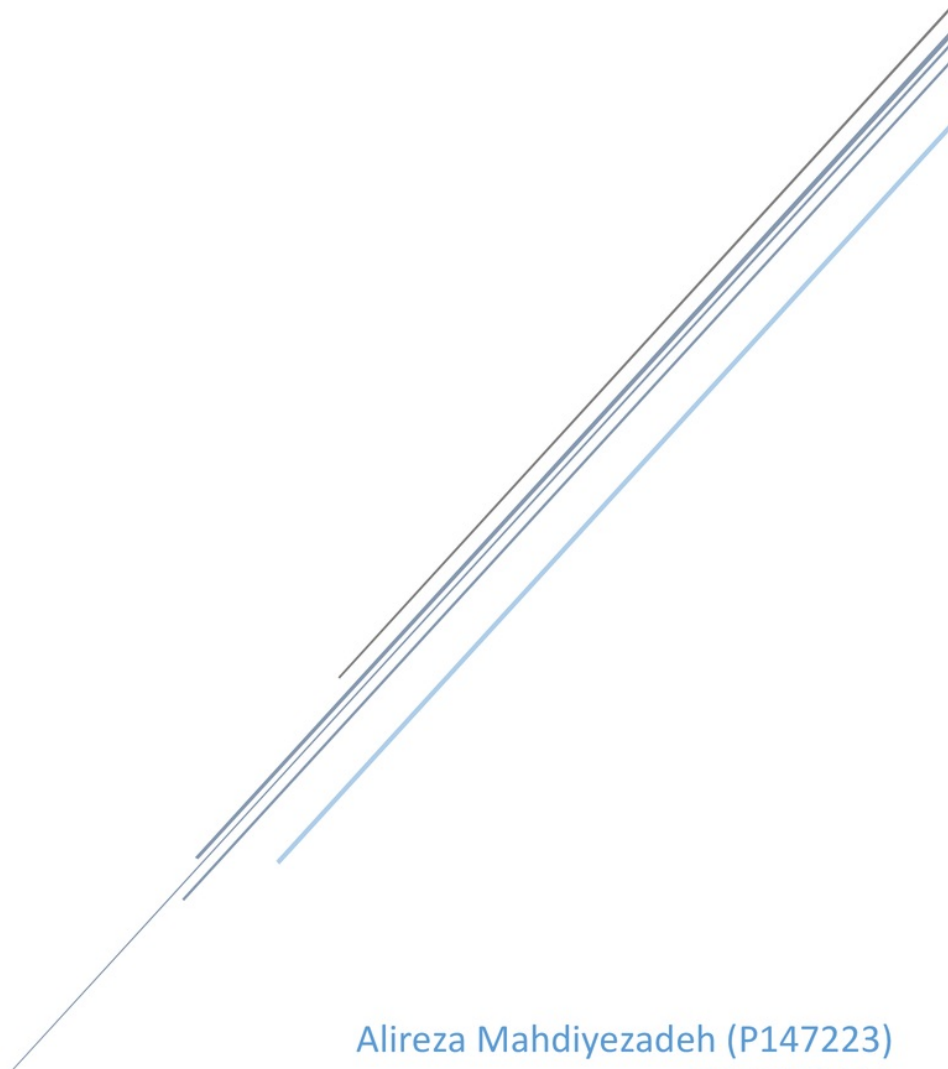
Final report

by Alireza Mahdiyezadeh

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REDESIGNING A SUSPENSION UPRIGHT FOR INCREASE
THE VOLUME FOR THE CHINESE MARKET

M6X00417



Alireza Mahdidezadeh (P147223)
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Table of Contents

1.0 Introduction:	4
2.0 The UK car manufactory:	4
3.0 Famous British car brands and volume:.....	5
3.1 Arash:	5
3.2 Cars volume in the UK been produce from 2011 to 2017 at the end of each year.	6
4.0 Chinese car manufactory:	7
5.0 Chinese high volume car producer:	8
6.0 List of the most popular Chinese car companies and brands:	9
6.1 GEELY:	9
6.2 CHERY:	9
6.3 HONGQI:.....	9
6.4 BRILLIANCE AUTO:	9
6.5 BYD AUTO:.....	9
6.6 SAIC MOTOR:	9
6.7 DOMGFENG:.....	10
6.8 FAW GROUP CORPORATION:.....	10
6.9 BAIC GROUP:	10
6.10 GAC MOTOR:.....	10
6.11 JAC MOTOR:	10
6.12 FOTON MOTORS:	10
6.13 WULING:.....	10
Vehicles volume has been produce in china from 2008 until 2018:.....	11
7.0 Take the low volume to high volume and corporation between the UK and china:	12
8.0 First term Project tasks and Gantt chart:.....	12
9.0 Methodology and design:	13
9.1 Manufacturing process:	13
10.0 Methodology and design process:	13
11.0 Physical test:	14
12.0 Original suspension upright FE model:	15
13.0 Packaging space:	15
14.0 Topology optimization by design studio:	16
15.0 Design the upright on CAD (solid works):	18
16.0 Final FE model of the final design, original design and test:	19
17.0 FEA results and percentage different at each point:	27
17.1 FEA and analyse:	29

18.0 Final FE model and Calculations:	29
19.0 Final FEA and result:.....	30
20.0 Material:.....	31
20.1 Magnesium:	31
20.2 Cast iron, ductile:	31
20.3 Aluminium alloy:	32
20.4 Three different possible material for upright manufacturing:	33
20.4.1 Different aluminium choice:	33
20.4.2 Aluminium alloys group:	35
21.0 Manufacturing technique:	35
21.1 Hot close die forging:	35
21.2 Moulding (compression) or squeeze casting:	36
21.3 Casting (centrifugally – aided):	37
21.4 Sand casting:	38
21.5 Lost-wax casting:.....	39
22.0 Manufacturing process for the original upright:	40
23.0 Manufacturing process for new designed upright:	41
24.0 Manufacturing cost of the original model:	42
25.0 Cost of the new model manufacturing and analysis:	43
26.0 Second term Gantt chart.....	44
27.0 Further work:	44
28.0 Issues and problems:	45
29.0 Conclusion:.....	45
30.0 Bibliography	46

List of figures:

Figure1: Aston Martin Vantage.....	5
Figure2: arash automotive.....	5
Figure3: The UK car volume.....	6
Figure4: Wuling 7 seater.....	8
Figure5: Chinese car manufacturing production volume.....	11
Figure 6: rigid for the test.....	15
Figure 7: packaging space model.....	16
Figure 8: designable and non – designable region.....	16
Figure 9: 30percentage mass of material.....	17
Figure 10: 13percentage material mass.....	17
Figure 11: 9 percentage material, final structure model.....	18
Figure 12: structure of the model included the attachment points.....	18
Figure13: suspension upright design.....	18
Figure 14: final suspension upright design.....	19
Figure 15: original and final model FE model displacement.....	30
Figure 16: Young’s modulus against cost.....	31
Figure 17: Fe-c (Iron-Carbonyl) phase diagram.....	32
Figure 18: aluminium silicon vs temperature phase diagram.....	32
Figure 19: aluminium.....	33
Figure 20: magnesium.....	33
Figure 21: cast iron- ductile.....	33
Figure 22: close die forging on rod.....	36
Figure 23: compression or squeeze casting moulding process.....	37
Figure 24: centrifugal casting.....	37
Figure 25: sand casting process.....	38
Figure 26: lost-wax casting.....	39

1.0 Introduction:

This project is to compare the Chinese car market to the UK car market and take action to produce the suspension upright with higher volume and a cheaper price in China. Different country and car manufacturer has its own strategy to produce the car component or even vehicle. For some of the manufacturing quality is the main thing and for the others quantity but it can be more interesting to find out how to quantity can be reduced while the quality is the same or even better. The main strategy of this project is to reduce the quantity with different manufacturing technique and design with controlling the quality and lighter component. In this project suspension upright will be redesign to take the model to the stage to use the lower amount of material. The material will considered for the stiffness and weight result as it can changed with different material and at the end manufacturing technique will be analysed. To take the suspension upright to the Chinese market with produce the higher volume manufacturing technique need to consider as the models can have different cost and volume of products with different manufacturing technique. Different manufacturing technique cost per model and unit can be produced per day will be a list at the end of this result. A student with using the different software and research collects all the information about this project. This report will be submit in Moodle and handed as two hard copies to the supervisors. At the beginning of this report, Chinese and British car manufacturing and the market will be introduced and compare the production volumes, therefore, the possibilities of producing the suspension upright with volume will be considered in the Chinese market.

2.0 The UK car manufactory:

The UK has the biggest number of car manufacturers in the world, as the most famous car manufactures called Aston Martin, Lotus and McLaren. From the past until now, some of the UK car companies has carried and provide the new and higher technology as part as motorsport notably light weighting and higher efficient power train and safety. Therefore, this element and high technologies have carried out the higher price of manufacturing and the final price of the cars and parts and the volume of them gets low and lower.

Based on 2017 SMMT on 2016 special car manufactories had around 3.6 billion pounds' specialist turnover, around 11.000 has been employed and 2000 cars have been made which is more than half that has been expecting in the world and will be expected to grow to 50.000 units by 2020.

UK special car manufactories are in the global marketplace and exporting the product around the world markets such as EU, US, Japan, MIDDLE EST and China.

Small volume manufacturers are increasing the products by 21% in 2017 compared to 2016. Some Absolut element has incrustrated as expected in lower volumes but some elements are decrees like fuel because of the higher number of the power train in the new cars. (SUSTAINIBILITY, 2017)

Social of motor manufacturers and traders limited (SMMT) car manufactories result:

- Had a combined annual turnover of almost 2.5 million pounds
- Employed around 10.000 stuff and specialist
- Made 25.000 vehicles a year
- Export over 70% of the product
- Bentley and Rolls-Royce motor cars have been exported over85%
- Over65%of the car specialist been scored in the Uk

(SMMT, 2017)

3.0 Famous British car brands and volume:

Famous British car brands are low volume, as the companies increase the quality and safety factors volume will decrease and the price will be increased, so the base of these manufacturers is to produce the unique and luxury product with low volume.

Aston Martin is one of the famous British car brands that has been built from mid-90th and hand it over the market and countries called (US, Kuwait, Italy and Ford) and also MG which is at this time (SAIC, China) manufacturing this brand (borro, 2014)



(Clarkson, 2018)

Figure1: Aston Martin Vantage.

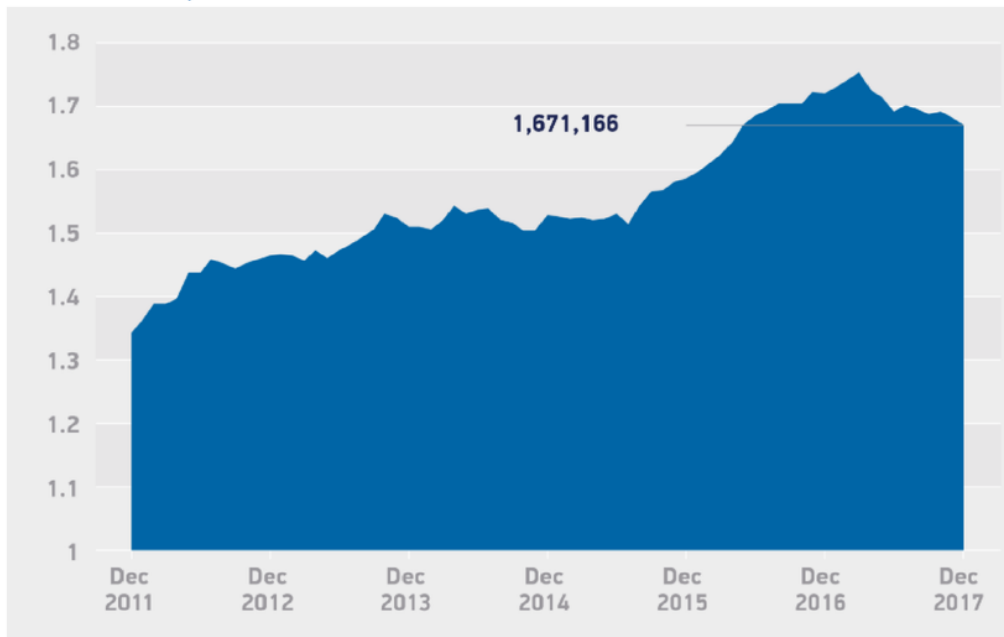
3.1 Arash:



Figure2: arash automotive.

AF10 and AF8 are the best example of the lowest volume car in the UK with prices of £320 K and £168K excluding the options as originally establishing by Arash Farboud in 1999 and called Farboud limited. From 2006 the name has been changed to Arash Farboud and first car this company has been producing it was Farboud GT at 2002. After Arash made AF10 he think to take the product to the higher volume so he designs the AF8 as less complex chassis and bodywork as (carbon fibre-honey corn and again Carbone fibre) with a smaller engine so reduce the price to take the AF8 to the higher volume in max 3 cars a year. (Arash, 2018)

3.2 Cars volume in the UK has been produce from 2011 to 2017 at the end of each year.



(Hawes, 2018)

Figure3: The UK car volume.

4.0 Chinese car manufactory:

To making the product and take them to the international market China has the biggest number in the world after the US. China made itself a bigger and stronger with a lower price of product, China by 1990 produced 3% of product at the global market but at this time 80% of the air-conditioner and heating system, 70% of mobile phone and 60% of the shoes in the world and also 50% of the cars and car parts in Asia. China has been followed the success of the countries such as Japan for electronic technology and quality and South Korea or Taiwan to increase the number of products and sale. (Bacon, 2015) how to improving the product, how to take a reaction if the first design has been failed and how and what is the best way to introduced to the international market and where to take it is the biggest questions between Chinese markets and manufacturing as they trying to improve the operation so that they can get maximum efficiencies that mean design, carefully and steeply choosing the proses it based on what kind of job need to be done to get the best result, again all about to have bigger efficiencies. (shih, 2018)

To looking for low cost and higher volume China is one of the best countries as many manufactories producing the product. To take the products to the higher volume the biggest issue will be quality as the lower cost and higher volume quality will be lower, but to sort quality problems any type of product need to have quality check and quality series to confirm that the product is ready to sale or export, quality services need to be include:

- Supply Chinese manufacturing management
- take the risk to zero or (risk-free)
- be second management of the factory as the quality check team
- logistics coordination
- sound product design
- laboratory testing and certificate
- Access to the product line that the company making
- Access to the raw material for the quality check
- final check for the entire product and certificated (c2wgroup, 2018)

One of the biggest examples of the car manufacturers take action to the chines market to improve the sale and volume is BMW. Company in China called BMW AG. to start BMW became a partner with a company called BRILLIANCE automotive group in China as they plan to increase the volume in 2019 to 520.000 cars, BMW joined the valentines with Brilliance to improve the all car models including 1, 3 and 5 series and also x1 sport and x3 SUV to better plane as electric version. The electric version of the cars is the biggest plan of the cars companies from 2025 to 2030, to save the world. Biggest and one of the best country in the world is China as they are a world leader in electric cars planned by 2030 to increase to over 10 million cars. Large numbers of car manufactories making the relationship with Chinese electric engine or electric car companies to take higher advantage of having an electric engine on their cars. (Tian, 2018)

5.0 Chinese high volume car producer:

One of the larger numbers of business in China is car manufacturing and companies related to, as the president of China XI JINGPING open the foreign manufacturers to have a chance and opportunity to improve their product and take it to the larger volume of manufacturing and sale in the Chinese market. (Tovey, 2018)

The Chinese market has been growing and improving their product from long years ago but the market has a successful from 2008 with 2.76 million car sale a year until 2017 with 24.72 million cars sell so Chinese car markets had a successful and fastest growing state around the world. (Greenfield, 2018)

Four main facts of Chinese car markets are:

- Innovation (technology / business model / power)
- Green cars (new energy / saving power / green business / promotion)
- Globalization (increase Chinese product and supply the world market)
- Collaboration (save market and cheapest product)

(Martin Tauber, 2017)

Over 30 car manufacturers are producing the high quality and cheap product to the Chinese and international market in 2018. China has the biggest car market in the world, Wuling Hongguang is the mixture car brand of General Motors and Shanghai Automotive Industry Corporation and Liuzhou Wuling Motors. This Chinese brand has most sell in China and popular in the international market in 2016 with the number of 650,018 vehicles and the price of £4700 to £7750 it depends on option per car been sold.



(Haj-Assaad, 2018)

Figure4: Wuling 7 seater.

Best Chinese car brand sale in 2017 was CHANGAN Company with a number of 1,055,096 car sale in all models.

China until 2008 was the biggest bicycle and bike country as for example the numbers of the car in Beijing was one car for every 10 bikes but after 2008 until 2017, car companies' growth really fast as the car manufacturers produce road cars such as luxury, sedan, SUV, van and sport road cars then China

has entered US market and take place there to export and import some product. In 2017 chines, cars took over 60% of the local place and most of the other percentages were German, Japanese and American cars. (brands, 2017)

6.0 List of the most popular Chinese car companies and brands:

6.1 GEELY: GEELY means lucky in mandarin is present from 1986 in Hangzhou, GEELY produce a large number of the car, motorcycle, transmission and different engines as they start manufacturing bikes in 1994, they producing the safest and higher quality version of models in China, as following: MK, CK, GC7, GC5, GX2, GC2 and MK cross with 1.24 million unit sale in 2017 and break the record with increase of sale compared to the following years as 63%. (ORG, 2018) In May 2017 GEELY, start to take 51% of the lotus and become the owner to increase the number of cars and sale to the Asia and African car market.

6.2 CHERY: CHERY is present from 1997 in Wuhan, China and top 5 successful and so far the best car manufacturer in China. This company has grown and increased the number of sales in China and international market fast as at last 9 years they hit a number of sale in China and export to more than 80 countries such as Eastern Europe, Africa, Asia and the Middle East. Chery produces van, SUV, and sedan as a luxury model such as x1, A18, QQEV and over 15 different models. Number of sales in 2017 was 680,000 model and numbers of sale been decreased by 3.5% compared to the following years. (Tony, 2018)

6.3 HONGQI: company present from 1958 in Changchun, China. HONHQI producing super luxury and comfortable Chinese cars that call them in China high class. Most success year of the sale of this company was 1981. Now they are going to start to release the self-driven car and will produced soon as the traffic test has done. HONGQI produce the model call HQ3 seems to be reminding of Bentley with high-class design, they sold 2.534 cars in 2013, and they said will showing the big surprise soon. (Xinhua, 2017)

6.4 BRILLIANCE AUTO: the company is the relationship of China with America in the parts and present from 1991 Shenyang, China. The company was producing the bus production in the past but at this moment they producing the sedan and small cars to Chinese and international market as the models of H320, M1 and FRV and the manufacturing line of bus and mini-van has stopped and sold to the company called JINBAI Marque. The company sold 101.317 units in 2017 with a number of sale increase 0.42%. (He, 2018)

6.5 BYD AUTO: not old but successful as the company been present from 2003 and produce the cars with multiple models as compact, hatchback, MPV and SUV. Company had following up-to-date technology from first day as producing the car with closest international market until now. They are on top of the list of the big sale in china and global market present at all the countries with electric cars and engine product, and sold 108.612 in 2017, as they have been slow at the beginning of the year and top of the electric car sale in china and third level in the world. (KANE, 2018)

6.6 SAIC MOTOR: present from 1955 one of the oldest car manufactory in China in Shanghai, China. Company was in the same level as MG and they produce the must professional sport road cars and luxury vehicles in China and joint ventures with GM, VW and VOLVO. Very big unit sale in 2017 with a number of 5,478,566 and very successful in the international market. (motor, 2018)

6.7 DOMGFENG: this company is on the list of four biggest companies in China and present from 1969 in Wuhan, China. A company is famous as producing the consumer and marketable vehicles in China such as Lorries, buses, joint the ventures all around China, and has manufacturing in the UK, Phillipian and Vietnam. Passenger cars became series to increase the production and lines in the last 8 years and had a 4,120,000-unit sale in 2017 with 12% increased. (Aurora, Dongfeng Motor sees 4,120,000 sales in 2017, 2018)

6.8 FAW GROUP CORPORATION: first Chinese state-owned manufacturer and specialises in a part of the cars present from 1953. Buses and heavy-duty trucks are been made from the past until present and export. The main part of the company is in Changchun with over 2 million sales in 2017 and been made in 36 different cities in China soon to increase the numbers of cars and product. (Mary, 2018)

6.9 BAIC GROUP: a state-owned company in Beijing, China presents from 1958 and produce commercial and passenger cars. This company has a big and long history in the past until became top ten and strong car manufactory in China and finally hit the numbers of the sale as its own of 2.25 million vehicles in 2014 and in 2017 company listed as a 4th largest company in China. (Heyi, 2017)

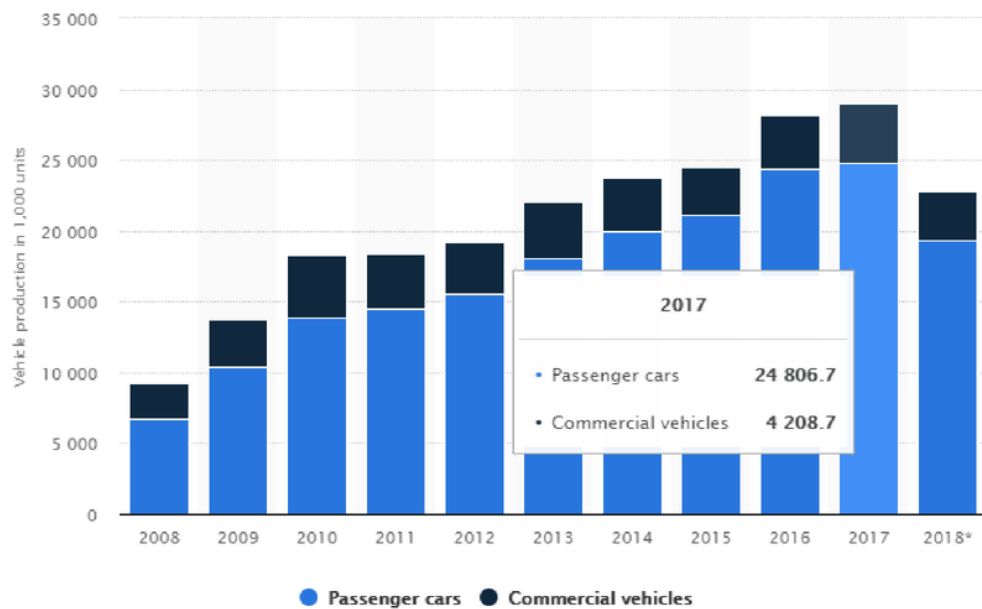
6.10 GAC MOTOR: another state-owned automaker car company in Guangzhou present from 1997 is GAC motor. Company sales, passenger cars and commercial vehicles called Gonow. The company introducing the most reliable and fuel-efficient SUV's in China with 508,600 unit sale in 2017 so the most efficient model was a jeep model with 200,000 unit seal of the total which is 508,600 cars. (Amanda, 2018)

6.11 JAC MOTOR: the main name of the company is Anhui Jianghuai automobile corporation and also famous for SUV's and trucks as in 2012 company produce more than 445,000 vehicles and from that time they have been listed on top 10 manufactory in China and increased to 510,400 unit sale in 2017. (Aurora, JAC Motors 2017 net profit slumped YoY 62.83% to RMB 432 million, 2018)

6.12 FOTON MOTORS: popular manufactory in china as they producing buses, trucks and sport utility vehicles and present from 1996 in Beijing, China. The 2011 was the golden year for this group as they sold 640,000 vehicles and made them one of the most popular companies in china.

6.13 WULING: Wuling been found in Hong Kong around 2007 as a multiple car company. They are support by GM and SAIC motors. Wuling is specials in small MPV's with a record of 650.018 sales in 2017 and also top 1 of the best sale in China with a model of Hongguang.

Vehicles volume has been produce in china from 2008 until 2018:



(Stipp, 2018)

Figure5: Chinese car manufacturing production volume.

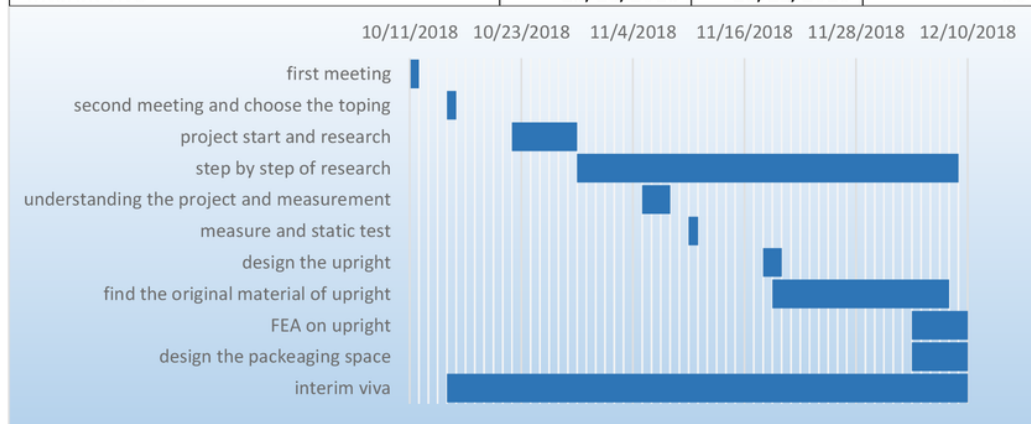
Main strategy of Chinese car manufactory is to produce the product with high quantity and standard quality while lowest cost as possible to take it to the local and international market therefore, this is the main reason that Chinese car manufactories are mostly high quantity.

7.0 Take the low volume to high volume and corporation between the UK and china:

At the end of the year in 2017 1.67 million cars has been made in the UK and British engine had a 6.9% increase compared to 2016 with a number of 2.72 million units in 2017. Around 24.8 million passenger cars and 4.2 million commercial vehicles been made in China in 2017 so totally 29 million vehicles have been made in 1 year in China, which is around 17 times more than UK. Numbers cannot explain the quality and price but if the quality need to compare numbers of similar quality of the Chinese cars are 2 times more than the British cars with around half price. for example number of all models of lotus has been made in the UK at 2017 was 783 vehicle which is more than 90 cars less than 2016 and around 0.01 per cent has been share to the international market. Lotus models named Elise, EXING and EVORA and the prices are from 30 to 60 thousand pounds it be contingent of models. Car companies are growing fast in China and producing new technology with all the models and the lowest price. In the international market at end of 2017 company called ARCFOX in Beijing produce the new small sports car with two motors of petrol and electric in China with the maximum price of 20 thousand pounds and it is a most similar model of Lotus cars. (sun, 2017) As time is change, cars are not only for transport. actually most of the young people looking at hobbies and sport, one of the new sports cars it is on the way to produce are Zen track, Zen track can be a race car or two-seater road car and the still of the car can be concept and cooper. As it has proven, Chinese car manufacturing strategy will based on cheap and high volume, therefore, the main plane is to take the Zen track to the Chinese market with lower price as the UK and quantity of 50.000 cars a year.

8.0 First term Project tasks and Gantt chart:

Task	Start Date	End Date	Time duration
First meeting	11/10/2018	12/10/2018	1
Second meeting and choose the toping	15/10/2018	16/10/2018	1
Project start and research	22/10/2018	29/10/2018	7
Step by step of research	29/10/2018	09/12/2018	41
Understanding the project and measurement	05/11/2018	08/11/2018	3
Measure and static test	10/11/2018	11/11/2018	1
Design the upright	18/11/2018	20/11/2018	2
Find the original material of upright	19/11/2018	08/12/2018	19
FEA on upright	04/12/2018	10/12/2018	6
Design the packaging space	04/12/2018	10/12/2018	6
Interim viva	15/10/2018	10/12/2018	56



Project has been done for the first semester and systematically has been followed to the last step but it ended up with some issues. Time for each task expected has slightly changed as understanding the packaging space and packaging space design took longer to be done and student had to take it over the second semester to be done and physical test and FEA on the original model has been repeated in the second semester.

9.0 Methodology and design:

Numbers of possible ways are available to redesign the suspension upright to make it lighter therefore cheaper. One of the ways is to take the original to the solid works software and make the FE model of the original design. When the results are shown part of the model that has extra material usage can be cut off and again repeat and repeat the test until it gets to the last stage and having the lighter and also stiffer component compared to the original component. This method does not give the accurate result as in most of the cases designer needs to spend more time as the other method and not having the ideal result and of course, time is money so more time will cost more. The second method is to design the new component from the beginning while calculating the forces and it can be possible with topology optimization. In this method, the designer can have the structure and basic shape of the model because of the topology optimisation result, take the result to solid works, and design the new model so less time will be spent on the design and accurate result in most of the cases. Meaning of the accuracy in the second design process is that design studio software will calculate the forces where they will be applied on the model and shows that which part of the model needs X amount of material, therefore, the designer will be aware of designing the component correctly. There are two things important in the second design process, first is software need to learn to use and run and the second thing is the cost of software. In this project, the second design process will be considered.

9.1 Manufacturing process:

1. Suspension upright design.
2. Material.
3. Manufacturing technique.

10.0 Methodology and design process:

The first action of having the cheaper component is to take the suspension upright to the lighter model. The method used for this action is to use the topology optimization to find out how much material and at which part of the model needed to design the new component with lower material usage. To use this method a few stages need to be finished and measured so will be listed from the beginning until the end:

1. Physical test of the suspension upright to measure the displacement.
2. Take the original CAD model and make the FE model of the upright.
3. Create a packaging space for the new design and topology optimization.
4. Set the packaging space in the design studio software and create the Non – designable part.
5. Run optimize the model in design studio software.
6. Take the final model into the CAD to design the new suspension upright.
7. Repeat the FEA for the new design.

8. Consider the manufacturing techniques and materials to find out the costs of the new model and compared to the old model.

All the steps will be explaining, why and how it needs to be.

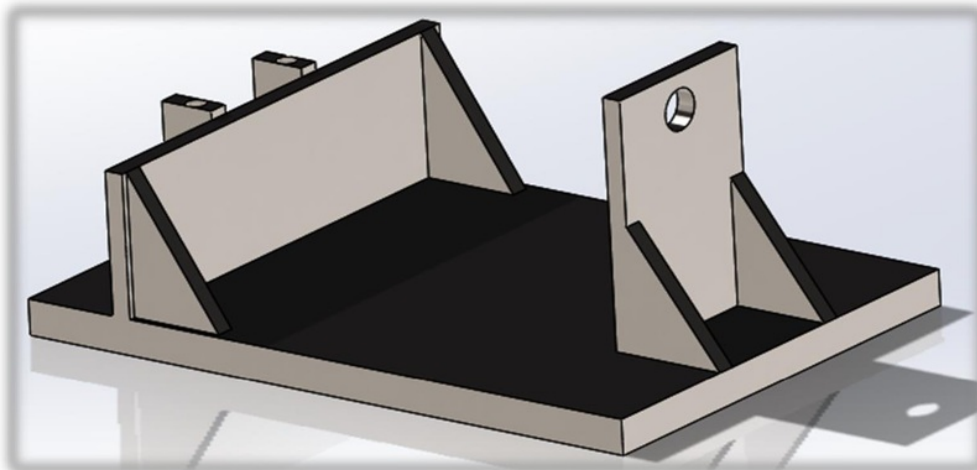
11.0 Physical test:

The material of the original suspension upright model has not been clear to make the FE model therefore, the first choice was to find the displacement of the original model by doing 21 physical tests at the 7-attachment point then take the result to FEA and repeat the test with different materials on FEA and then compare the result. The must closest results will show the material of the component and the FEA result need to save for the final stages to compare with FEA result of the newly designed component.

Materials and tools needed for the test will be:

1. DTI to measure the displacement.
2. 10 N force as a weight.
3. Clamp to set the model and rigid to the solid place or solid table.
4. Rigid to set the model on and clamped to the solid table.
5. Metal hanger.
6. Roller or Vernier.
7. Scales to measure the weight.

In this stage, the model has tested and reputed 21 times for the X, Y and Z direction at 7 points. Each time the place been clamped, fore has been applied and the place that DTI has been set up has been taking the pictures to set the FE model the same. For this test, 100 N equals 10200 grams' force been applied at each point, measure the DTI result, and save them for the next steps and compression. Rigid or model stand made by a workshop supervisor and set up for the test by the student.



(paul, 2018)

Figure 6: rigid for the test.

(X, Y and Z) test at each point will be posted as figures with the FEA results at the end of the design process and also data will be listed at the end of the design process as stiffness result for compression:

12.0 Original suspension upright FE model:

Finite element analysis is the test that can solve any engineering problems. This method of test in engineering call FEA and mostly been used by the soft wear called solid works. FEA test is taking the result, as three part to analyse as they called analytical method, which is the results, are 100 % accurate, results been closed from solution and result are completed itself. The second part is a numerical method, which finds the problems and takes them to the real-life problem and solve them and results are solving by mathematical solutions. The third part is an excremental method, which is measurement, can to be actual to get the actual result and the time needed to run and cost of the soft wear. FEA can solve the problem, test the component before manufacturing, therefore, save time and money but soft wear cannot use unless learn, and train how to use it can be the only disadvantage of FEA. (Gokhale, 2008)

FE model has been creating for the original model at 7 points and (X, Y and Z) at each point. Model has been set up and loaded exactly same as physical test to get the result and use the result as it mentioned earlier for two facts, first is to find the right material of the original suspension upright and second is to save the results and compare them to the final design FE model. To run the model in FEA first, material need to be chose and next step is to set the model and fixed the same as the physical test, next step is to apply the load which, is 100 N exactly same place as physical test has been done and mash the model to make it ready for the run. Mash can be done at small and large element so smaller element can give a more accurate result as large mash and also at smaller mash time will be spend compared to the large mash. Model is ready to run now and displacement result will collect to calculate and find the stiffness result at each point. Stiffness result and FEA figures are will forward at the end of the design process to compare with final model results

13.0 Packaging space:

To run the topology optimization available space for the new design and attachment points are need to be design. Available space in this case called packaging space and need to be create in CAD.

At this part of design process, assembly of the zen-track suspension has been setup on solid works soft wear and create the tube as dimensions of inner alloy wheel then subtracted all the part apart from upright from the tube and create the packaging space. Mash the packaging space model and chose the material will done in following step. Which is aluminium alloy 6061 for it and save it as a Nastran file to run it in the design studio (Genesis) soft wear.

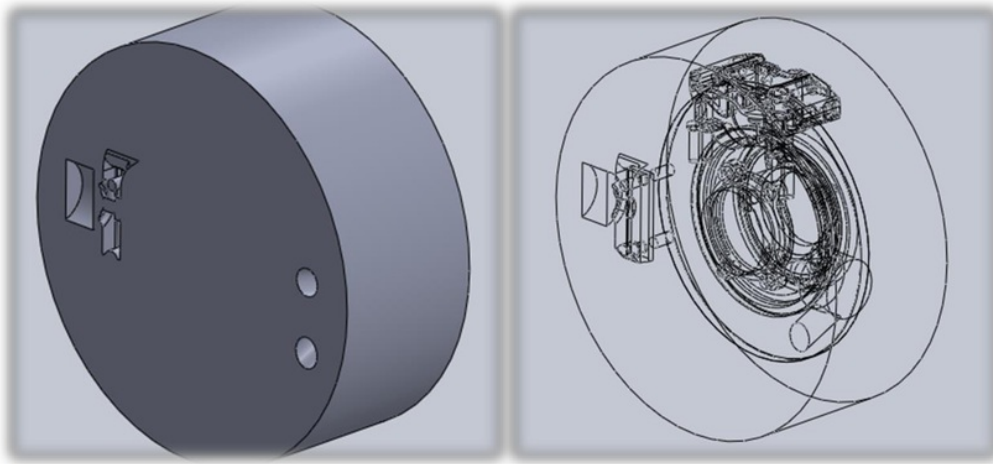


Figure 7: packaging space model.

14.0 Topology optimization by design studio:

Topology optimization is the method that calculates the loads are applying on the model and will result that how much mass of the structure need to be for the model and where the element and material need to be to create and design the model. The main reason for doing this method is downsizing and find the shape and structure of the model while the force is applying on the model. Structure of the model is the result of the topology optimization therefore; it needs to transfer to the design soft wear to design the model with the lowest material as needed for the component. Eiffel tower is one of the famous structures has been created and made by this method. There is two big disadvantage of doing this process is the final structure and result are too complex to be as a model to manufacture and the second one is that soft wear need to be trained and fully learn to use. (Sigmund, 2003-2004)

The first stage of running this soft wear for the new model is packaging space has been inserted to the design studio soft wear, by using the packaging spaces non-design model has been creating as green colour as it will show in the figure number 8.

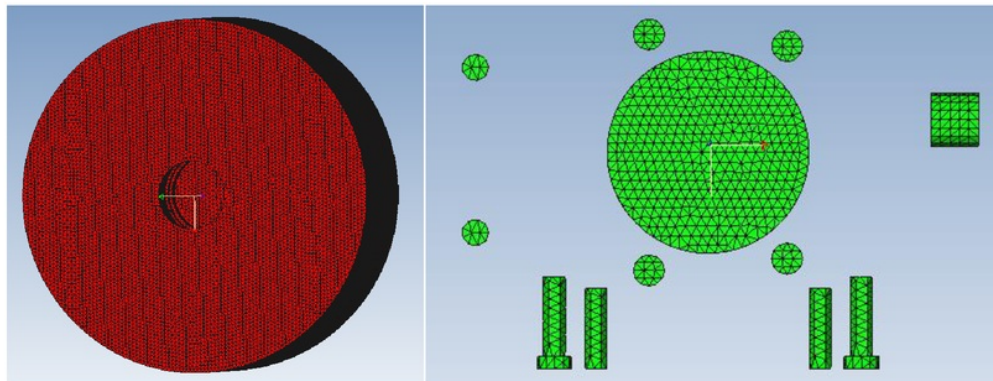


Figure 8: designable and non – designable region.

The next step is that bearing need to be set as a fixed place then apply the loads on all 7-attachment points in three directions. Next step is to take the design to the first order and set the optimization mass to the different percentages to get to the structure of the suspension upright. In this case, mass

has been set up on 30 % material and then reduce to 20 %, 13% and finally 9% to get to the stage that the minimum mass of material needed to build the new model. The following figure is showing the structure of the model, where the material needs to be in 30 % mass. As it shows in figure nine, the mass percentage of material used to build the model more than what will expected to test needs to redo with a lower percentage.

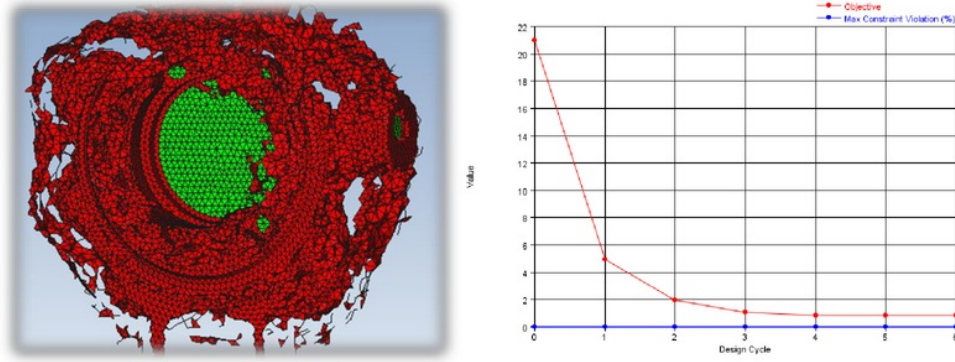


Figure 9: 30percentage mass of material.

Following figure in showing that 13% material mass has been used to create the structure but result is showing that model has been used large amount of material even more material as it is on the original model of suspension upright therefore test need to be repeat with lower percentage.

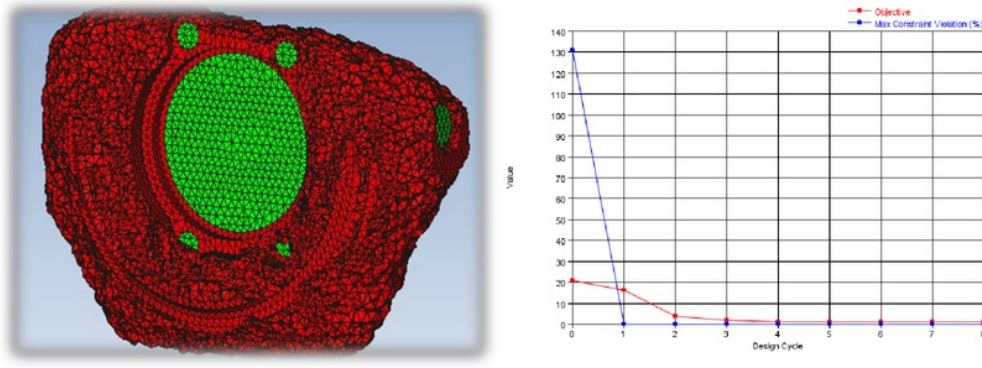


Figure 10: 13percentage material mass.

The Test at this step by using 9% of material from 30% mass has done to get the structure of the model. The structure has been resulted for the model used 9 % of the mass and will use as a structure to design and create the new suspension upright and will show in figure number 11. The red colour is proving of the structure for the new model and will insert into the solid work soft wear to design the new suspension upright.

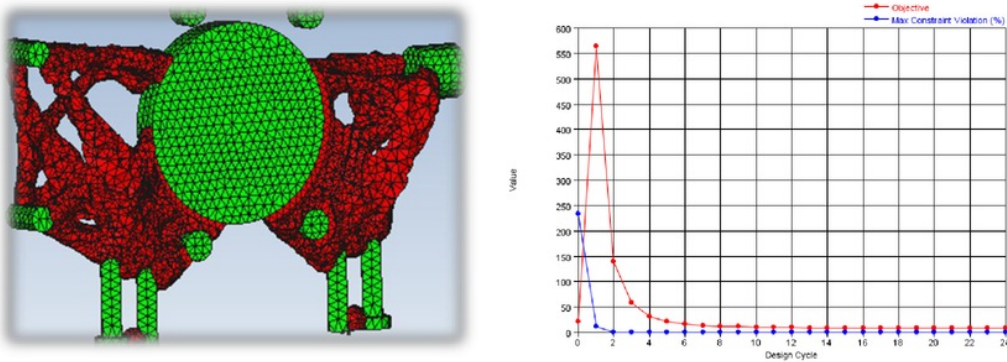


Figure 11: 9 percentage material, final structure model.

15.0 Design the upright on CAD (solid works):

The structure been inserted into the solid works; therefore, attachment parts need to be inserted in to continue the design. At this step from the original suspension upright model, attachment points been cut and insert into the structure design file and it is proving in the following figure. As it, shows in the following figure student followed how much and where exactly materials need to be place for the model and designed the new suspension upright.

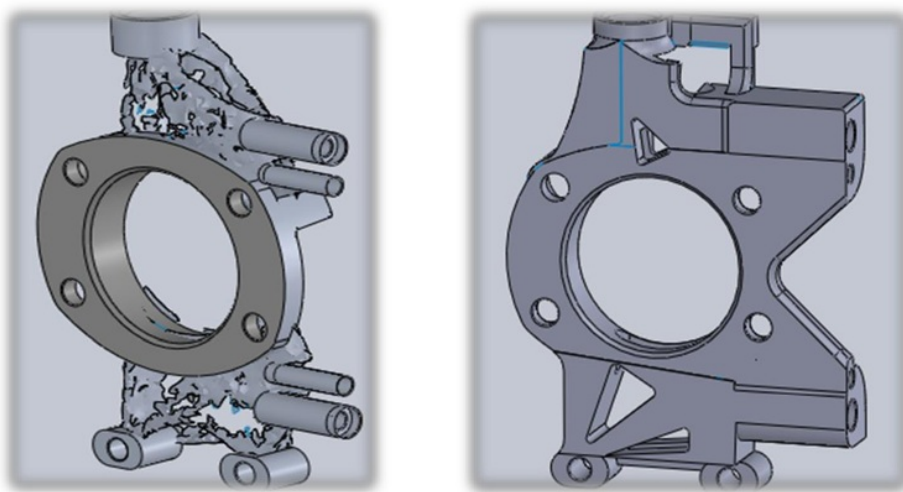


Figure 12: structure of the model included the attachment points.

Figure13: suspension upright design.

The first thing in the design is that student try to design and put the material exactly what it has been shown in the result of topology optimization. Biggest disadvantage of the designed model is that the model will have a high cost to manufacture the model and the main idea is to reduce the cost to have a cheaper model. Therefore, design needs to have some change to be easier and cheaper to manufacture. The second design been done to solve the manufacturing problem and it shows in figure 14.

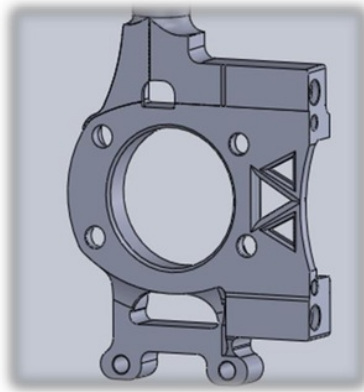


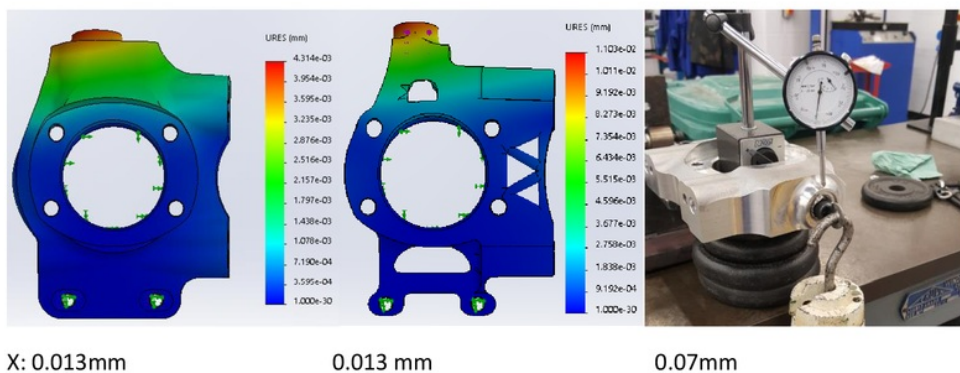
Figure 14: final suspension upright design.

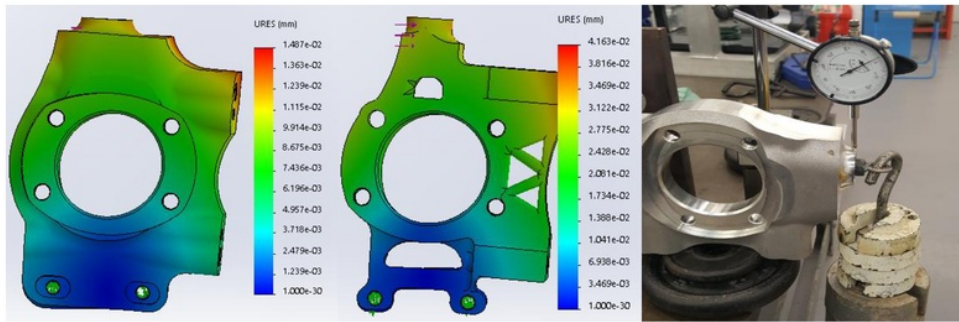
In this design, the student tried to measure the parts and thickness and then instead of having a big gap in the middle of the new design set the model as a solid part with lower thickness but bigger surface to have ideal result, easy and cheap manufacturing process.

16.0 Final FE model of the final design, original design and test:

To make sure that newly designed suspension upright has a good or closest result as the original model while reducing the weight, FEA needs to do for the new designed upright with the same principle as the old model (fixture, load, mesh and place of data reading). following tables and pictures are proving that stiffness is at some point lower and in some points are higher but the main thing is even if they are lower the changes are not the big numbers so this design can take future for the final test. Stiffness results has been calculate and shows in the tables in the next following steps but original FEA tests are inserted in next steps as the prove document.

Original Fe model vs new FE model: Displacement at X, Y and Z. Lower wishbone.

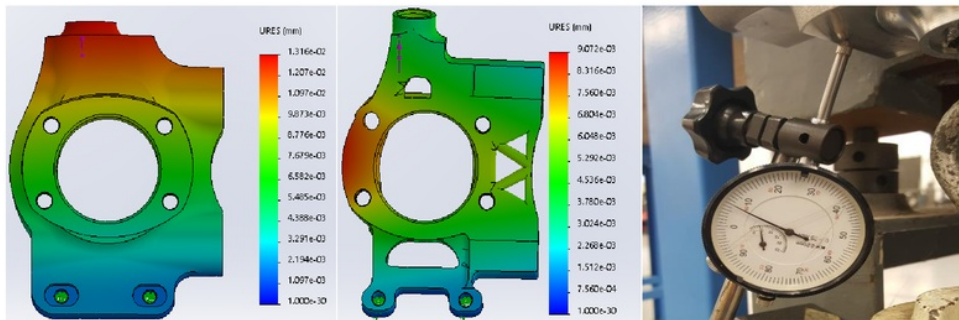




Y: 0.015mm

0.042mm

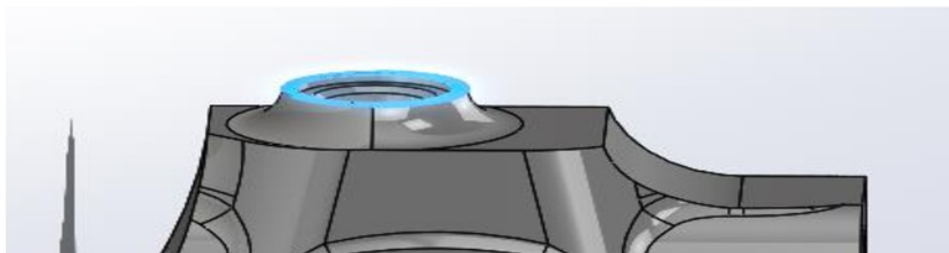
0.022mm



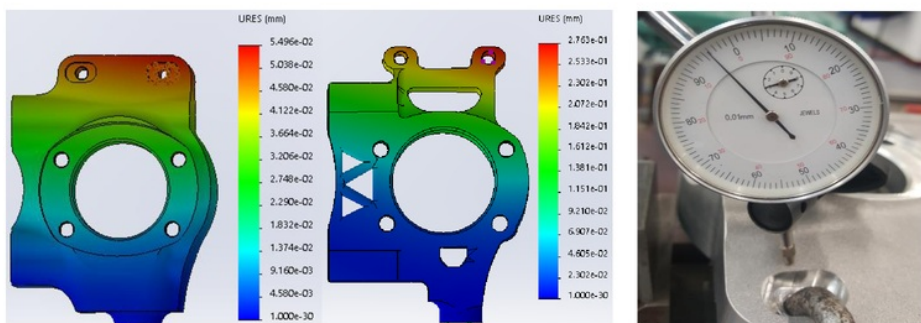
Z: 0.0043mm

0.009mm

0.0042mm



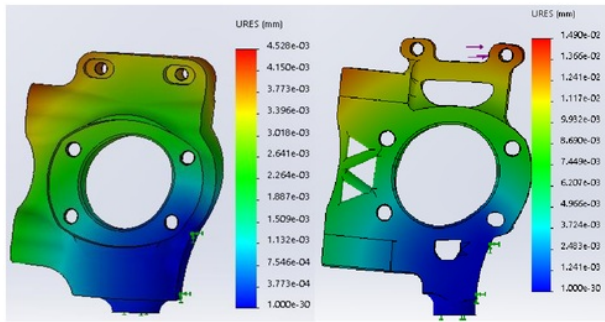
Upper wishbone: X Y and Z from top to the bottom. Right side.



X: 0.055mm

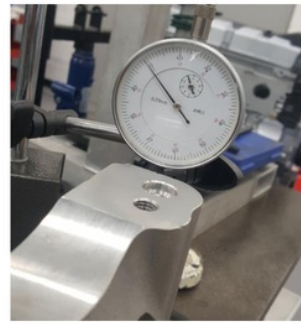
0.0276mm

0.041mm

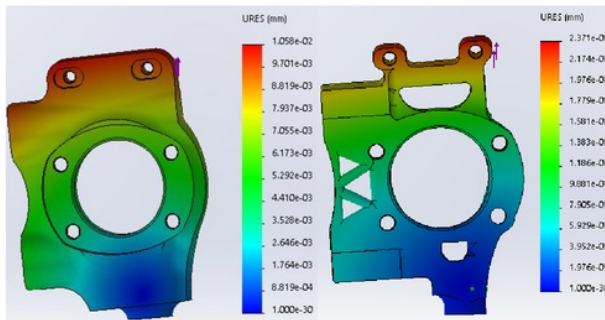


Y: 0.0045mm

0.015mm



0.008mm



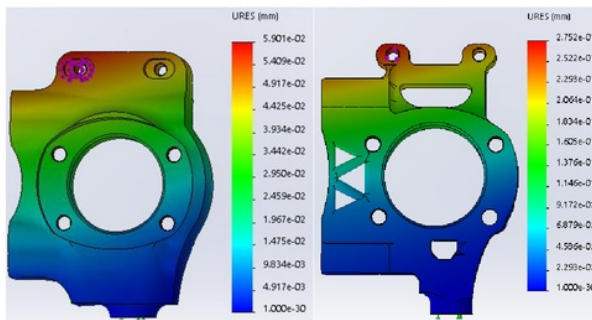
Z: 0.01mm

0.024mm



0.040mm

Left side.

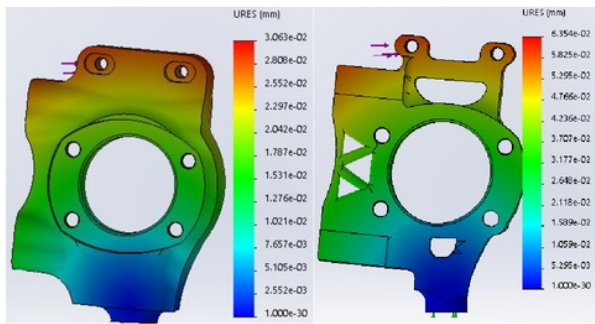


X: 0.059mm

0.28mm



0.045mm

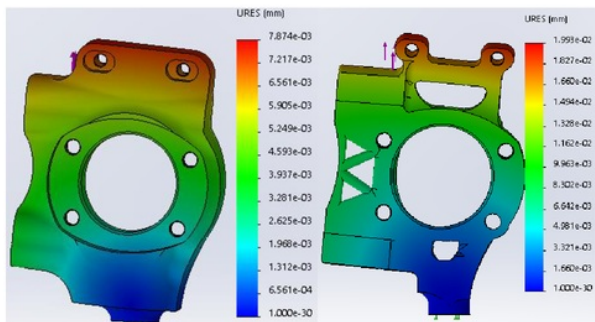


Y: 0.03mm

0.64mm



0.01mm



Z: 0.008mm

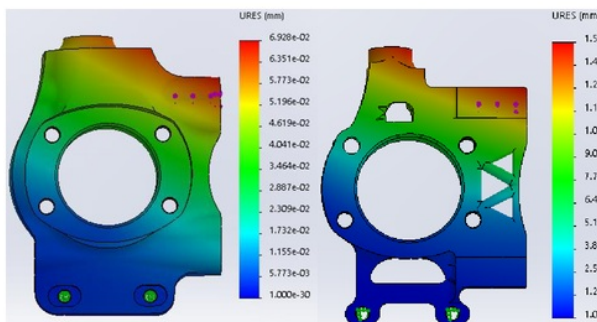
0.02mm



0.008mm



Brake area by lower: larger point.

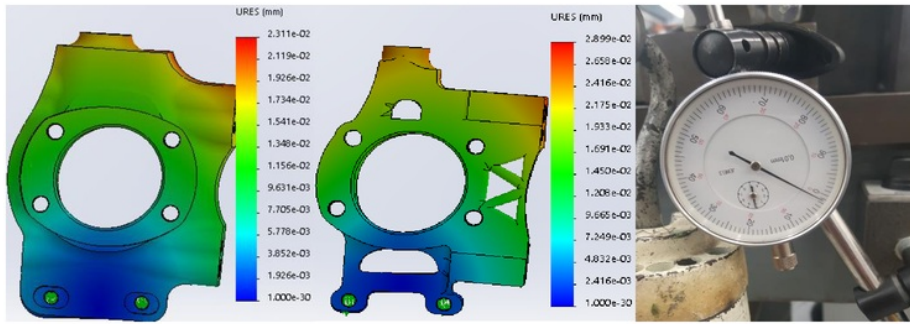


X: 0.07mm

0.154mm



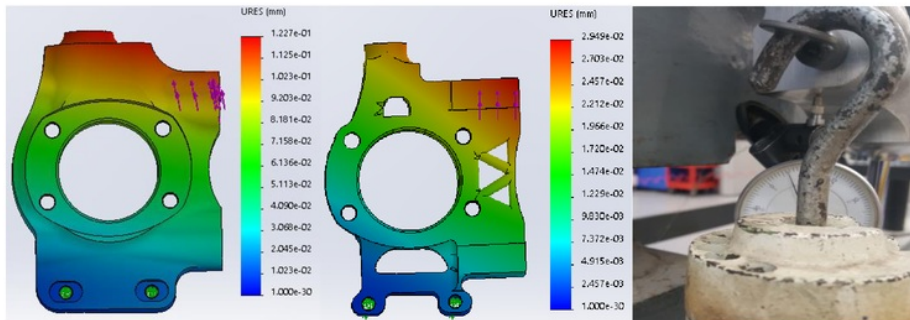
0.012mm



Y: 0.03mm

0.029mm

0.012mm

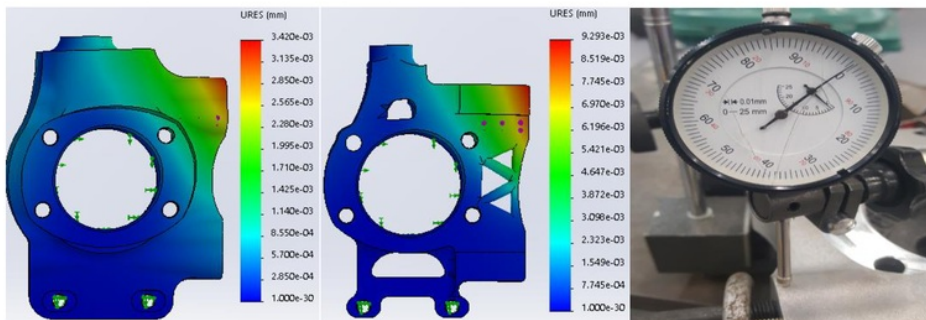


Z: 0.012mm

0.0294mm

0.063mm

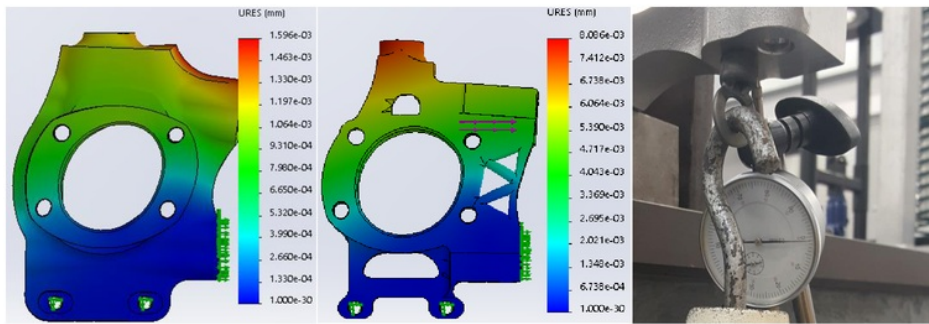
Small point.



X: 0.0034mm

0.0092mm

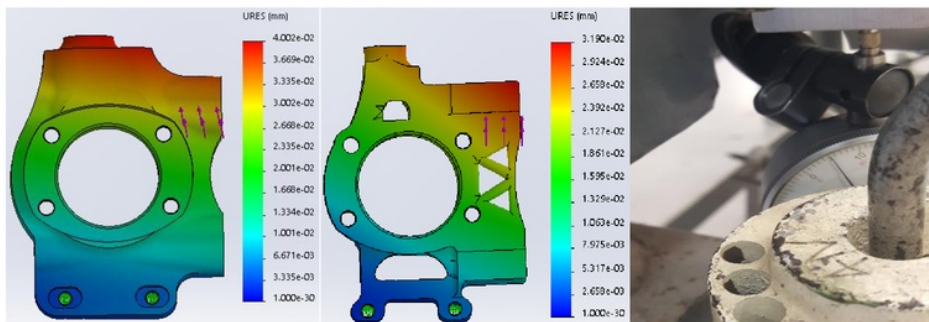
0.004mm



Y: 0.016mm

0.008mm

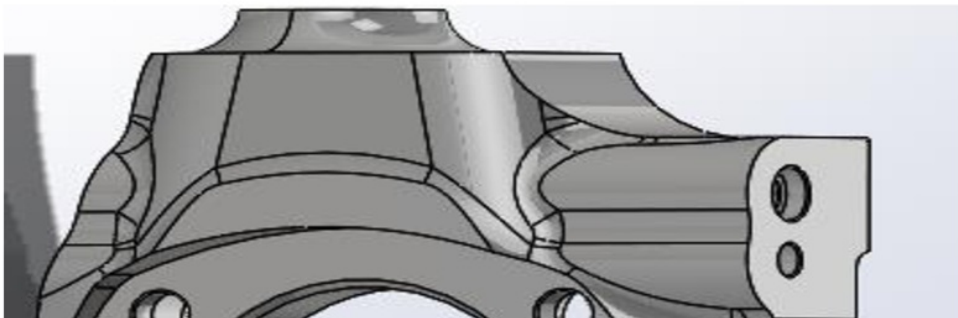
0.009mm



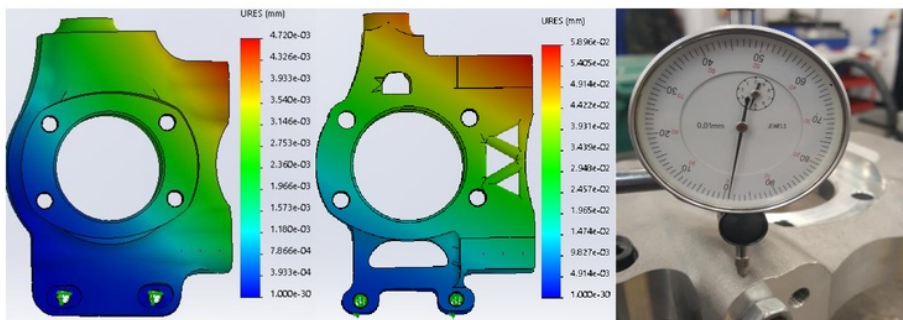
Z: 0.04mm

0.032mm

0.048mm



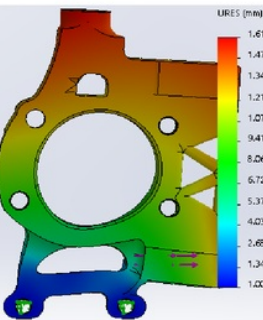
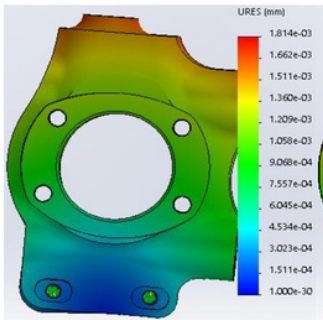
Brake points by upper side: large point.



X: 0.005mm

0.059mm

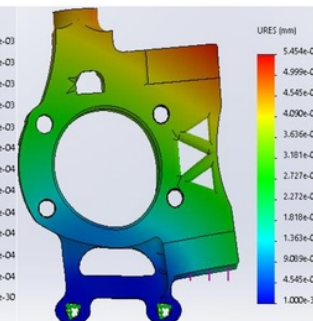
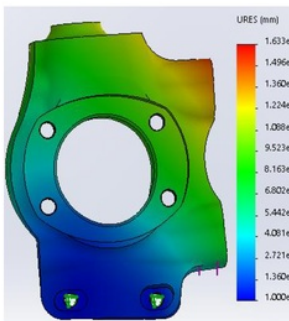
0.0089mm



Y: 0.0018mm

0.0016mm

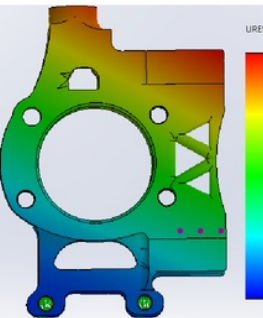
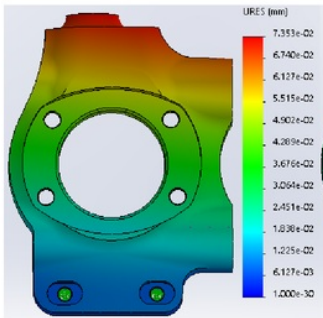
0.008mm



Z: 0.0016mm

0.006mm

0.002mm

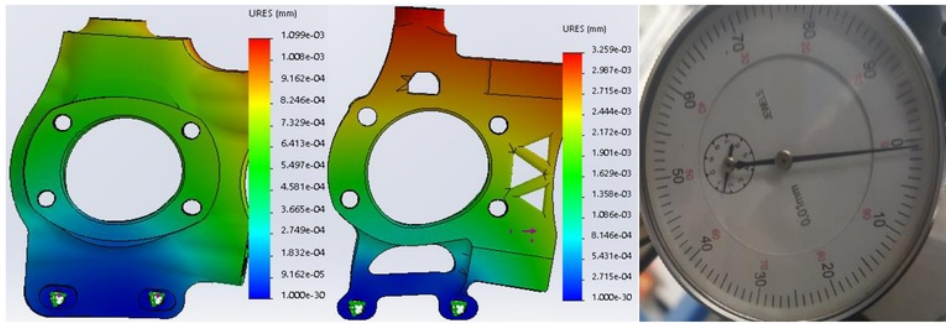


X: 0.07mm

0.09mm

0.018mm

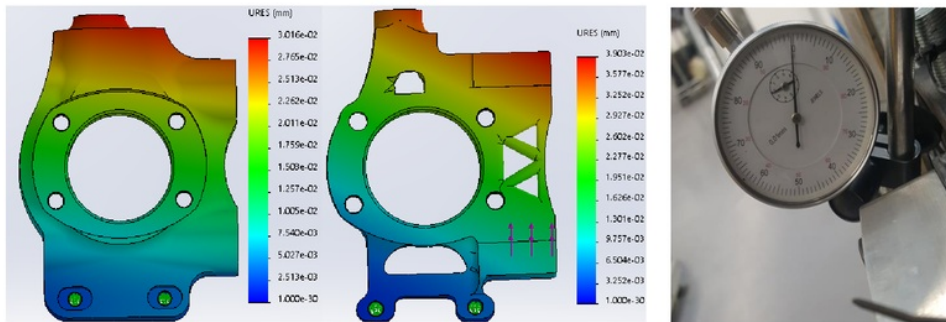




Y: 0.001mm

0.0033mm

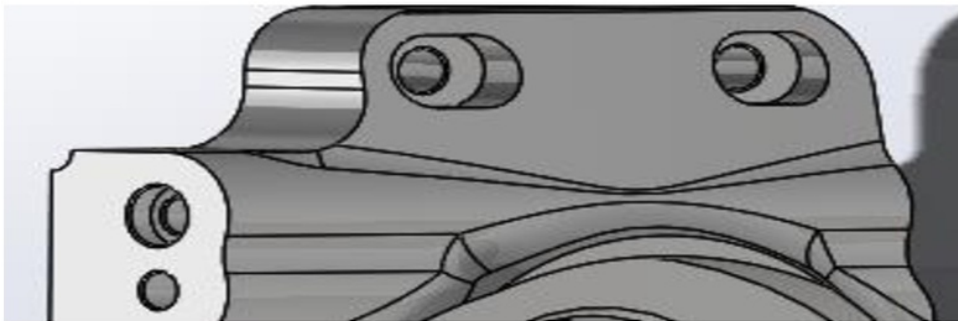
0.007mm



Z: 0.03mm

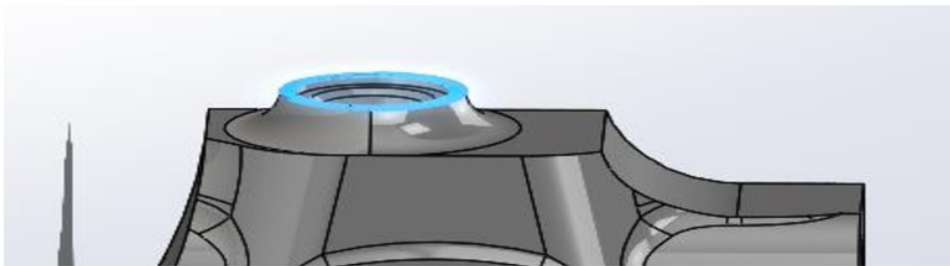
0.03 mm

0.008mm



17.0 FEA results and percentage different at each point:

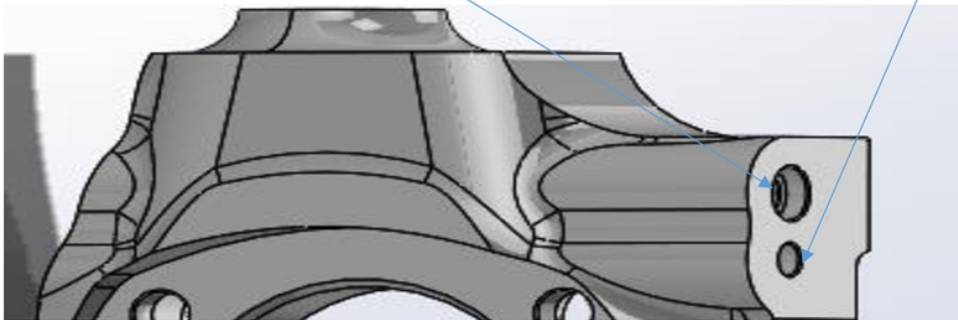
attachment points	test N/mm	original FE model N/mm	% different to test	final FE model N/mm	% different to original model
X	1428.571429	7692.307692	53%	10000	13%
Y	4545.454545	6666.666667	14%	2380.952381	-28%
Z	23809.52381	23255.81395	-9%	11111.11111	-20%



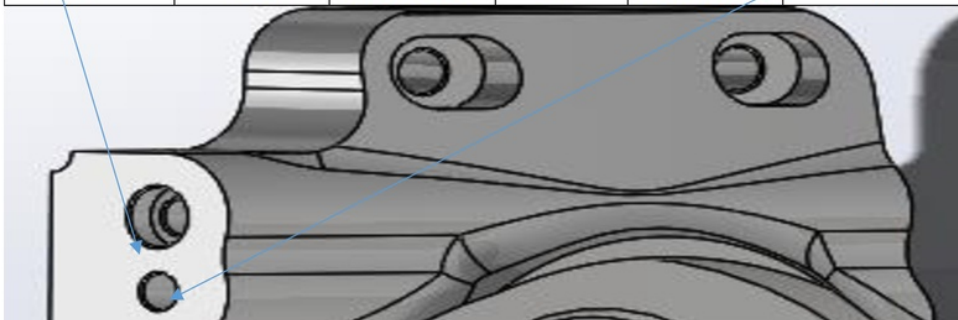
attachment points	test N/mm	original FE model N/mm	% different to test	final FE model N/mm	% different to original model
X	2439.02439	1818.181818	-7%	3623.188406	19%
Y	12500	22222.22222	17%	6666.666667	-33%
Z	2500	10000	-4%	4166.666667	24%
X	2222.222222	1694.915254	-7%	357.1428571	-47%
Y	10000	3333.333333	-3%	1562.5	-21%
Z	12500	12500	0	5000	-25%



attachment points	test N/mm	original FE model N/mm	% different to test	final FE model N/mm	% different to original model
X	8333.333333	1428.571429	-58%	649.3506494	-22%
Y	8333.333333	3333.333333	-4%	3448.275862	10%
Z	1587.301587	8333.333333	52%	3448.275862	-24%
X	25000	29411.76471	11%	10869.56522	-27%
Y	11111.11111	6250	-17%	12500	20%
Z	2083.333333	2500	12%	3125	13%



attachment points	test N/mm	original FE model N/mm	% different to test	final FE model N/mm	% different to original model
X	11235.95506	20000	17%	1694.915254	-11%
Y	12500	55555.55556	44%	62500	11%
Z	50000	62500	12%	16666.66667	-37%
X	5555.555556	1428.571429	-38%	1111.111111	-12%
Y	14285.71429	100000	7%	30303.0303	-33%
Z	12500	3333.333333	-37%	3333.333333	0



17.1 FEA and analyse:

Different colour in the table is presenting the different part of the component. One of the reasons to do the physical static test and original FEA test that material has been found when the results have been the similar or closest possible number to each other. The second reason for having the FEA result of original component is to compare them with a new design and help the student while the design process to the final stages. While the design process and ending up with the final design FEA test at the same material been a repeat to compression of the original design and new design then as it shows the stiffness. FEA result in most of the points are lower with very small change and they are shows by negative symbol, some of the points are higher so the percentages are positive, and in the last point, they are equal. Percentage different between test and original FE model can be because of some physical issue and they will list below:

1. DTI seating.
2. Model clamping issue.
3. Load issue, as in this case was measure with 100N so the weight has been use was 10Kg but it should be 10.197 Kg. different weight would calculate and results differently.

In this case, before design process student been consider that reducing the weight of component will have resulted of having the lower stiffness on most of the point but it has tried to take the design to the stage that to have smaller changes of stiffness at all the points. Stiffness changes been show by percentage at each x, y and z points between the test and original FE model and between the original FE model and new design.

18.0 Final FE model and Calculations:

Final step of design process is to work out how much force will be applying from the brakes and wishbones to the upright and redo the FEA test for the upright with real data or real forces. At this stage, braking and wishbone will be calculating with following equations:

$$\text{Braking force} = (\text{weight} \times \text{long G} \times g) / 2$$

$$\text{Upper wish bone} = (h1 \times \text{braking force}) / (h2 - h1)$$

$$\text{Lower wishbone} = (h2 \times \text{braking force}) / (h2 - h1)$$

The h1 and h2 are the height from lower and upper wishbone to the ground.

Therefore:

$$\text{Braking force} = 4756.6 \text{ N}$$

$$\text{Upper wishbone} = 4157 \times 2 = 8314 \text{ N}$$

$$\text{Lower wishbone} = 3593.9 \text{ N}$$

19.0 Final FEA and result:

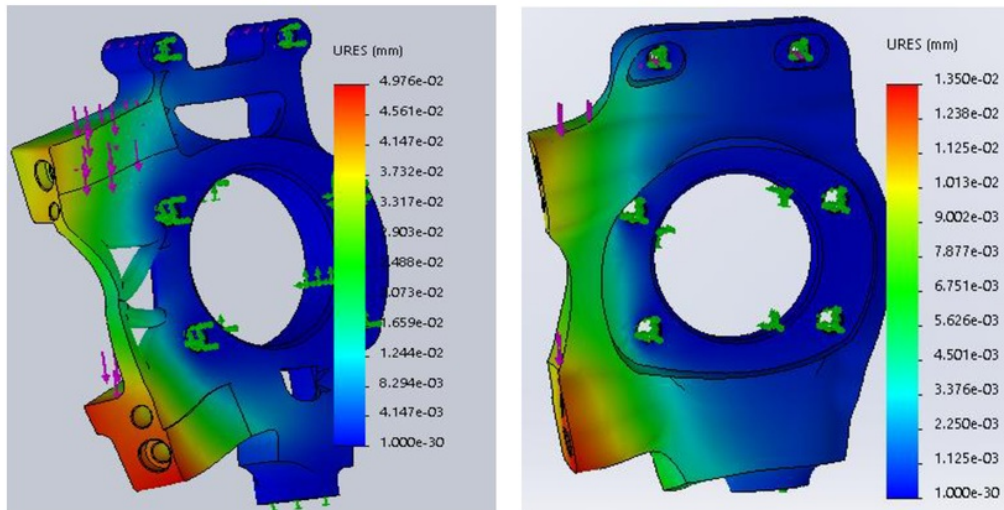


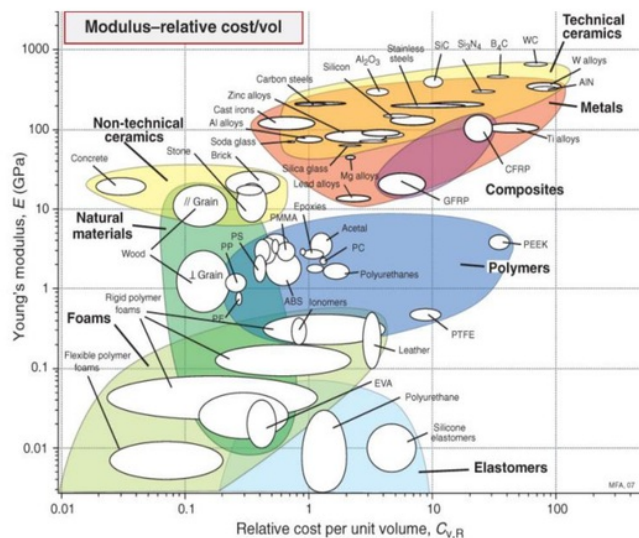
Figure 15: original and final model FE model displacement.

Stiffness: 2000 N/mm for the new model and 7000 N/mm for the original model.

At this part FEA results has been proven that new model has not got much different compared to the original model and also it shows on the figure with calculated forces model has not been field so the new design can be safe and ready to take to the next steps which is choosing the material and manufacturing technique.

20.0 Material:

The material is the main body of the model or component. Everything around creates by type of material that supposed to. For example, stone, wood, metal, plastic and composite etc. are material. Different design or component has created by one or even more than one type of material all depends on the use of the place will use. Most of the glasses are from the plastic or wood and tables are wood or metal. Materials are choosing as the facts of density, stiffness, price etc. but in this case, stiffness and price are the main facts of choosing the material. Figure 16 is the best example of how different material and young modules having different cost and what is the best choices of material for this case. Three best and possible choice of material for the suspension upright will be analysis in the next following sections.



(Stiffness and weight: density and elastic moduli, 2011)

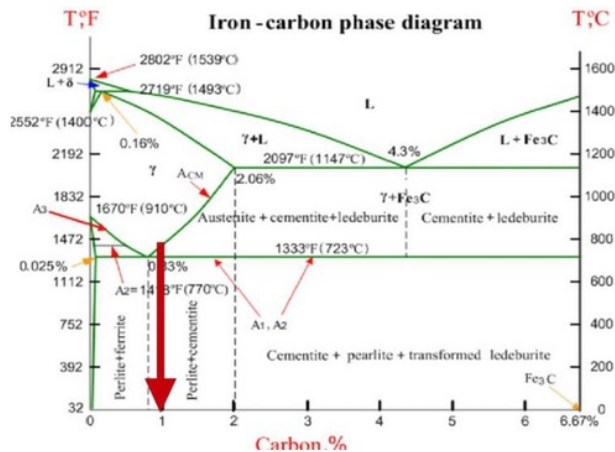
Figure 16: Young's modulus against cost

20.1 Magnesium:

One of the super light and cheap in the group of material is magnesium. Lower density compared to aluminium and the same group of aluminium alloys took this material to the top five of the automotive industry list and useful. Magnesium has a list of alloy with aluminium so magnesium alloy is a list of the best light and cheap material. Beryllium is the only lightest material as magnesium. Best temperature of usage for magnesium alloys is less than 150 °C. (baker, 1999)

20.2 Cast iron, ductile:

Some of the suspension parts are create by the material called ductile in the steel family. This material is one of the stiffest and cheapest materials that can use for the upright but only the biggest disadvantage of this material is the high density compared to most of the alloys. This material is create by a different percentage of iron and Carbone. The iron-carbon phase diagram is the best example of how a different percentage of Carbone can affect the temperature, hardness and at the same time density. (Mason, 2018)



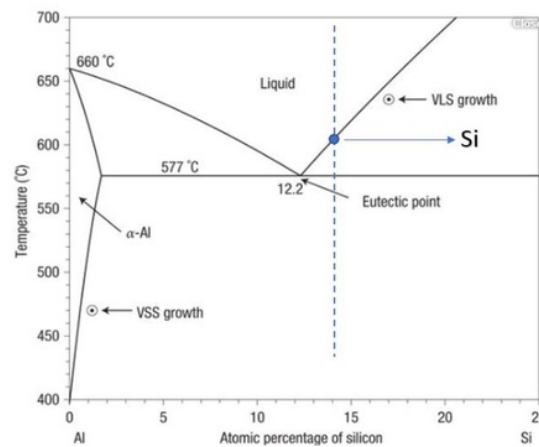
(Damodar Khobragade, 2017)

Figure 17: Fe-c (Iron-Carbony) phase diagram.

20.3 Aluminium alloy:

Aluminium alloys are the best, most important and most useful light alloys that compared to the price being to the top of the list of the most use in motorsport and car industry. They are separate from the family of two groups of casting and wrought alloys. As it says at the beginning, they are useful because of lower density as steel and iron families with high strength, excellent thermal high reflective surface, and low melting temperature and easy to weld and cast. They are in the low cost of material families but prices still twice as steel families. (L.Rooy, 2004)

Most cast aluminium alloys based on an alloy of aluminium with 1 to 18 percent silicon and different percentages of aluminium and silicon will affect the temperature and melting temperature, which will show in figure 18.



(Chen, 2018)

Figure 18: aluminium silicon vs temperature phase diagram.

20.4 Three different possible material for upright manufacturing:

materials →	Aluminium alloy	ductile	Magnesium alloy
Density	2.69e3 – 2.73e3 Kg/m ³	7.05e3 – 7.25e3 kg/m ³	1.75e3 – 1.87e3 kg/m ³
Yield strength	92.6 – 108 MPA	250 – 680 MPA	70 – 215 MPA
price	1.5 – 1.63 pounds per/kg	0.23 – 0.24 pounds per/kg	1.87 – 2.15 pounds per/kg

Table: compression of three cheap material for upright. (edupack C. , 2018)

This table is an analysis that the advantage and disadvantage of each three materials that is the best possible material to manufacture the upright. In this table, magnesium has lower density so it can be one of the choices of the light component but at the same time has a slightly higher price and lower stiffness. The best and the high number of stiffness and cheap price of raw material is for ductile but one of the biggest advantages of this material is very high density compared to the magnesium alloy and aluminium alloy. High melting temperature point is the other disadvantage of ductile therefore more power and costs to melt. Aluminium is one of the best choices of manufacturing the upright as the low price of raw material and higher stiffness compared to magnesium but it has higher density compared to magnesium and lower density compared to ductile.

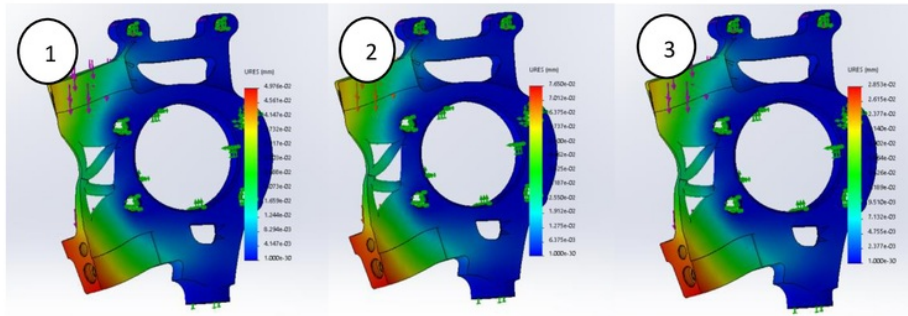


Figure 19: aluminium

Figure 20: magnesium

Figure 21: cast iron- ductile

Figure 19, 20 and 21 is what FEA proved as displacement which is cast iron with displacement of 2.85e-2 mm has better result and stiffness compared to the aluminium and magnesium then magnesium has lower stiffness with displacement number of 7.65e-2 mm. aluminium has lower stiffness as steel or cast iron but higher than magnesium.

20.4.1 Different aluminium choice:

Original Zen track suspension upright has been creating and manufactory as 6061 aluminium alloy as it has find while compared the result of the test with FEA of the original model. Closest result of the FE model to the test prove the material, which is in the FEA test different material compares with an actual physical test and the closest material result proves the material of the original model. Material to be recommending for manufacturing of the newly designed suspension upright is being A206- T7 and Al-alloy 6061so to analyse both of alloys property will be in following steps as a table. (gmbh, 2018) (Pandey, 2018)

Aluminium 6061 alloy with engineering name of EN AW-6061(EN AW-AL Mg1SiCu) with engineering number of 3.3211 vs aluminium A206-T7 with engineering number of AMS 4236 has been composition as:

6061 alloy	A206-T7
Al 95.8-98.6 %	93.4 – 95.3 %
Cr 0.04-0.35 %	Ni: 0- 0.05 %
Cu 0.15-0.4 %	4.2 – 5 %
Fe 0-0.7 %	0 – 0.1 %
Mg 0.8-1.2 %	0.15 – 0.35 %
MN 0-0.15 %	0.2 0.5 %
Si 0.4-0.8 %	0 – 0.05 %
Ti 0-0.15 %	0.15 – 0.3 %
Zn 0-0.25 %	0 – 0.1 %
Other 0-0.15 %	0 – 0.15 %

(edupack C. , 2018)

Aluminium and aluminium alloys has lower density so the component, compared to steel or cast iron will be lighter. High stiffness and low material cost is the other advantage of aluminium. Melted point of aluminium and aluminium alloys are low so less power needed to melt the material therefore lower cost.

With melting temperature of 580 to 650 °c and base price of 1.53 to 1.65 pounds'/ kg vs A206-T7 will be melt at 535 to 650 °c and price of 1.65 to 1.78 pounds/kg and physical and mechanical properties of:

6061 alloy	A206-T7
Density: 2.69e3– 2.73e3 Kg/m ³	2.77e3 – 2.83e3 Kg/ m ³
Young modules: 66.6 – 70 GPA	69.4 – 71 GPA
Yield strength: 92.6 – 108 MPA	333 – 357 MPA
Fatigue strength: (10 ⁷ cycles) 91 – 106 MPA	195 – 215 MPA

(edupack c. , 2018)

20.4.2 Aluminium alloys group:

Aluminium alloy family	Formability and workability	machining	Heat treating	strength
Alloy 1100	excellent	good	Not heat treatment	bad
Alloy 2011	good	excellent	Can be heat treatment	Excellent
Alloy 2024	good	Fair and acceptable	Can be heat treatment	Excellent
Alloy 3003	excellent	good	Not heat treatment	good
Alloy 5052	good	Fair and acceptable	Not heat treatment	Excellent
Alloy 6061	good	good	Can be heat treatment	Excellent
Alloy 6063	good	Fair and acceptable	Can be heat treatment	good
Alloy 7075	poor	Fair and acceptable	Can be heat treatment	Excellent

(Kaufman, 2000)

To consider what type of aluminium alloy family needed for what part or what type of component it is important to check this table out. For example, to have the model with easy machining 2011 alloy is the best choice or to have a model with high strength 1100 alloy is the worth choice therefore different alloy will prove in this table with advantage and disadvantages list to consider the best choice. Aluminium alloy 6061 in this table has a stable result which is at all different part has a good average of forming, machining, heat treating and strength, therefore, it can be one of the best choices of material for the new component.

21.0 Manufacturing technique:

Suspension upright can produce by different manufacturing technique and different manufacturing technique is to carry the different cost per model. In this stage, different manufacturing technique will be, introduce therefore analysis the different manufacturing technique and cost.

21.1 Hot close die forging:

Hot close die forging is a part of the deforming group in manufacturing methods. In hot close die forging process, metal will be formed with the pressure of the head, which is called ram and forms the hot metal or alloy with fixed upper and lower dies under and over the ram. This method has been recommended for high quality, volume models as randomly a model can be manufactured from 10 to 300 per hour, and each model will cost from 24.4 pounds to 45 pounds. (edupack C. , 2018) This technique needs to be done for some complex models with small edges. Metal can be forged but the easiest material in the list of forgeable materials are included aluminium, magnesium, copper alloy and steels. This manufacturing process is recommended for high stressed mechanical parts such as the crankshaft, connecting rod and upright.

Note: price cost and manufacturing volume per unit is all depends on the shape, size and material. Heating temperature will be it depends on the material properties.

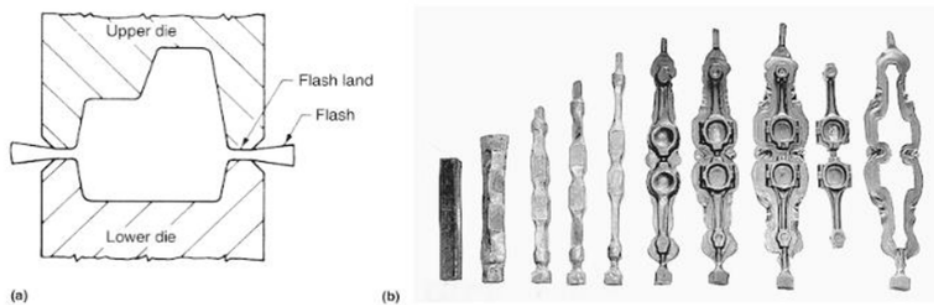
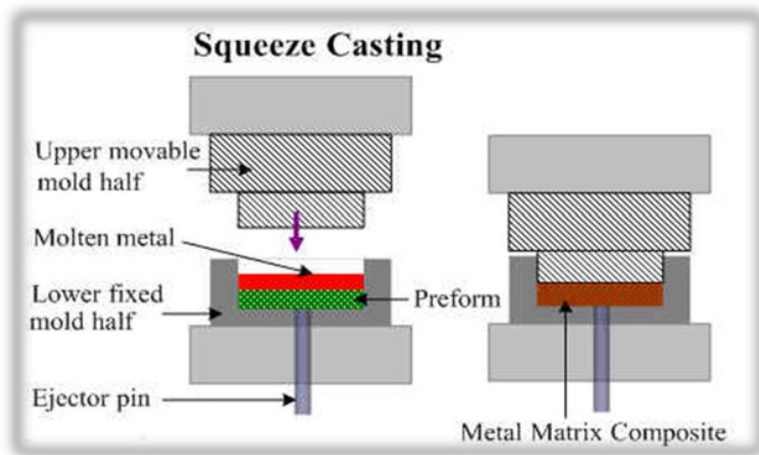


Figure 22: close die forging on rod. (Taylan altan, 2005)

21.2 Moulding (compression) or squeeze casting:

Compression moulding is a main polymer forming process but in some cases, it is better to use for some low melted temperature metals and alloys and it is called squeeze casting. This process is partly the same to squeeze casting and forging but in this case melted metal will be injected into the model space and fill it up. In this process, melted metal or alloy will be injected as a charge into the lower die and the upper die will be squeezed on the material to shape the model. This process is present in two types as heated die for the polymers and cold die with melted metal or alloy for the non-polymer material such as aluminium or magnesium. (I. Isayev, 1987) The cost of model per unit manufacture within this method is between 13.6 to 32.6 pounds. This process can produce 10 to 100 models per hour. Squeeze casting is excellent for the simple shape models and in all the cases model needs to be machine some of the side's edges and holes. (edupack C. , 2018)

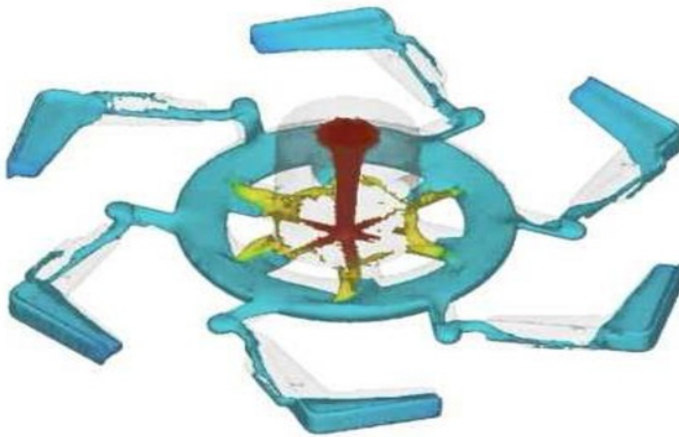


(Danzur, 2013)

Figure 23: compression or squeeze casting moulding process.

21.3 Casting (centrifugally – aided):

This method is one of the casting group, which is can be done for most of the metal and alloy materials with limited sizes. In this process, numbers of models will set up with a fixed distance from the centre of the rotation axis. Melted material will fill the models with the pressure of rotation. In this process, models can stay from 50 to 200 manufacturing units or can be wax for the complex of very small dimension models. Price of the models manufacturing with the method is between 17.6 to 132 pounds and can be manufactured between 1 to 200 models per hour which are each casting time can produce 60 to 90 models. (edupack C. , 2018) In this manufacturing technique tools cost need to be consider from 71.50 to 715 pounds.

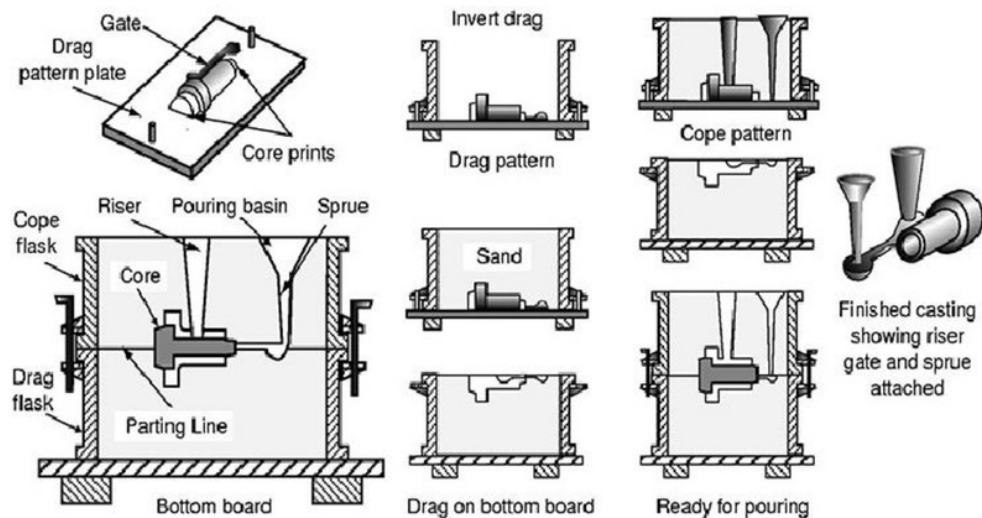


(Science, 2010)

Figure 24: centrifugal casting.

21.4 Sand casting:

Sand casting is one of the oldest methods of the forming family from mid-1800 and first die casting alloys done at the 1930s. This process will start to cast the model with the amount of sand into the die casted aluminium or wood. Next step is to split the model from the sand, dry the sand with gas fire, and drain the melted metal or alloy gently to the casted area. This process can produce 1 to 20 models per hour which are each casting time can be done for 1 to 10 model. Minimum cost of 17.50 to maximum cost of 126 pounds will be for each unit. Tools life in this method is only once each time of casting but the casting tools are cheaper than the other manufacturing process. Quality of the casted surfaces are poor and need to be a machine after the casting process. One of the biggest advantages of this manufacturing process is over 95 percent of the models can be manufactured with this technique. Metals and alloys are can be cast but alloys of aluminium, zinc, magnesium and copper are mostly be cast by this method. (Barkhudarov, 1988)

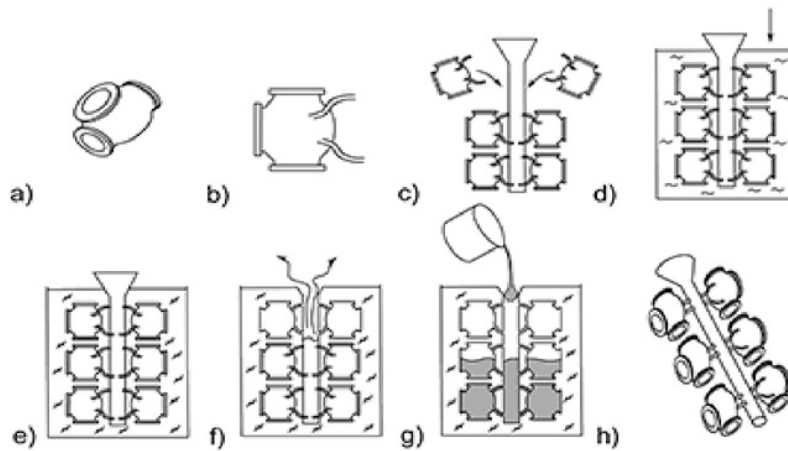


(Solutions, 2014)

Figure 25: sand casting process.

21.5 Lost-wax casting:

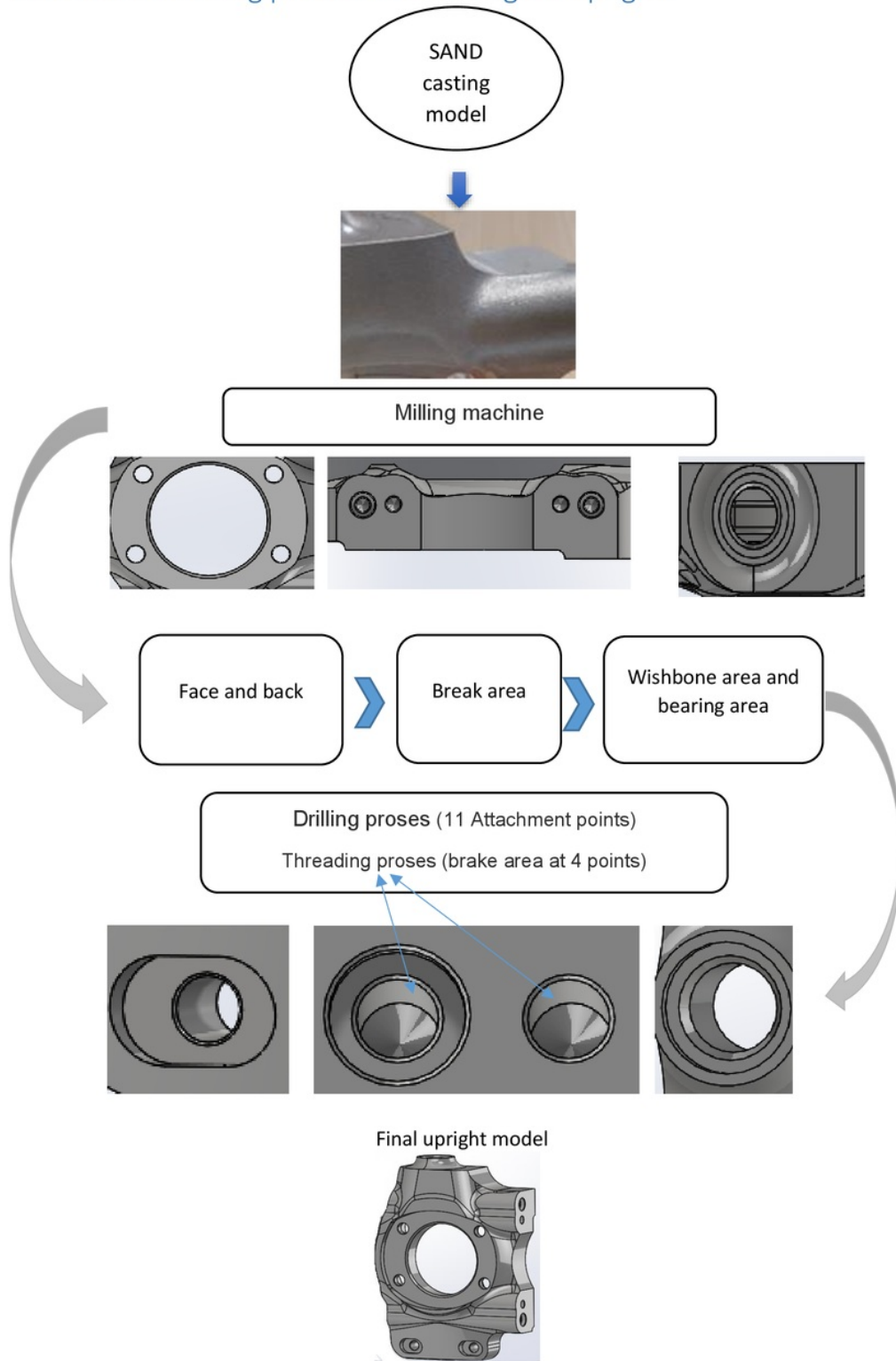
Lost-wax casting is the oldest method of casting and forming. This manufacturing technique is present for more than 4000 years. This method at the beginning been used to create and shape the gold and metal arts. After years and years, when the technology gets higher this method been use for more complexes and very small dimension of models. This process at some stage is similar to sand casting but in this method, the wax will create the space of model and when it covered by ceramic, the wax will melt by heat or fire and the model space will be ready for casting. Each casting time at this method will produce more than one model and final casted models are together having the trees root shape. Bad surface will be the biggest disadvantage of this casting method and the models all need to be a machine after the casting process. Two to 100 models per hour can be produce by using this process with the cost of 20 to 150 pounds. (Fred R.Sias, 2005)



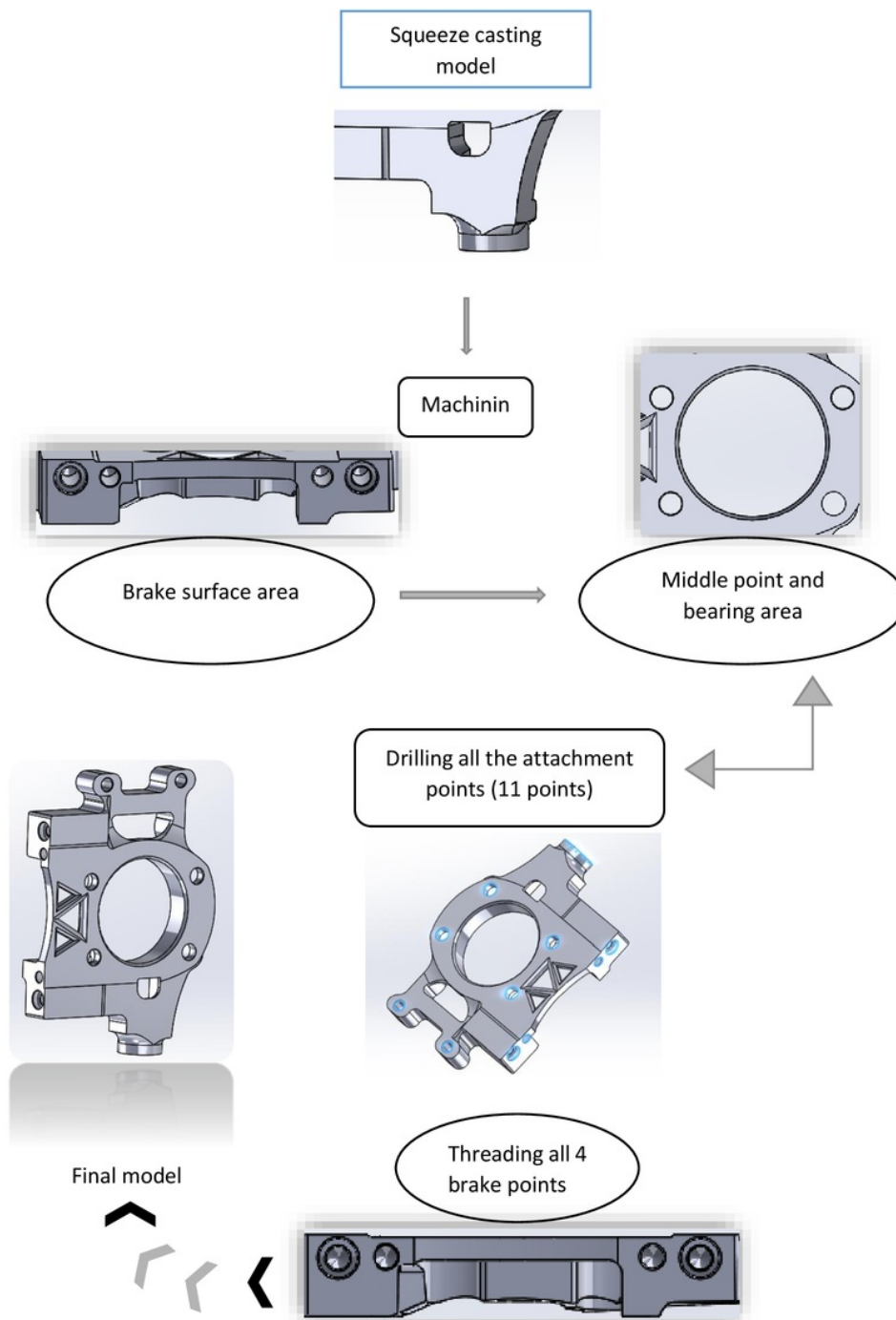
(Mögele, 2016)

Figure 26: lost-wax casting.

22.0 Manufacturing process for the original upright:



23.0 Manufacturing process for new designed upright:



24.0 Manufacturing cost of the original model:

Cost and manufacturing	Sand casting	Centrifuge casting	Squeeze casting	forging	Lost-wax casting
Unit cost	£22	£24	£23	£29	£25
Units/hour	20	200	60	300	100
Tools cost	£10	£100	£500	£3000	£45
Units produced / tool	10	90	100000	100000	8
Tooling cost / unit	£1	£1.11	0.5p	3p	£5.63
machining	£15	£15	£11	£13	£21
drilling	£8	£8	£8	£8	£8
threading	£4	£4	£4	£4	£4
Unit cost	£50	£52.11	£46	£54.03	£63.60

Figure: manufacturing cost of original model. (edupack C. , 2018)

In this table, the cost of the original has been calculated at each unite with the different manufacturing process. Original suspension upright has been produce by aluminium alloy 6061 and sand casting process but the new design will produce by different manufacturing technique and aluminium alloy 6061 material. Newly designed manufacturing cost will be calculate in the next table, therefore consider which manufacturing technique need to choose to manufacture the new suspension upright.

25.0 Cost of the new model manufacturing and analysis:

Assuming the cost of original upright is 50 pounds and need to take to $50.000 \times 2 = 100.000$ unit produce a year then:

Cost and manufacturing	Sand casting	Centrifuge casting	Squeeze casting	forging	Lost-wax casting
Unit cost	£20	£22	£21	£27	£23
Units/hour	20	200	60	300	100
Tools cost	£10	£100	£500	£3000	£45
Units produced / tool	10	90	100000	100000	8
Tooling cost / unit	£1	£1.11	0.5p	3p	£5.63
machining	£15	£15	£11	£13	£21
drilling	£8	£8	£8	£8	£8
threading	£4	£4	£4	£4	£4
Unit cost	£48	£50.11	£44	£52.03	£61.60

(edupack C. , 2018)

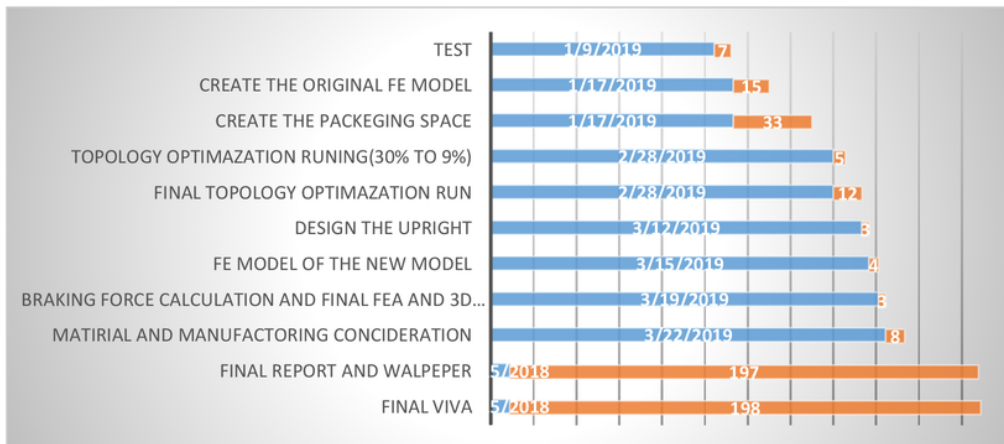
If the factory works 260 days a year and each day 10 hours so, 385-model need to produce a day so all the manufacturing techniques can be done for the new upright design. From the top list, cheapest processes from A to Z will be sand casting, centrifuge casting, squeeze casting and forging. compression is cheaper because of the surface of the squeeze casting model will be more flat as the other techniques, therefore, less work needs to be done(machining), it will be cheaper overall compare to another processes but drilling process will be the same as the original model which is all the attachment points. Most of the Cast iron or steel materials cannot produce by squeeze casting process so to use the cast iron sand casting will have recommended.

Note: tooling cost will divide by numbers of cycle and result add to the cost of one model. One of the biggest future advantages of using compression or squeeze casting process is off in the future, volume needed of upright gets higher then more model can produce a day and also with $50.000 \times 2 = 100000$ units a year 38.5 model need to be produced per hour.

Different manufacturing technique is presenting different cost and unit can be produce per hour. In the cost list best and possible five manufacturing technique for this model has been considered. The cheapest way of manufacturing technique in the list is squeeze casting and can produce up to 600 model a day. To take the volume to 600 units a day production this manufacturing technique is the first and best choice. If the factory decides to produce the model more than 600 unite a day then the next choice will be centrifuge casting so the cost per model will be £50.11 and 2000 model can produce a day by this manufacturing process.to produce up to 3000 model a day best and next possible choice is forging.

26.0 Second term Gantt chart:

Task	Start Date	End Date	Time duration/day
Test	09/01/2019	16/01/2019	7
Create the original FE Model	17/01/2019	01/02/2019	15
Create the packaging space	17/01/2019	19/02/2019	33
Topology optimization run (30% to 9%)	28/02/2019	05/03/2019	5
Final topology optimization run	28/02/2019	12/03/2019	12
Design the upright	12/03/2019	15/03/2019	3
FE model of the new model	15/03/2019	19/03/2019	4
Braking force calculation and final FEA and 3D print the final design with previous design	19/03/2019	22/03/2019	3
Material and manufacturing consideration	22/03/2019	30/03/2019	8
Final report and wallpaper	15/10/2018	30/04/2019	197
Final Viva	15/10/2018	01/05/2019	198



At the beginning of the second term project has been plane but same issue as first term has happened as in some task more time needed to be spent but at overall project and project poster has been done successfully before the dead line .

27.0 Further work:

One of the most important works that need to be do for this project in the future is to do some fatigue test to find out the maximum and minimum percentage of damage at different parts and maximum life of the new design. Second test is to take the new designed model to solid works and set the model on the original assembly of the Zen track and run it as motion analyse and simulation motion for the FEA result and analyse the result to see if the new designed upright need any change on the design.

28.0 Issues and problems:

In the physical test, the middle point could not be measure as at the end of measurement some changes have been doing on the rigid but to set the DTI could not be setup to the place that is the closest place to the middle point; therefore, they have not been measure. Because of this issue, the middle point has not been measure at all the steps it has been add to the design only because of this issue.

200 g weight was present for the test in the workshop but it was not possible to hang in model so the weight used for the test was less than 10 N therefore test results was not the same as FEA result.

29.0 Conclusion:

Cheap and high volume car production is the main strategy of the Chinese car manufactories. The Chinese car market is in the top three of quality and quantity of the Asian car market and in some facts take the production to Europe and the USA. To take the production from the UK to China component weight has been reduce while the new design and material and manufacturing technique has been consider to reduce the component cost. To reduce the weight three facts have been consider and analysis first is design, new design have used lower material compared to the old design. Second is material, cheap and stiffer material has been represented but the material has been sued for the original model will be used as a material. Third and most important is manufacturing technique, in this part cheapest and quickest manufacturing technique is considered to be squeeze casting but it can be changed with quantity so, all the manufacturing techniques are listed with the costs.

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