Design and modelling of the NEXTEV supercar steering wheel

Graduation Project David Groen

NON-CONFIDENTIAL VERSION

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蔚来汽车
NEXTEV

UNIVERSITY OF TWENTE.

GRADUATION PROJECT : DESIGN AND MODELLING OF THE NEXTEV SUPERCAR STEERING WHEEL

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PREFACE

This thesis is written as part of my graduation project to conclude my Industrial Design programme at the University of Twente.

The thesis covers the design and modelling process of the NextEV supercar steering wheel. This project has been executed in an automotive design studio in the UK. This gave the opportunity to work together with all the designers, clay modellers and digital modellers of the supercar project.

The project is highly confidential. This is the non-confidential version of the thesis, which only describes the methods used to get to the results. The project is focussed on the visual aspect which cannot be shown in this version. Therefore this version might feel incomplete compared to the confidential full thesis.

Throughout the project, many people have helped me with their knowledge, craftsmanship and experience. Without their help the result would not have been at the same level. Thanks for your input and time. To mention everybody individually seems otiose, but I would to thank two people specifically.

David Hilton as company mentor was the most important source of inspiration and feedback. His dedication, design experience and positive attitude towards my project and my results made a huge difference in succeeding this project and making me a better designer. I was always treated as a full member of the team.

Also a special thanks to Wouter Eggink as University mentor. His valuable input and experience helped to keep the project and workflow moving towards the right direction.

David Groen

SUMMARY

NextEV is a Chinese electric-vehicle startup, working towards a mass-market battery-powered car at average consumer price[1]. To showcase their potential, NextEV is launching a 1000+ bhp electric supercar, expected to debut in 2016[2].

One of the most difficult parts of the car is the steering wheel. Not only does it need to have a high quality design level, it also needs to have perfect ergonomics and multiple functions, all combined in a form that shares the same language as the rest of the interior. This requires knowledge in all of the design facets from project planning to market research, product analysis, ergonomics, sketching, clay modelling, digital modelling and design evaluations. This thesis discusses all these steps that were made during the design and modelling of the NextEV supercar steering wheel.

The project was divided into two main phases: the analysis and the design phase.

The analysis phase defines the design language of the steering wheel by visualizing the design keywords, materials and market position in mood boards. After multiple meetings a function analysis and a global function mapping have been made. Together with an ergonomic analysis of multiple steering wheels, these items form the programme of requirements.

The design phase was divided into three stages, each with their own physical model. The initial sketches, renders, ergonomic clay handles, digital models and spoke proposals have lead to the first milled foam model.

During the second stage the package was finalized and the design converged to a model that is ergonomically correct. 3D scans were used to create data from the physical master model. A design direction was chosen at the end of this stage, combining features of my design and a design of another designer.

The last stage finalized the design and made the digital file master. An Alias model was built which later on can be used during the manufacturing. Details were also modelled. The project finished with digital design changes based on the feedback of the final review.

The result was a digital release to the engineers in order for them to design the internal components of the steering wheel. Looking back, the design has come a long way with a nice and balanced end result and an enormous learning experience.

After this project, the design will come back multiple times for small design alterations to solve some manufacturing limitations. This however is out of the scope of my project.

1 http://www.bizjournals.com/sanjose/news/2015/09/15/exclusive-chinese-tesla-rival-nextev-coming-to.html

2 http://www.reuters.com/article/autos-china-electric-idUSL5N1162SQ20150831

SAMENVATTING

NextEV is een startende Chinese elektrische autofabrikant met de bedoeling om grootschalig betaalbare elektrische auto's te produceren[3]. Om te laten zien wat ze kunnen lanceren ze in 2016 een supercar met meer dan 1000 pk[4].

Een van de ingewikkelste onderdelen van de auto is het stuur. Deze moet niet alleen een kwaliteit ontwerp hebben, maar ook een perfecte ergonomie, meerdere functies en een beeldscherm huisvesten. Dit allemaal in dezelfde vormtaal als de rest van het interieur. Dit vereist de kennis in alle vakgebieden van het ontwerp; van project planning tot marktonderzoek, product analyse, ergonomie, schetsen, klei modelleren, digitaal modelleren en ontwerp evaluaties. Deze thesis behandelt al deze stappen die zijn doorlopen tijdens het ontwerpen en modelleren van het NextEV supercar stuur.

Het project was onderverdeeld in twee hoofdfases: de analysefase en de ontwerpfase.

De analysefase definieerde de ontwerptaal van het stuur door het visualiseren van de themawoorden, materialen en marktpositie in collages. Na meerdere vergaderingen werden de functieanalyse en de globale functie indeling gemaakt. Samen met een ergonomische analyse van meerdere stuurwielen vormde dit het programma van eisen.

De ontwerpfase was onderverdeeld in drie stappen met elk hun eigen fysieke model. De ideeschetsen, renders, ergonomische klei handgrepen, digitale modellen en spaak voorstellen hebben geleid tot het eerste gefreesde schuimmodel.

Tijdens de tweede ontwerpstap werden de indeling van het stuur vastgesteld en werden de verschillende ideeën samengevoegd tot een ontwerp dat ergonomisch correct is. 3D scans werden gebruikt om data te maken van het fysieke ontwerp dat toen nog de master was. Een ontwerprichting werd gekozen aan het eind van deze ontwerpstap, waarbij mijn ontwerp en een ontwerp van een andere ontwerper werden gecombineerd.

De laatste ontwerpstap rondde het ontwerp af en maakte het digitale model de master. Een Alias model werd gemodelleerd dat later gebruikt kan worden voor de productie. Details zoals de knoppen en flippers zijn ook gemodelleerd. Het project eindigde met digitale aanpassingen aan het model gebaseerd op de terugkoppeling van de laatste bespreking.

Het resultaat is een digitaal model dat naar de ingenieurs werd gestuurd om de interne componenten van het stuur te ontwerpen. Terugkijkend heeft het ontwerp enorme stappen gemaakt met een mooi en balanceerd ontwerp en enorme leerervaring als resultaat.

Na dit project zal het ontwerp nog meerdere malen terugkomen voor kleine aanpassingen om limitaties in de productie op te lossen. Dit valt buiten mijn project.

3 http://www.bizjournals.com/sanjose/news/2015/09/15/exclusive-chinese-tesla-rival-nextev-coming-to.html

4 http://www.reuters.com/article/autos-china-electric-idUSL5N1162SQ20150831

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LIST OF DEFINITIONS & ABBREVIATIONS

Hub	The centre part of the steering wheel
IP	Instrument panel
Project	The steering wheel graduation project, unless specified as the whole supercar project
Rad	Radius fillets
Rim	The actual wheel of the steering wheel, without the spokes
Spoke	The steering wheel spokes connecting the rim to the hub

1: Introduction

1.1_NEXTEV

NextEV is a Chinese electric-vehicle startup, founded in 2014. They are working towards a mass-market battery-powered car at average consumer price[5].

The company is based in Shanghai, with workplaces at global locations in China, North America and Europe. With an investment of hundreds of millions of US dollars, NextEV is founded by world-class Internet and technology leaders, who bring with them an unrivalled understanding of the marketplace, automotive landscape and of car owners themselves[6].

NextEV gathered together the finest talent from automotive engineering, technology, design and software, to bring their vision to life. Their family of smart, outperforming electric vehicles will re-define the entire user-experience. The main company goal is to empower car owners to feel nothing but pure delight, by ending the aggravation, the pollution, the ongoing expense and time-consuming maintenance[7].

NextEV won the world's first FIA Formula E championship in history.[8]

5 http://www.bizjournals.com/sanjose/news/2015/09/15/exclusive-chinese-tesla-rival-nextev-coming-to.html

6 https://www.linkedin.com/company/nextev

7 http://join.nextev.com

8 http://www.nextev.com/racing-formula#

To showcase their potential, NextEV is launching an electric supercar, expected to debut in 2016. A range of high-performance family cars will follow. The EV supercar is expected to outperform all internal-combustion engine supercars in the world.[9]

1.2_FRAMEWORK

One of the important components is the steering wheel. NextEV already made a few designs and a global idea of the steering wheel, but the true design phase still needs to be done before the production phase.

Leading the design of the supercar project is David Hilton, Senior Design Director of NEXTEV. He studied Product Design in Cincinnati and has worked for all major car OEMs. As former Head of Exterior Design at Bentley, David Hilton knows how to lead a design team. David Hilton is the company supervisor for this graduation project.

1.3_GOAL

The goal of this graduation project is the design and modelling of the steering wheel for the development of the NEXTEV supercar. This complex project requires all of the automotive design skills, from project planning, market research, product and ergonomic analysis, to design sketching and rendering, clay modelling, digital modelling, and design evaluations. The research methods used are market exploration, observations and ergonomic evaluations, both by internal and external sources. To make quick design adjustments whilst being able to feel the steering wheel in the hands, clay modelling will be an important tool. Depending on the design, another big focus is on the digital modelling.

9 http://www.reuters.com/article/autos-china-electric-idUSL5N1162SQ20150831

1.4_PROJECT SCOPE

While starting this project, the assignment and goal were clear. However, the focus within the project was determined later to be flexible with the design.

Beforehand the idea was to do most of the modelling in clay. Later in the process however, it will be decided that there should be a bigger focus on the digital modelling because of the design direction and the possibility of combining a milled foam model with adjustments and design changes in clay.

1.5_PROJECT STRUCTURE

The project is divided in two main phases. The analysis phase and the design phase. During the analysis phase, all different aspects of the steering wheel are analysed and researched. The design phase is divided in three stages, each with their own physical model. The result is a digital release to the engineers in order for them to design the internal components of the steering wheel.

Due to the confidentiality of the supercar project, only the work, sketches, models and photos made by David Groen are shown in the full version of the thesis, unless specified differently. This non-confidential version will not show the sketches, models, photos and design information which describes the form. The steering wheel does of course work together with the rest of the interior, but this is visual interaction cannot be shown in this thesis.

1.6_RESEARCH QUESTIONS

The assignment description results in a number of research questions. These are used to get an understanding of the project. The questions will be answered in this thesis.

1. What steering wheels are on the market?
    - 1.1. How are the steering wheels categorized?
    - 1.2. What materials are used?
    - 1.3. What colour combinations are used?
    - 1.4. What functions are used?
    - 1.5. What design features are used?
    - 1.6. What information is already available?

2. What functions are required?
    - 2.1. Which functions have the highest priority?
    - 2.2. How are the functions mapped?
    - 2.3. What are the possible solutions for the mapping problems?
    - 2.4. What internal components and packaging are needed for the functions?
    - 2.5. How are the functions controlled?

3. What are the program requirements for the steering wheel?
    - 3.1. What is the locations and angle of the steering wheel?
    - 3.2. What are the dimensions and hard points of the steering wheel?

4. What ergonomics are involved?
    - 4.1. How does the user use the steering wheel?
    - 4.2. What dimensions are important?

5. How does the interior accommodate the steering wheel?
    - 5.1. How does the interior collaborate with the steering wheel?

6. Which design concept is best suited to the programme of requirements and design aesthetics?

1.7_PLANNING

To start the project, an interactive Gantt chart is built in Excel. This allows to make a project planning based on work load percentages or days, which automatically aligns the tasks accordingly. The current day and finished tasks are highlighted. Multiple items will happen at the same day during the project but this planning is a good guide to get the project going, to work towards the deadlines and to see what needs to be done.

2: Analysis

2.1_LOOK AND FEEL

Automotive design is a highly visual form of design. All discussions and weekly updates are substantiated by images in order to quickly share ideas and design directions. This is why most of the analysis has been documented visually. The images are from the internet, but composed into mood boards to fit and describe the themes and design language.

NextEV's key words for the steering wheel are visualized to get an understanding of the look and feel of the steering wheel.

2.2_MATERIALS

The mood board of the possible materials takes the themes into account. Later on in the project, the material combinations for the interior are determined and applied to the steering wheel.

2.3_COMPETITORS

To show the market compared to the competitors, the competitor analysis show what direction to go for. Next to these, a big number of steering wheels have been analysed. There doesn't seem to be a standard layout for the different function.

2.4_ERGONOMICS

For the ergonomic analysis different steering wheels have been tested, ranging from normal car steering wheels to race car steering wheels. The positions of the hands and fingers have been evaluated, together with the location of the function switches on the steering wheels. The most important functions are located in a way that they are accessible with the thumbs without changing the hand location on the handles.
The main problem seems to be with the fingers at the back of the rim. Most steering wheels don't accommodate these perfectly. Multiple meetings with engineers helped to get a better understanding of the ergonomics and possibilities. Later on in the project, the ergonomics of the models are evaluated with a race car driver.

2.5_FUNCTION ANALYSIS & MAPPING

The meetings with the engineers also defined a function list with the functions on the steering wheel. During the competitor analysis and meetings with the engineers it became clear that there isn't a real protocol about the placement of the different functions. A logical and simple idea for the layout is proposed, but the exact idea cannot be mentioned in this non-confidential version. An image is made that shows a global function mapping that will be used in the designs.

During the project the function list changed a few times by combining, omitting and changing some functions.

2.6_PROGRAMME OF REQUIREMENTS

The previous information and meetings led to an initial programme of requirements. All the dimensions, features and functions are described in the programme of requirements.
This will change slightly during the project.

3: Design

3.1_Stage 1

3.1.1_Initial sketches

Before starting the project, a few designs for the steering wheel were already made by another designer. Those designs were not perfect, but the proportion are good at this moment. These proportions are used for the initial sketches. Different options are tested to see what works with the style intent for the project. The sketches start with sketches on paper, followed by renders in Photoshop. To maintain the specifications in the programme of requirements, the design has moved around in a way which satisfies all points.

3.1.2_Handle ergonomics

The ergonomics are an important part of the steering wheel. The ergonomics can be divided into three parts:

- The handle ergonomics, which is a comfortable grip for different size hands at the given steering wheel location.
- The button ergonomics, which is a button layout that is easy to reach and use for different size hands.
- The steering ergonomics, which is a usable steering wheel during steering.

To incorporate the handle ergonomics into the design from the early stage, multiple clay handles have been made. These models are evaluated by a number of people with different size hands from small to large, which all fit well. The first model is scanned to be used as guideline for the modelling.

3.1.3_Digital sketch model

A digital model is modelled in 3Ds max to make a quick assessment of the Photoshop renders and sketches. The 3D scan of the handle is used as guideline for the rim. The 3D model showed a few flaws which are not apparent in 2D Photoshop renders. This changed the design direction.

3.1.4_Design changes

A new design feature has been introduced with multiple sketches to fix the flaws from the previous model. Different options are proposed in sketches and translated to 3D. Because of the design direction, it was decided to continue digital directly, since this would be too difficult in clay. A rough digital model is made to evaluate the design.

3.1.5_Digital model

The digital model is fine-tuned and finished to be send to the mill. Photoshop renders are made based on screen shots of the digital model. These are used to accomplice the physical model during the review.

3.1.6_Foam model

The digital model is milled in foam and painted for the first review. This model is the first stage, without any details. In order to fit the model in the interior, a placeholder for the steering column rod is modelled and milled at the back of the steering wheel. This slides

inside a steering column tube. The model is painted in the specified colours for the interior. Each colour describes a different material.

3.1.7_FEEDBACK REVIEW 1

During the review the steering wheel is evaluated by the whole team. Overall, the design direction is received positively. The next step is to add the details and process the feedback.

3.2_STAGE 2

3.2.1_DIGITAL MODELS

The second stage continues digitally, changing the model based on the feedback and evaluation of the first mill.

Two models are made. One being a similar to the first model, but with changed proportions. The second being a model with different rim and spokes and slight changes to the hub. The digital models are both milled in foam to be evaluated and modified with clay.

3.2.2_CLAY MODEL

The milled models show positive and negative points. Both models will be painted for a review later on but the second model will be the main direction for now. The proportions are better and the difference in between the two is good to compare.

The grip needs clay work to get better handle ergonomics, and the button need to move for the button ergonomics and hand clearance. These changes are made on the left hand side first to compare the differences. This is balanced to the right hand side after establishing the correct shape. The thumb area is also shaped to an good looking form that still works ergonomically. A Photoshop render is made to show the design proposal.

3.2.3_STEERING COLUMN LOCATION

For the previous review, the steering column was set up from a distance of points on a foam model. This isn't really accurate.

The correct location of the steering column is really important since the steering wheel height, the IP and the vision line from the eye point work closely together. The steering column points are taken out of the engineering data and located in the interior buck with the measuring bridge to fix the steering column at the correct location.

3.2.4_DIGITAL MODELLING SUPPORT

During this time two other digital steering wheel models are made by other designers and modellers based on my research and specifications and the sketches of two other designers. Let's call these model P and Y.

The designer of the model P was working at a different location. Since the modeller didn't really have a designers eye, I helped to translate the idea's into a three dimensional shape. With only a render of the front available, my input formed a three dimensional shape of this design.

Working together with an Alias modeller gave good insight into the workflow and methods of modelling in Alias. This is valuable later on in the project.

Model Y didn't include a back which makes it difficult to compare with the other steering wheels in the interior model. A simple back and column rod placeholder are modelled in Alias.

3.2.5_DESIGN CHANGES

In consultation with the engineers, we came to the conclusion that a certain part of the steering wheel wouldn't work. To fix this, a change with clay is tested on the model P foam mill. This improvement wasn't good enough, which made the decision to add a bigger change to model Y. The steering wheel is tested with the engineers and works great.

Based on this, the steering wheel package file in Alias is updated showing the correct three dimensional locations for the different items in the steering wheel, including rim dimensions.

After the meeting with the engineers, the same changes are applied to the master model. The model is scanned to use digitally. With this data, the Photoshop render is updated. Additional changes have been made to increase the ergonomics while maintaining a good looking design.

3.2.6_CLAY MODEL

As last step in this stage, the clay model is finished to a balanced model with small tweaks to the rim and hub. The design has been simplified without losing too much of the ergonomics.

This design model is painted, scanned and used for the most important review where it will be compared to the P and Y model.

3.2.7_FEEDBACK REVIEW 2

During the review of this stage, a design direction is chosen. The spoke and hub design of the Y model is chosen, but on ergonomics and shape my rim is a lot better. Therefore it was decided to combine my rim with the spokes and hub of the Y model. However, the hub still needs work because the design doesn't fit the package completely. Next to that, the back of the steering wheel could be better. In the next stage, all of this will be combined, designed and modelled into a digital model.

3.3_STAGE 3

The third stage starts with a rear 3/4 Photoshop render of the chosen design direction. A few changes are made so it works better with the rest of the interior.

3.3.1_ALIAS MODELLING

During the previous stages, all my digital models were modelled in 3Ds max. This is good for quick poly modelling, but not usable for manufacturing which need high quality NURBS surfaces. To get this surface quality, the third stage is modelled in Alias.

The model is built around the previously created package file and latest 3D scan. An integration from the model Y spokes to my rim is designed and other design problems have been solved. A part of the rim is modelled by a professional Alias modeller because of the complexity and time constraint.

Different buttons have been designed, trying to get an integrated design that works together with the rest of the interior.

3.3.2_RACE CAR DRIVER TEST

At the same time, a race car driver has visited the studio to test and confirm the usage and ergonomics of the physical models from last stage. The feedback is positive. The changes are received positively and the overall feel of clay rim is good.

One slight issue with the thumb area is noted which will fatigue the thumbs too quickly. Changes to prevent this are tested on the clay model and applied to the digital model.

3.3.3_FINAL RENDER

For the final mill and to continue into production, the digital model has been given to a professional Alias modeller. Based on my design input the incorrect surfaces have been fixed, rads have been added and difficult parts have been modelled. A Photoshop render is made to support the physical model during the last review.

3.3.4_PHYSICAL MODEL

The last model is milled and painted externally. I did however assemble all the components. Besides that, the steering column is fixed after an imprudent engineer broke it, just in time to be useful during the last review.

3.3.5_DESIGN ADJUSTMENTS

Based on the feedback of the final review and the ergonomics of the physical model, small design changes are made to give the whole interior the same look. Luckily combining the rim and spokes worked out in the physical model with only a minor tweak to the one of the rads. These changes are communicated to the Alias modeller trough meetings and mails.

With these changes and some modelling work on the details the project is finished. The final model is send to the engineers who will design the internal components.

4: Conclusion

4.1_RESEARCH QUESTIONS

During the project the following questions have been answered, of which most were clear during the end of the analysis phase:

1. What steering wheels are on the market?
   - 1.1. How are the steering wheels categorized?
     The steering wheels have been categorized to find the right design direction
   - 1.2. What materials are used?
     In the end the materials were determined by the colour and trim team, but the material analysis helped to give a design direction
   - 1.3. What colour combinations are used?
     In the end the colour combinations were determined by the colour and trim team
   - 1.4. What functions are used?
     The function list has been made together with the engineers
   - 1.5. What design features are used?
     In the end, the design mainly followed the interior and not other available steering wheels
   - 1.6. What information is already available?
     During the analysis phase of the project, all available information has been gathered to get an understanding of the project

2. What functions are required?
   - 2.1. Which functions have the highest priority?
     The highest priority functions have been listed
   - 2.2. How are the functions mapped?
     A systematic layout has been made
   - 2.3. What are the possible solutions for the mapping problems?
     Different options have been proposed to combine and simplify the layout which helped solving any problems
   - 2.4. What internal components and packaging are needed for the functions?
     The internal components have been discussed with the engineers and used during the digital modelling to ensure a feasible design
   - 2.5. How are the functions controlled?
     Different options have been discussed with the engineers

3. What are the program requirements for the steering wheel?
   - 3.1. What is the locations and angle of the steering wheel?
     The steering wheel location and angle from the engineers has been tested and tweaked in the interior buck
   - 3.2. What are the dimensions and hard points of the steering wheel?
     The dimensions and hard points have been discussed and determined with the engineers

4. What ergonomics are involved?
   - 4.1. How does the user use the steering wheel?
     The different scenarios have been discussed with the engineers
   - 4.2. What dimensions are important?
     By using a reference steering wheel and building physical models, the important dimensions have been determined

5. How does the interior accommodate the steering wheel?
   - 5.1. How does the interior collaborate with the steering wheel?
     Design elements of the interior have been copied to the steering wheel

6. Which design concept is best suited to the programme of requirements and design aesthetics?
   Different design options have been evaluated and discussed with the design team during the project

4.2_EVALUATION

The goal set for the project is completed. A feasible design of the steering wheel is delivered which will go into production.

The time plan worked out and helped to get the project moving in the right direction, although it took some long days now and then to get everything finished in time. Beforehand, the plan was to do more clay modelling since that's the field I want to work in. This was however not the best option with the design direction. As a result, a bigger focus was made on the digital modelling. However, by combining the digital modelling and clay modelling in milled foam models with clay adjustments, I think we got a way better result than using only one of the two.

At first, the fact that my design at the end of stage 2 was not fully chosen was regrettable, but in the end I think it worked out for the better. Besides, this gave an interesting new design challenge during the last stage since the design was far from complete. Next to that, the opportunity to learn Alias from the professionals was great. This will also help in the future as a clay modeller to be able to communicate with digital modellers and designers.

Personally I am satisfied with the results. The result feels like a balanced and good design conclusion of all the work. More than all, the project was an enormous learning experience which I am grateful for. Not only on a designers level, but also as an employee.

I learned:

- to design and model a steering wheel
- how to work in a design studio as part of a team
- the proper ways of clay and Alias modelling
- important lessons on automotive design
- the importance of good communication
- that working 70 hours a week is not impossible and totally worth it for such an amazing project
- to interpret another designer's design and combine this with your own ideas
- to give design direction to alias modellers
- how to work with confidential data

... and probably a lot more

Working in the studio was good with a lot of freedom on how I wanted to organize the project, but enough guidance to keep it moving in the right direction. All the colleagues were down to earth, talented and motivated which was a real motivator to perform even better. I definitely see myself working in this kind of environment in the future.

It was quite a privilege to be able to go through all the different design and modelling facets for a production vehicle as a student. I would absolutely do a project like this again!

4.3_RECOMMENDATION

Although the design of the steering wheel is almost done, a few things are on the list to follow up. A few rads needs to be added. The idea for the buttons is there, but these should be rebuild by a professional Alias modeller. To conclude the project, an exact list of recommendations is send with the note that I am open to future advice and feedback.