CHALMERS

Buckle development for stroller restraints

Investigation and design of buckles for Holmbergs Childsafety AB

Master of Science Thesis

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CHALMERS UNIVERSITY OF TECHNOLOGY
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Perface

The report is a result of thesis which conducted at the Department of product and production development, Division of Design and human factor at Chalmers University of Technology. The project sponsor has been Holmbergs Childsafety AB in Anderstorp, Sweden. The project constitutes of 30 hp (ECTS) and has been ongoing from March 2010 to November 2010.

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We would also like to thanks industrial design engineer Zhinan Zhang for his advice and helping on inside structure of ROTO, and to all the participants in our interviews and observations.

Finally we want to thank our families and friends for the ever-lasting support and affection.

Gothenburg 2010
Zheng Chen&Ling Ma

Abstract

Holmbergs Childsafety AB is one of the world's leading suppliers of buckle, harnesses and connectors to child seat manufacturers worldwide. Meanwhile, there have been significant market growths of stroller restraint system during the last years. Therefore, a new buckle for stroller restraints will be developed for Holmbergs Childsafety AB.

The goal of this project is, to study how user operate buckle, analysis different type of buckles and design stroller buckle that fulfills the requirements in terms of technical specification, safety, design, ergonomic and cost. The investigation was completed through interviews, observations, literature study and store visiting around stroller restraints. Users, buckles and operation analysis were studied in development phase. A specification of requirement was list according to these study and requirements from Holmbergs Childsafety AB.

In the design phase, two development approaches were used to find different solutions, five concepts were chosen. After discussing with development group of Holmbergs Childsafety AB and a decision analysis against requirement specification, two concepts, OHO buckle and ROTO were selected for further refinement. Two prototypes were created and evaluated against specification of requirement as well. OHO and ROTO diverse widely with each other in terms of price level and functionality. They all fulfill most of requirement but have their strongest point in different areas.

Keyword: Stroller, Buckle, Children restraint system, Holmbergs Childsafety AB, Mechanism.

Table of content

1 INTRODUCTION

Holmbergs Childsafety AB is one of the world's leading suppliers of child safety seat restraint systems and components of restraints, with the philosophy of designing and producing products with high degree of quality and value (Holmberg.se, 2010). On one hand, the company is experienced of child safety seat restraints manufacture. On the other hand, there is a significant market growth of strollers these years. Though buckles of various restraint systems seem different, there are many similarities between child safety seat restraints and stroller restraints. A new stroller market would be developed for Holmbergs Childsafety AB if the opportunity could be seized.

1.1 BACKGROUND

To develop stroller market, a buckle particularly for strollers needs to be prioritized. On one hand, the stroller buckle solution should be with respect to the company's experience of safety seat restraints design and the distinguishing features of stroller restraints. For instance, safety seat buckles require higher security, while stroller buckles require lighter weight and more convenience (Wilson, 2009). On the other hand, besides safety seat, the stroller buckle should also be resembled with other baby transports. As a result, baby transports, child restraint systems and buckles are studied and compared.

BABIES' FACING DIRECTION AND AGE OF VARIOUS BABY TRANSPORTS

Baby transports include infant car seats, baby carriages and strollers, which are all used for transporting and carrying infant, but they differ from each other in term of baby's facing direction and age. First, an infant safety seat is mounted on the seat of a vehicle to protect the infant, in the case of a crash. It is legally required to be used for children up to 2 years old or more. Second, a baby carriage is generally used for babies from new born up to around 6 months, in which the infant always lays down facing the pusher. At last, a stroller is designed for babies who have the ability to sit and hold their heads up. Mainly it is used for children from 6 months up to around 4 years old. An adult caretaker could choose facing direction for baby, usually forward, instead of facing the pusher (Wikipedia, "baby transport", 2010).

COMPARISON OF SAFETY SEAT AND STROLLER RESTRAINTS

Both safety seat restraint and stroller restraint share common structure. They are forms of protective equipments which are fabricated from straps and locking hardware. Each restraint generally consists of anchors, adjusters, shoulder restraint, a buckle, lap straps and a crotch strap (Official Journal of the European Union, 2005). Look at the figure 1-1 below. Stroller restraints are focused on, so all the child restraint systems in this paper refer to stroller restraints except being mentioned especially. Besides structure, they have similar protection and safety functions.

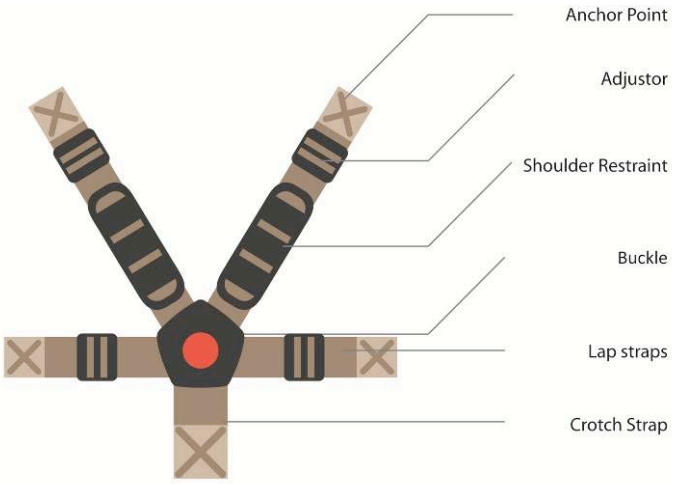


FIGURE 1-1COMPONENTS OF CHILD RESTRAINT SYSTEM

The two kind of restraint should be released easily and avoid being opened by children themselves. On one hand, parents should be able to unbuckle the child restraint system and release the child from the seat and the restraint in short time, especially from a child car seat, since there are some opportunities that car may catch fire after a collision. Though a stroller may not have the same serious issue, the restraint system still needs to be handled easily. On the other hand, both buckles in car seat and stroller need to avoid unauthorized opening. A car seat belt would not provide protection if it is not buckled in, and it is the same as a stroller buckle. These are the similarities of these two kinds of restraints, but there are also some differences, in term of standards, utility conveniences and complexity.

In term of standards, infant car seat restraints are required by relatively unified standards, while there is not any widely accepted standard for stroller restraints (Wilson, 2010). Since the high speed of vehicles lead to high risk of death and injury on children, the EU requires usage of safety care seat in vehicle legally. Children less than 12 years old are required to use car safety seat restraints

(Official Journal of the European Union, 2005). However, the use of stroller restraint differs in various countries, and usually, children's age is ranged from 6 months up to 4 years old. Even though there is no unified standard, the security awareness of stroller restraints is ascending.

Besides standards, another difference is convenience of usage. Restraint systems for stroller need to be more convenient than child seat restraint system. Car seat restraints are used only in vehicle. However, parents use strollers every day and everywhere. For instance, strollers' scenario could be home, shopping mall, park or even beach. As a result, buckle for stroller need to easy to operate in order to satisfy the users' demand under different conditions. Besides conveniences, the structure complexity is different.

At last, compared with stroller restraint, structure of safety seat buckle is more complicated. The reason is that security requirements of vehicle components are much higher than strollers' and the restraint cost should be coincided with the surrounding system. Since a car costs much more than a stroller, correspondently, the restraint of stroller should cost less than that of a car seat restraint. This decides that the restraint structure of strollers should be simpler (Wilson, 2010).

Differences between 3-point and 5-point Restraint Systems

There are mainly two types of child restraint systems, 3-point and 5-point system. The difference is the shoulder restraint, which is configured to limit forward motion of the torso and upward motion of the lap straps. Certainly, from the perspective of the baby who is protected by these safety belts, it feels more comfortable in a 3-point restraint system, for it can turn around as its wish. However, without a shoulder restraint, a 3-point restraint can hardly prevent the baby from rolling out of the stroller. Therefore, it is the five points system that EU safety standards recommend, and it is regarded as the main object of study. (Wilson, 2010) Since a five-point system has a higher degree of safety and is recommended, but a three-point system contributes to comfort for the baby, some restraint manufactures provide solutions for converting a 5-point system into a 3-point restraint.

Instead of using connected shoulder and lap straps, separate shoulder and lap straps are applied so that it is possible to convert the 5-point restraint between 3-point-utility and full-utility mode. Full-utility mode means a restraint is under the protecting mode with all the 5 straps connected to the buckle. On the other

hand, 3-point-utility mode means a restraint is under the protecting mode with only crotch and lap straps connected to the buckle. The shoulder restraint is left unused.

Introduction of Clasps and Side Release Buckles

There are mainly four types of conventional buckles, clasps, slide buckles, belt buckles and side release buckles, among which clasp buckles and side release buckles are widely adopted in stroller field (Figure 1-2). A clasp buckle consists of two main parts, a hook part and a loop part. It connects two ends with the hook lock on the loop (Meredith, 2008). A side release buckle, on the other hand, consists of a latching portion and a receptacle portion. The latching buckle member consists of a center guide, two spring arms each has a lock block at the end. The receptacle part has a front opening and two side openings which lock the two spring arms of the latching portion. This kind of buckle is quite often to be found on backpacks (Meredith, 2008).

Figure 1-2Clasp and Side Release Buckle

1.2 Aim

The aim of this project is to develop two buckles which are able to fit to 5-point restraints. During the buckle development, safety, ergonomics, cost, as well as aesthetics will be taken into consideration.

1.3 Outline

The outline of the report is described first for better comprehending. First of all, all methods and theories which will be applied and mentioned are listed in the methodology part. The rest of the report is divided into three phases (Figure 1-3 below). In the research phase, users and buckles studied. Five specifications listed at the end of this phase, which used as guides in the design phase. One hand operation, fewer components and convertibility should be achieved if possible. Application of differences between age groups and press opened buckles is recommended.

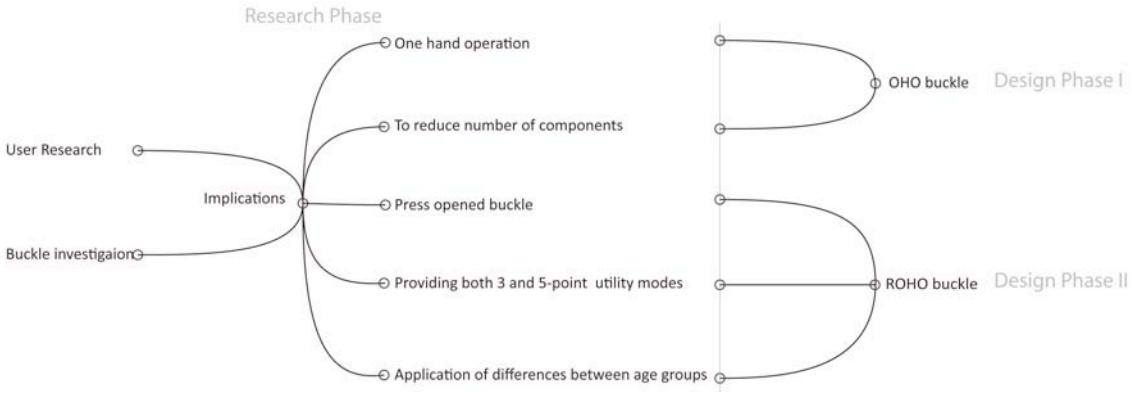


FIGURE 1-3 OUTLINE OF THE REPORT

In the design phase, ideas are generated according to the specifications as far as being mentioned. Since these specifications could not be combined, two final concepts are reached. Firstly, OHO buckle was generated to achieve one hand operation and low-cost. Second, ROTO was designed, with mainly considering convertibility, press opened and security.

1.4 DELIMITATION

Delimitations in this project have been described below.

The project mainly focuses on buckle instead of other parts in restraints system.

The project would not go depth into tensile force test for prototype.

1.5 REQUIREMENTS

The stroller buckle should conform to particular technical requirements. First, the buckle should be possible to fit to a 5-point harness system. Second, the design of the buckle must prevent the possibility from being left in a partial closed position. The buckle must not lock when the parts have not been inserted the right way and only lock when all parts are engaged. At last, the slot holes must be suitable for a strap of 25 mm wide and the upper two slot holes must be 45 degrees from horizontal.

2 METHODOLOGY

Application of methods and theories in different phases is summed up in this chapter (See table 2). In the user research phase, interviews, observation, persona and scenario were conducted. In term of buckle investigation, benchmarking, ergonomic theoretical studies, task analysis and subjective analysis were adopted. During the idea generation part, brainstorming, constraint-based motion imitation and decision analysis were applied. FMEA was used in the final result part. Each method is described below as well as their implementations.

Research Phase	User research	Interview
		Observation
		Persona
		Scenario
	Buckle research	Benchmarking
		Ergonomic theoretical study
		Task analysis
		Subjective analysis
Design Phase	Idea generation	Brainstorming
		Constraint-based motion imitation
		Decision analysis
	Final results	FMEA

TABLE 1METHODOLOGY

2.1 INTERVIEW

Interview is the most fundamental method for gathering information regarding what people think according to Bohgard et al. (2009). It could be divided into structured, unstructured and semi-structured interviews. In structured interviews, close ended questions are contained. Interviewees have to answer the same questions exactly in the same order. It is suitable for getting quantitative data. In unstructured interviews, people are can choose to answer a limited and pre-set range of questions, so that they express individual responds. In a semi-structured interview, interviewers are allowed to bring up new questions, according to the answers (Bohgard et al., 2009).

The first Interviews were conducted in order to study how strollers are used in an indoor environment. A semi-structured interview was prepared, in which numerous environment-related questions were devised. It was carried out in an indoor shopping mall, Nordstan in Gothenburg and took a half day. Ten adult caregivers were involved. All of them were parents of babies, nine were female. In this interview, five questions were given. At last, videos were recorded if allowed. From the open-end questions and conversations with the interviewees, reflections were recorded (Appendix A).

The second interview focused on aboard environment. It was conducted on transportations, such as bus and tram in Gothenburg in winter, twenty peoples were involved. The second interview was a structured interview, there were 14 questions in total, and each question contained several options, which was convenient for the interviewers to follow (Appendix B).

2.2 Naturalistic Observation

Naturalistic observation is one type of observation methods and it involves planned watching, recording, and analysis of observed behavior. In the naturalistic observation method, objects' behavior or phenomenon in its natural setting was carefully observed and recorded by the researcher, sometimes over a prolonged period. The researcher cannot directly interfere with in any way. In the social sciences, observing of humans or animals activities in real life settings was usually involved. It provides opportunities, for researchers, to study objects in their nature environment to obtain better understanding from objects' perspective. The advantages of it are getting first-hand information, simple to use, verifying data from other source. However, it is relatively small sample size, maybe affected by observer's subjective perception and behavior can only be described, not explained (Ngo, 2009).

A small scale observation was conducted in a children product exhibition in Svenska Mässan, Sweden. Since the respondents were observed unobtrusively, they could act in their natural habits. In this observation, children behavior and restraint usage of adult caregivers were studied.

2.3 Persona

Persona could be used for describing users and the target group. It consists of a picture of a person and a brief description which relate to his or her lifestyle and

connection to the products. Typical user and how he or she usually interacts with product could be represented by persona.

Based on interviews and observations, two personas were constructed. In the first persona, surrounding of adult caregivers was described, which included lifestyle, activities, physiology and so on. For the second persona, psychological characteristics of toddles and body development were taken into consideration (Appendix C).

2.4 SCENARIO

A scenario is a method that creates a story of how the product will be used in this context. It can be made using written storyboards, acted video recording or tested objects from rapid prototyping tools. In a scenario, at least one goal and one actor should be contained and there is a defined starting state for the episode that interacts with the actor when using the product. It needs to involve several tasks for the actor to complete. This method creates a circumstance that the product is to be used, and finds problems before making a product developing, which could be hard to predict. The environment and way of usage would be clearer by scenario. It is always in the early developing stages (Carroll, 2000).

According to the information of the second interview, a scenario which focused on stroller usage on tram in winter was created. Some using problems with stroller restraints and buckle were found under this circumstance (Appendix D).

2.5 BENCHMARKING

In benchmarking, competitors on the market are compared and analyzed. An investigation of similar type of product and solutions are conducted. It could gain better understanding on competitors' weaknesses and strengths. Benchmarking could be used in development phase and acts as an inspiration to new ideas.

The benchmarking was conducted in several child product stores in Gothenburg to investigate buckles. Photos of buckles outlooks and operation postures were taken. Brands, types, features and functions were researched. The results of benchmarking were basis of security, converting, releasing analysis and brainstorming (Appendix E).

2.6 Ergonomic Theoretical Study

Ergonomic theoretical studies focus on gathering theoretical knowledge in anatomy and physiology of body parts, which could be applied in further ergonomic analysis. For instance, it could be used in task analysis, subjective analysis, Electromyography, Predictive Ergonomic Error Analysis and so on. First of all, a certain part of body or muscle would be chosen. Then, theoretical knowledge around structure, skeleton, vessel, ligament and nerves of this body part were studied. Base on this information, knowledge and relations could be gathered among body anatomy and functions. Subsequently, reasons and types of injuries, trigger point of load of this part could be known.

Hand functional resting position was found after analysis of hand structure, skeleton, vessel, and ligament and so on. The study of joint, strain and hand injuries shows that hand was sensitive, flexible can easily get overloaded or injured during physical work. Much strain and narrow space on joint, blood vessels, nerves, muscles and tendon could cause joint problem and hand injuries. Meanwhile, hand functional resting position was found. In this position, hand could be nature and relax. As a result, the hand functional resting position is suggested. This position was applied in buckle releasing analysis (Osvalder and Bligård, 2008).

2.7 Task ANALYSIS (HTA)

Task analysis (HTA) is a method that could describe how tasks are performed systematically and shows the relation between different sub-tasks. It breaks down a task or a goal into sub-tasks and a sub-task as a goal can be broken down once more. When people operate products, there may be some obstacles. With task analysis, difficulties could be predicted, systematically and evaluated in the perspective of usability, ergonomic and functional requirement (Osvalder and Bligård, 2008) (Bohgard and Dahlgren, 2009).

Pressing-opened buckles and pinching-opened buckles were researched with this method. Releasing and closing task were divided into several sub-tasks. It was found that more problems existed in releasing procedure, such as some buckles required more hand strength which cause pain.

2.8 Subjective Analysis

With subjective analysis, experiences of subjects can be estimated, since experience of discomfort, pain and so on can be difficult to measure objectively. However, this method offers an objective way to express those feelings visually, with combining rating methods, such as CR-10 and body maps. As a result, it could make sure a balance between objective and subjective measurement and provide good communication for experience. On the other hand, subjective analysis is only based on individual experience rather than statistical data (Osvalder and Bligård, 2008).

The subjective analysis was conducted mainly on buckle releasing procedure. Operations of pinching-opened buckles and pressing-opened buckles were compared. Eight types of existing buckles were involved, which had been studied in HTA. Photos were taken to show hand gesture in opening procedure.CR-10 was applied to rate the extent of discomfort. Hand map was used to visualize the localization of discomfort. Two participates were involved.

2.9 Constraint-based Motion Imitation

This method is created to imitate motions according to computer constraint-based animation theory. The animation theory is applied to preserve or change relationship of two objects, according to constraints pre-defined, in computer animation field. A constraint is applied to a motion so that the object would not move in term of constrained features, while in the terms of the undefined parameters, movements are still available (Gleicher, 2001).

The buckling motion was imitated by this method. The buckling task could be divided into two sub-tasks, placing the two portions in the right place and finger movement. To achieve the first sub-task, one hand should hold one portion, while the other hand attach other portions, which could be regarded as constraining an object to another with “constraints”. The second task could be regarded as “path animation”. As a result, the buckling motion could be described and compared detaily and definitly.

2.10 Brainstorming

Brainstorming could create a large amount of ideas. Before the brainstorming, the background of the project needs to be clear (Landqvist, 1994). Possible solutions could be explored.

Three specifications from the research phase were selected for brainstorming, security, convertibility and press opened. Solutions to each specifications were generated, so that three “idea drives” were established.

2.11 Decision Analysis

Decision analysis is a method which could be used in concept evaluation. Concepts are evaluated according to pre-defined objectives. First, a weight is given according to the importance of each objective. Second, each concept is scored by a number from zero to ten. “0” represents that the concept is not comparable with the objective at all, while “10” is completely comparable (Kepner Tregoe, 2010). At last, a score matrix is reached, so that concepts could be compared easily and objectively.

Three concepts formed from brainstorming were evaluated by this method. Explanation for each score is also available in the matrix. As a result, concepts could be compared and selected according to the matrix.

2.12 FMEA

FMEA is a method that could be used in analyze potential failure mode in a system, machine or piece of equipment. Failure modes are problems in a process that may influence customer. Possibility of failure types and the effect on the system of each type of failure are examined. The method is applicable in evaluation and testing period in product development process and it could help a team to identify failure and its severity.

Potential and actual failures of the buckle concept were examined by FMEA. Buckle technical and function problems were identified, and then some of the failure modes were solved, while the rest failures need to be tested and solved by engineering group in further development.

3 RESEARCH PHASE

For gathering information about users and buckle design, some design methods were conducted which include interview, observation, persona, scenario, and benchmarking as well as ergonomics analysis. First, user behaviors in different environment were studied. Second, buckle releasing and converting were analyzed. Then cost and security solutions were discussed. At the end of this phase, implications from this phase are listed for buckle design.

3.1 USER RESEARCH

Stroller buckle needs to meet demands of users in various scenarios. Two interview studies, observations and a literature study were conducted to research user behavior and scenarios. From these studies, it is shown that strollers are used nearly every day and everywhere, such as in shopping mall and aboard buses. There are mainly three types of using environment, indoor, outdoor and aboard trams and buses.

USER BEHAVIOR IN INDOOR ENVIRONMENT

In term of adults, there is high amount of restraint non-use and 3-point-harness using (Figure 3-1), so a harness providing both 3 and 5-point is preferred. One example is that, indoor environments, such as cafeterias, supermarkets and shopping malls are warm, a little noisy and low speed, so the adult caretakers seem more relax and regard security as a secondary concerning. The caretakers in this context are mainly concerned about comfort of children. For example, some argue that if the harness is too confining (Lerner, Huey and Kotwal. 2001). The observing showed that sometimes they make the shoulder strap act as a lap strap and tie the lap strap together around children's waist.

FIGURE 3-1 RESTRAINT USE IN INDOOR ENVIRONMENT

In term of children, they perform a variety of movements in strollers, so child restraint should not compromise children's comfort (Lerner Huey and Kotwal, 2001). In the indoor environment, the surroundings are static and boring, so they may be attracted and become exciting and curious. Children from six months up to four years are curious about the world as well. As a result, their behavior could be leaning and twisting and their activities could be sleeping, eating, playing and so on (Figure 3-2). Thus various gestures make children dislike being constrained and bounded in their seats.

FIGURE 3-2 CHILDREN BEHAVIOR IN INDOOR ENVIRONMENT

USER BEHAVIOR IN OUTDOOR ENVIRONMENT

In outdoor environment, which includes street, park, beach, hill, step, and so on, restraint system seems to be used with high safety consciousness. On one hand, according to the report of Lerner, adult caretakers would be apprehensive for children's safety especially on crossroad, stairs or slope road. On the other hand, children do not squirm or attempt to escape much, when the stroller is in motion. This may because the moving child is more interested in viewing surroundings or calmed by motion (Lerner, Huey and Kotwal. 2001).

DEMANDS OF CAREGIVERS ABOARD

In the aboard environment, adult caretakers are more concern with the security of children. On one hand, the stroller needs to be pushed up and down from vehicle. On the other hand, the bus could be dangling and crowded, and it may brake and turned suddenly. Thus, babies in strollers are more likely to fall out of the seat. In this case, security would be taken into more consideration of parents. An aboard scenario in winter is described in appendix (Appendix D).

According to the interviews in aboard environment (Appendix B), a majority of the users show interest in one-hand-operation buckle. Since most users would use the stroller on a transport and they also have quite a lot of belongs in their hand, such as clothes for their babies, for themselves and shopping bags. Moreover, not all the customers can find a seat on a public transport. So a

parent has to handle the buckle with one hand engaged and lean on the wall of the tram. Furthermore, when the users are asked about if they need a one-hand-operation buckle, almost all the interviewees agreed. A one hand operation solution should be found if possible.

3.2 Buckle Investigation

Stroller buckles were investigated in term of operation, cost and security solutions. First, after analysis of buckle releasing operation, press opened buckle more seems to be operated in ergonomic way. Second, converting operation and convertible buckles were studied. Third, relation between components and cost was discussed. At last, solutions to avoid unauthorized opening and rationality of work load were investigated.

Buckle Releasing Analysis

According to the gesture of opening operation, buckles could be divided into two types, pinch opened and press opened ones. For pinch opened ones, they could be opened by pinching two sides of a buckle together with thumb and forefinger. Pinch opened buckles require more strength during both opening and closing procedure. This kind of buckle locks and unlocks by elastic deformation provided by latching portion.

Figure 3-3 Pinching-opened buckle

The press opened type is opened by pressing middle button. Press opened buckles offer a big button and majority of this kind of buckle seem easy to open. The buckles lock and unlock by elastic deformation provided by spring inside or plastic material in receptacle part (Figure 3-3).

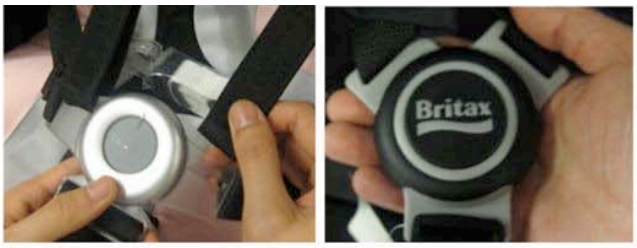


FIGURE 3-4PRESS OPENED BUCKLE

POSTURE LOAD OF PRESS OPENED BUCKLES

Task analysis, subjective analysis and theoretical study were conducted, and it shows that press opened buckles have more advantages over pinch opened ones in term of posture load. Firstly, releasing task is divided into sub-tasks (Figure3-5). Dark colors are marked to show which sub-task was hard to operate. According to task analysis, pinching-opened buckles, 1, 2, 3 and 7 require more posture load and they are relatively hard to open. On the other hand, press opened ones, 4, 5, 6, and performs better.

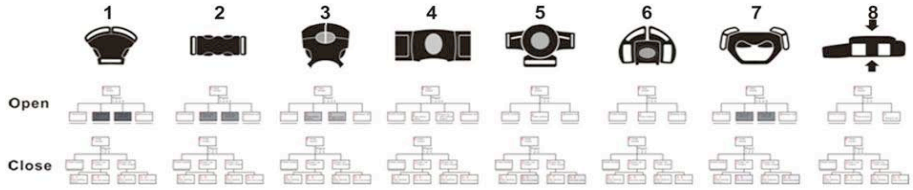


FIGURE 3-5TASK ANALYSIS FOR DIFFERENT TYPES OF BUCKLE

Secondly, according to subjective analysis, open posture of pinch opened buckles is not in correct ergonomics way and it also requires high finger strength. These may lead to strain in finger and joint (Figure3-6 left). On the other hand, hand posture of press opened buckles is more relaxed and natural (Figure 3-6 right).

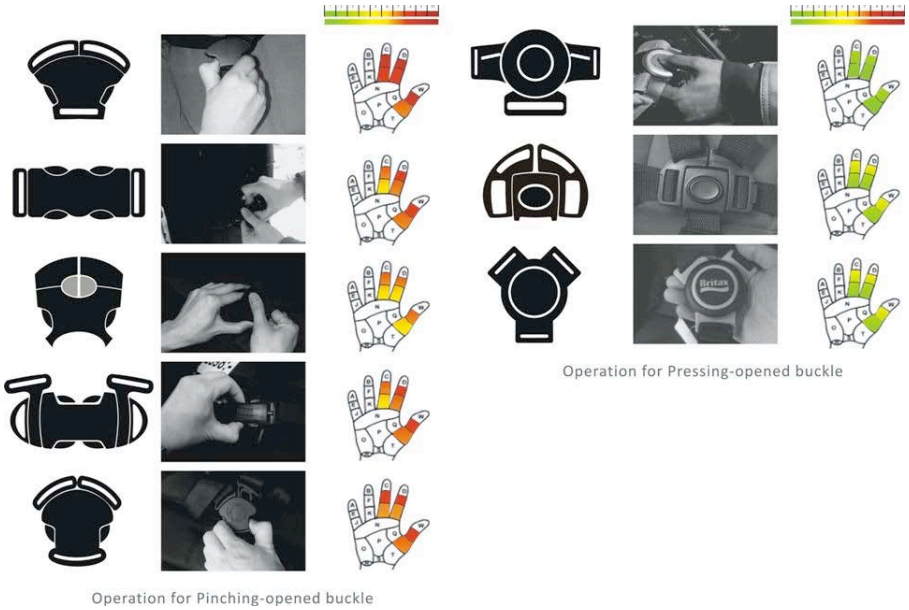


FIGURE 3-6 SUBJECTIVE ANALYSIS FOR POSTURE LOAD

Thirdly, press posture is closer to 'hand functional resting position' (Figure3-7), in term of ergonomics theoretical study. On one hand, a hand functional resting position is more relaxed for human according to joint anatomy (Osvalder, 2009), and joints would recover well from this position (Gillespie, Wilhelmi, 2009). On the other hand, in an incorrect ergonomics position, strain and narrow space for muscle and joint on finger could cause pain and injuries. As a result, since posture of press is closer to hand functional resting position, hand is relatively relaxed and natural compared to pinch opened buckles.

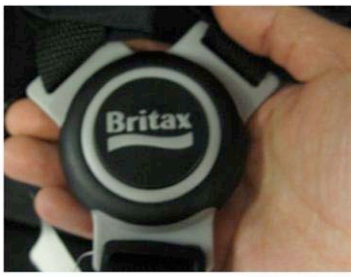
FIGURE 3-7HAND FUNCTIONAL RESTING POSITION

CONVERTING ANALYSIS

According to convertibility, buckles could be sorted into unconvertible and convertible buckles. For unconvertible ones, shoulder straps and lap straps could not be disconnected, thus it only provides 5-point-utility mode. However, a convertible buckle could provide both 3-point-utility and 5-point-utility modes, so that users could chose to use the shoulder restraints or not. Both these two

types of buckles share some common features, for example, crotch slot is nearly horizontal. The figure below shows the two types of buckles (Figrue3-8).

Convertible buckle



Unconvertible buckle

FIGURE 3-8 CONVERTIBLE AND UNCONVERTIBLE BUCKLE

There are three differences between these two kinds of buckles, in term of number of adjustors, slots and angle of upper slot. First, for most unconvertible buckle, the shoulder straps and lap straps need to be adjusted together, so there is one adjustor for changing the length of the whole strap. For convertible buckles, the shoulder straps and lap straps could be used and adjusted separately. Second, majority unconvertible buckle contains 3 slots, one crotch slot and 2 upper slots. For a convertible one, it contains 5 slots, one crotch slot, two upper slots and two slots for waist straps.

Third, angles of upper slot of these two buckles are different. On one hand, the angles of unconvertible buckles need to be around 45 degree, which can keep the lap straps in horizontal position and shoulder straps in almost vertical position (Figure 3-9 a). On the other hand, these angles for convertible buckles are not 45 degree and the angles should coordinate with the position of upper anchor point and buckle. However, since some strollers provide adjustable anchor points, the position of these two ends varies and the angle of straps varies, too. As a result, according to investigation and measurement of existed products, the angles of convertible ones are ranged from 75 degree to 82 degree (See figure 3-9 b).

FIGURE 3-9SHOULDER SLOT FOR CONVERTIBLE AND UNCONVERTIBLE BUCKLES

CONVERTIBLE BUCKLE STUDY

Since convertible buckle is preferred in indoor environment, converting operation and structure of existed ones was analyzed (Figure 3-10). On one hand, if the shoulder restraint and the lap straps could be connected, the buckle could be buckled by latching two times (Buckle 1, 2, 4, and 6). Under five-point-utility mode, it could be convenient for users to operate. On the other hand, for those ones which could not be connected, they have to be buckled by latching four times to achieve 5-point utility (Buckle 3 and 5). As a result, an attachable “shoulder-lap” conversion mechanism is preferred.

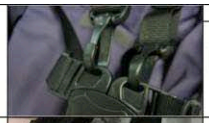
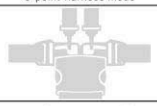
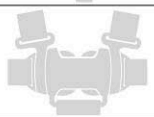
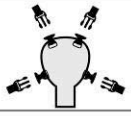
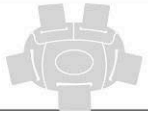
		3-point harness mode	5-point harness mode		
1					This buckle applies hook mechanism. This type of conversion is very common. It requires finger strength and fine finger movement which would cause discomfort in operation.
2					The buckle reduces latching part of shoulder restraints since it is converted by removing straps directly. it is designed to be converted by sliding. And i t can not be converted unless releasing.
3					Shoulder and lap latching parts are separate rather than attachable. The shoulder restraints have to be removed together with lap straps. It is converted by latching and pressing.
4					It is wildly applied in side release buckle. To achieve 5-point-utility mode, the loop of shoulder restraint is slided. To remove the loop, the latching part has to be pinched.
5					Shoulder and lap latching parts are separate rather than attachable. Side release buckle is applied in converting operation.
6					The structure is compacted and shoulder and lap strap can be assembled. It is sliding that the buckle is converted by.

FIGURE 3-10TYPE OF CONVERSION

The first type, “hook”, should be avoided. First, it requires high finger strength, since the length of the hook is relatively short and it requires large deformation. Second, it is thumb pinching that the operation is involved, so fine finger movement is required. To substitute this type of converting, buckle 2, 4 and 6 could be positive inspiration. Buckle 2 reduces the latching part of shoulder restraint. The forth buckle is a convenient solution for updating side release buckle.

COST AND COMPONENTS

The number of components contributes to reducing cost to the largest extent and it is mainly estimated in this project. On one hand, according to the description of cost by Wilson, during the manufacturing of child safety seat buckles, factors that impact buckle cost is number of molds, assembling labor, material amount, and production process. Among these, number of molds influences the cost to the largest extent. (Wilson, 2010) Since number of molds is mainly decided by number of components, cost could be reduced by reducing components. On the other hand, number of molds is also affected by shape and structure design which could be accessed in design phase, while assembling labor, material amount and production process was difficult to estimate.

SOLUTIONS TO AVOID UNAUTHORIZED OPENING

There are some incidents and injury caused by unauthorized unbuckling, according to 7 reports from United Stated Customer Product Safety Commission (CSPS). The average age of children in the incidents is 21 months, with the youngest child aging 12 months. (McDonald, 2001) As a result, solutions to avoid children's unbuckling should be taken into consideration. And existed solutions on the market have been researched first.

According to Haidle's description (Haidle. 2005) and research of existing security solutions, there are mainly four differences, hand strength, hand size, intelligence and coordination, which have been applied in buckle design (Figure11). Operation for the buckle No.1 adopted high hand strength to ensure safety, but opening discomfort for adult caregivers has been increased. Intelligence differences have been applied in 2, 3 and 4 buckle design so that work load could be reduced. For the last buckle, differences of coordination and hand size have been used, which is also a solution to reduce work load. As a result, application of differences between age groups is recommended, which could avoid unauthorized opening and decrease work load.

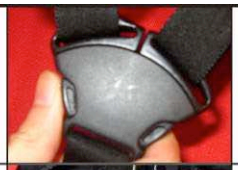
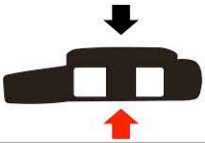
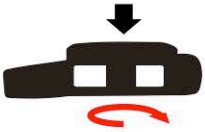
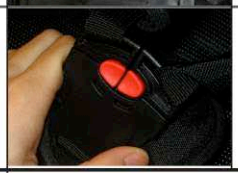
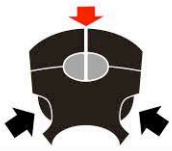
1			This buckle could be opened by pinching two latching parts. It is without an extra safety mechanism. Differences of **hand strength** are applied.
2			This buckle could be opened by pressing top button and bottom button together. It is with an extra safety mechanism. Differences of **intelligence** are applied.
3			This buckle could be opened by rotating mechanism on bottom, and then pressing button. It is with an extra safety mechanism. Differences of **intelligence** are applied.
4			When user press the particular place, it require low finger strength. However, if user pressed other place, it requires relatively higher finger strength. Differences of **intelligence** are applied.
5			This buckle could be opened by pressing middle safety button and launching parts together. It is with an extra safety mechanism. Differences of **coordination and hand size** are applied.

FIGURE 3-11OPENING COMPARISONS, IN TERM OF SECURITY

Application of Intelligence and coordination differences between age groups should be taken into consideration more. According to Arnberg, children would find it hard to open buckle when it requires both finger strength and technical skill (Arnderg, 1976). Therefore this could be an efficient way to reduce unauthorized open. Moreover, for those buckles equipped with these safety mechanisms, finger strength is not highly required.

Work Load Analysis

Grip strength and pinch strength of weakest women and strongest children around 4-year old have been reseached. On one hand, according to literature, pinch strength is approximate 30% of grip strength (zhang,2006). Since, the buckle should be convinient for adults, but difficult for children to open, 95 percent women opening conviniently and 5 percent babies openning extremly were chosen. Grip strength of 4 years boy dominaint hand is approximate 66N (Molenaar ex al. 2008). As a result, pinch strength for children under 4 years old should not be larger than 22N. On the other hand, grip strength and pinch strength for 95 % women are around 230N and 76N respectively(Chen,2000) (Table 2).

	Grip strength	Pinch strength
Women (95%)	230N	76N
Children (5%)	66N	22N

Table 2 grip and pinch strength for adult women and children

Work load in different cases have also been compared, since children and adults would operate the same buckle with different hand gesture. First, in grip opened cases, an adult would open the buckle by gripping, while children would hardly open it with a smaller hand. The most possible open gesture for children is squeezing by two arms, but this require high coordination ability. Therefore, it is quite difficult for them to unbuckle. Second, in case of pinch opened buckles, adults would open it by pinching, but children can hardly open it unless gripping. At last, in general case of press opened ones with safety button, an adult would open by pressing button, while a baby would open it by pinching with two hands. Look at the comparision figue below.

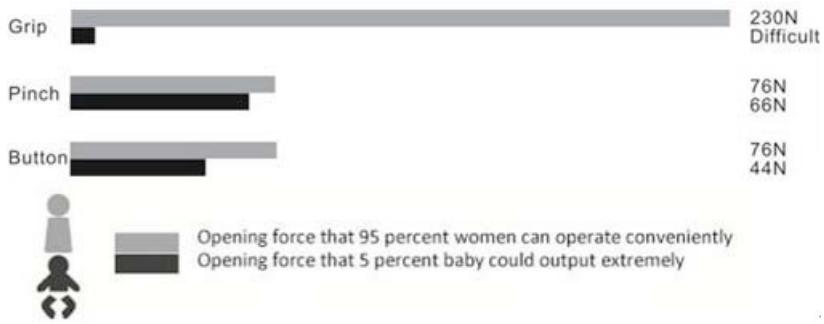


FIGURE 3-12 RATIONAL WORK LOAD OF DIFFERENT OPERATION

3.3 IMPLICATIONS FOR DESIGN PHASE

According to user research and buckle investigation, five specifications are listed as implications in table below for design phase. Though all the chapter previous reach conclusions, since not all the results mentioned in research phase are accessible for idea generation directly, only the five specifications are listed. Subtitles of research phase are listed correspondently, so that sources of each specification are available.

User Behavior in Indoor Environment	A harness providing both 3 and 5-point is preferred.
User Behavior in Outdoor Environment	-
Demands of Caregivers Aboard	A one hand operation solution should be found if possible.
Buckle Releasing Analysis	-
Posture Load of Press Opened Buckles	Press opened buckles have more advantages over pinch opened ones.
Converting Analysis	-
Convertible buckle study	-
Cost and components	Reducing cost by reduce number of components.
Solutions to Avoid Unauthorized Open	Application of differences between age groups is recommended.
Rationality of Work Load	-

TABLE 3 SPECIFICATIONS

For better meeting these specifications, two design phases were conducted. On one hand, some of specifications are conflict. For example, a press opened and convertible buckle could require more components and a one-hand-operation buckle could lead to unauthorized open. On the other hand, two aimed designs are appropriate for different target market strategies. As a result, two concepts

are going to be generated. One of these could be operated by one hand and low cost. The other one is convertible, with consideration of press opened and high security (Table 4)

A one hand operation solution should be found if possible.	Design Phase I
Reducing cost by reduce number of components.	
A harness providing both 3 and 5-point is preferred.	Design Phase II
Press opened buckles have more advantages over pinch opened ones.	
Application of differences between age groups is recommended.	

TABLE 4 SPECIFICATIONS IN DIFFERENT DESIGN PHASE

4 DESIGN PHASE I

In this phase, concepts have been generated according to the specifications of one hand operation and fewer components. First, as one of the most low cost buckles, side release has been analyzed. Second, buckling motion has been imitated by constraint-based animation theory, so that a solution to one hand operation is achieved. Then the OHO idea has been refined in term of outlook, indication and material. At last, this concept has been evaluated and tested by method FMEA and a prototype.

4.1 SOLUTION TO REDUCE COMPONENTS

After analyzing around a hundred US patents of stroller buckles, vehicle safety seat buckles and belt buckles, it was found that there are four basic components of a buckle, two catching ends, a trigger device and a conversion devise. The two catching ends fasten two ends of straps. The conversion devise is usually a spring, so that the buckle could be converted between open or close mode. At last, the trigger device is usually a button, so that the buckle could be controlled. As a result, to reduce the number of components could be achieved by integrating basic components together.

Side release buckle is a positive inspiration reducing components (Figure 4-1). There are only two components of a side release buckle, receptacle potion and latching potion. On one hand, the latching portion is integrated with the function of one catching end, button and conversion device. On the other hand, the receptacle part also serves as a cover.

FIGURE 4-1 SIDE RELEASE BUCKLE

Furthermore, in order to find new solutions to reduce cost, new mechanism solutions are generated. First, gestures have been researched according to ergonomic literature and verbs in dictionary. Second, eight movements have been selected and concept ideas have been generated according to these verbs.

At last, after optimization and integration of the mechanisms, two solutions have been found (Appendix F).

4.2 Solutions to One Hand Operation

A solution to one hand operation has been achieved by analyzing side release buckle. First, buckling motion has been imitated, so that the influences of operation could be concluded. And then suggestions to simplify the operation procedure have been listed. Second, participates in buckling procedure have been reduced so that the buckle could be handled by one hand. Third, a concept called OHO buckle is found and described. At last, this concept has been compared with a typical buckle.

Influences of Buckling Motion

According to the constraint-based animation theory, if an object is constrained by both these two constraints, point constraints and orientation constraint, the object is not supposed to be modified in any spatial parameter feature. Look at the figure below.

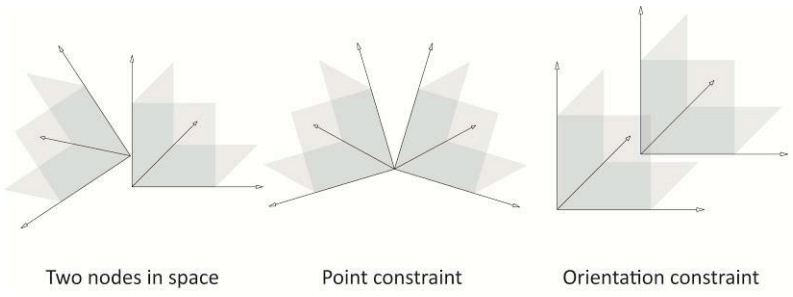


Figure 4-2 Two Objects in Space

On one hand, a point constraint constrains an object to the point in space as the rotate pivot position of the object. So when an object is constrained to a point, the position of the object's rotate pivot is defined as the selected point. As a result, the constrained object could not move in any axis, but it can still be modified in term of rotation at the defined pivot. On the other hand, an orientation constraint modifies the rotations of the constrained object so that its local axes match those of the constraint object. That an object is constrained to another object means all the axes of it have to be paralleled with the object which it constrains to. So the constraint object could not be rotated on any axes, but it still can move along a axis. (Alias, 2010) Constrains are one of the factors which impact the buckle usage.

Besides path animation and constraint which are called sequence factors, number of participates and muscles applied impact the assembling task, too. (See figure 4-3). In term of the task, constrains and path animation decides how many steps in the whole procedure. And the number of participates indicates the resources included. In term of human beings, application of muscles contributes to different feelings, which is another factor which impacts operation. As a result, an easy-to-operate buckle means limited number of assembling steps, fewer participates and controlling a relatively simple part with stronger muscle. Two buckles, side release buckle (A) and clasp (B) are compared with respect to sequence factor, participate and muscle, for they are most widely used in strollers.

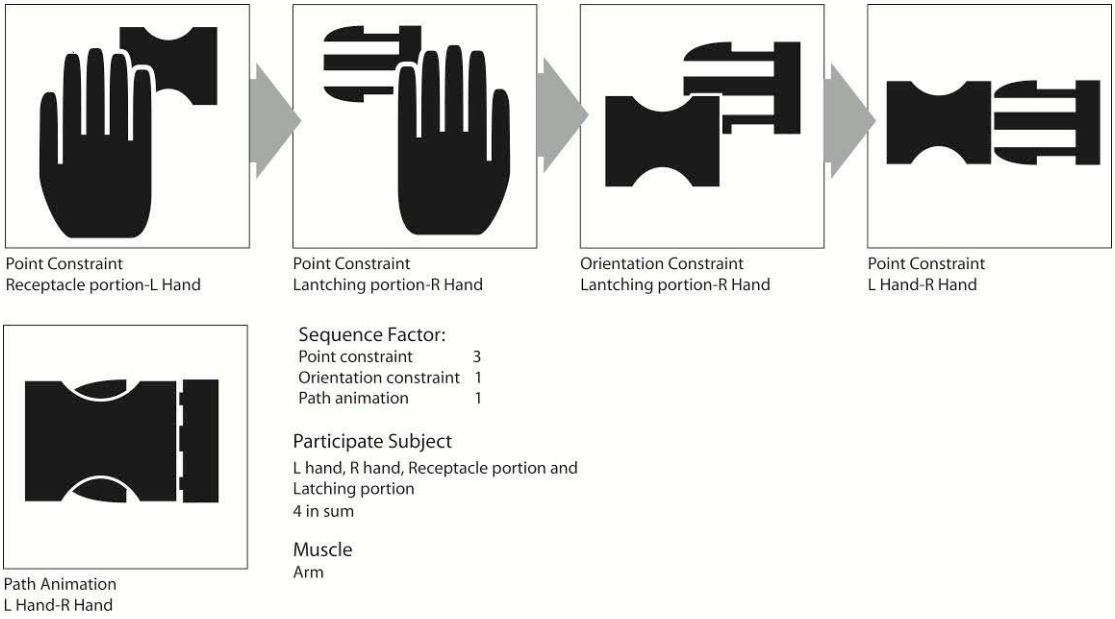


FIGURE 4-3ENCLOSING PROCEDURE OF SIDE RELEASE BUCKLE (A)

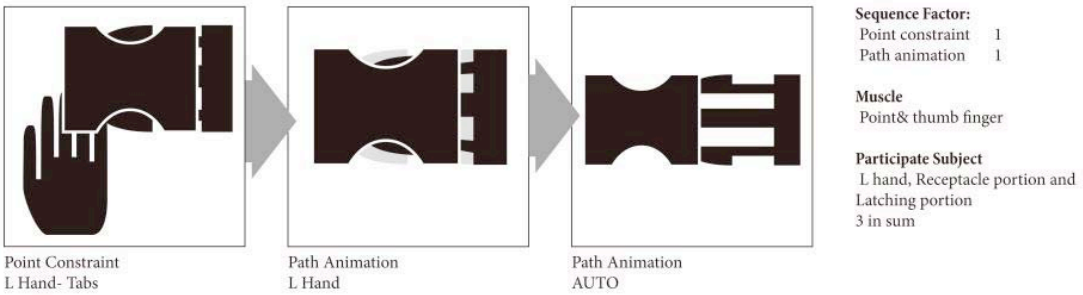


FIGURE 4-4OPENING PROCEDURE OF SIDE RELEASE BUCKLE (B)

Look at the figures 4-3 and 4 above. For the side release buckle (A) the whole task can be divided into five steps. First step is to hold the receptacle part,

which could be regarded as a point constraint. The second step is to find the latching portion with right hand, which is another point constraint. The next step is to set the latching portion and the receptacle portion in the same orientation, in order to assemble later. Fourthly, contact the latching part with the open slot of receptacle part. At last, push the latching tabs into the receptacle portion. The last step is a path animation of simple straight line.

There are four participates and finger muscles are involved. Left hand, right hand, receptacle portion and latching portion are used. To open and close the buckle, a user should pinch the parts, so point and thumb finger have been engaged. The clasp buckle is analyzed with respect to sequences factors, participates and muscles, too.

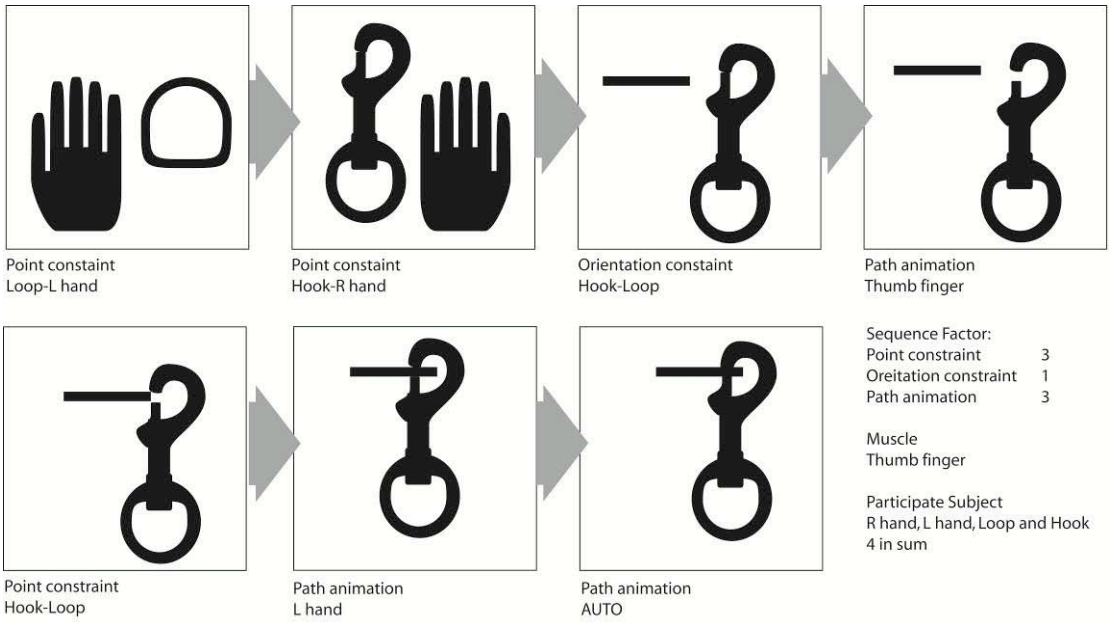


FIGURE 4-5ENCLOSING PROCEDURE OF CLASP (B)

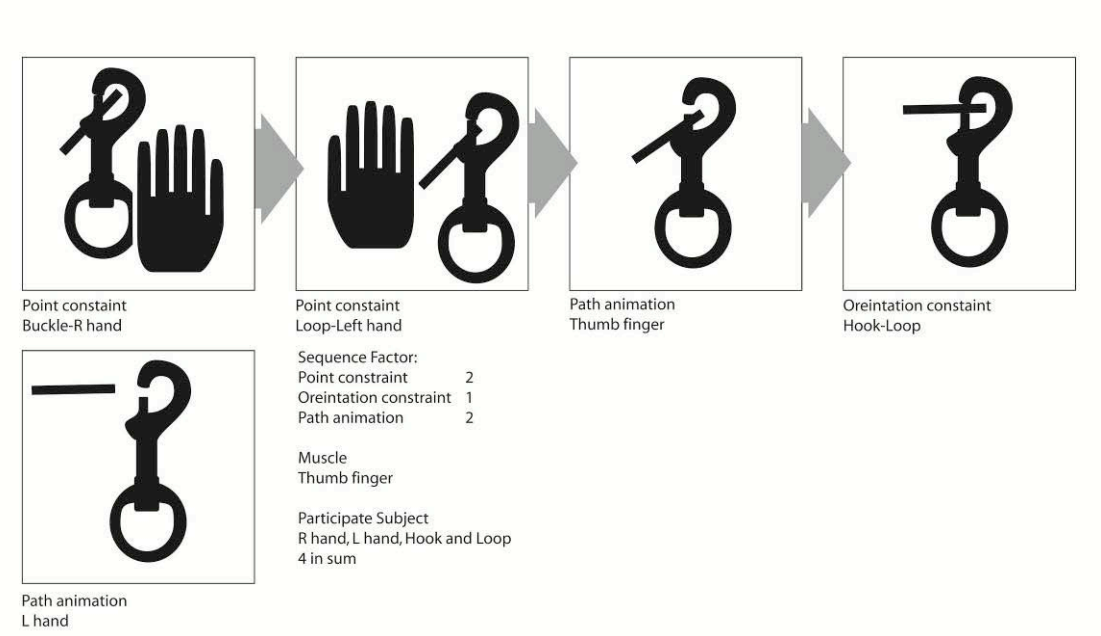


FIGURE 4-6OPENING PROCEDURE OF CLASP (B)

The side release buckle is much more convenient than a clasp. In term of closing procedure, there are five steps for a side release buckle, while seven for a clasp. Buckle A is opened automatically, while the clasp requires being opened manually. On the other hand, for a stroller buckle is for a 5 point restraint, while the side release buckle and the clasp are for 2 ends connection, a stroller buckle is analyzed. Look at Appendix E.

After analysis of the two buckles, a buckle could be improved from five aspects. First, the enclosing procedure is more difficult than releasing procedure, so there would be more potential in improving the efficiency of close process than opening. Second, to touch an object is easier than to coordinate the orientations, so orientation constraint steps should be reduced and replaced as much as possible. Third, demand of operating accuracy could be reduced, in term of enlarging assembling area. Fourth, apply stronger muscle to handle. At last, reduce number of participates.

RESULTS

To reduce orientation constraints, the target-assembling area should be larger than area in all the other directions. The reason why orientation constraint task is hard to accomplish is that both the two assembling parts have large faces in all directions. Coins and dices can be compared taken for an example, and they could be imaged as the latching portion and the desk can be regarded as the receptacle portion. When a coin drops on the desk, generally, there are only

two situations appearing, head or character. However, when a dice is thrown on the desk, there are six candidate numbers. The assembling area should be large enough, so that there is only situation that two parts meet each other in space.

To handle the buckle more easily, arm muscles could be applied. On one hand, the operation process could be simplified by handling a buckle with relatively stronger muscles. On the other hand, both clasps and side release buckle require finger movement to handle. After comparing different gestures of a caretaker, gripping is one of the suitable gestures, for it is arm muscles that applied during operation.

To reduce the number of participates, one-hand-operation buckle is an alternative. For a five point child resistant system, there are generally at least five participates in an enclosing procedure, two latching portions, one receptacle portion and two hands. No object could be reduced except one of the hands. At last, with respect to all these solutions above, a rubber grip buckle is designed based on the side release buckle, for it is relatively low cost and easy to operate (See figure 4-7).

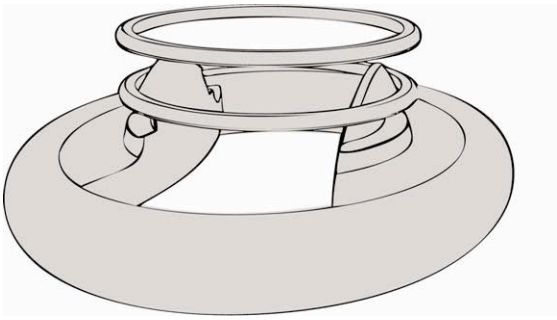


FIGURE 4-7 ASSEMBLING AREA OF OHO BUCKLE

The one-hand-operation (OHO) buckle, which consists of one grip (receptacle portion) and two ring parts (latching portion), achieves three improvements compared with a side release buckle. First, the target-assembling area is much larger than the non-assembling one, so that the procedure could be simplified in term of orientation constraint. Second, mechanisms and covers are integrated as much as possible. The rubber grip has been integrated with cover part and spring, and latching tabs and rings are designed explored. At last, it ensures safety, by taking advantage of differences between adults and children, in term of hand size. There is no safety button, so it is easy to open by an adult. However, for the buckle is designed to be open by griping, a baby can hardly held the grip as an adult does, unless pressing the buckle by two hands.

STRUCTURE AND OPERATION

The structure of the OHO buckle is descripted in the figure below (Figure4-8). The OHO buckle consists of 5 portions, two rings, two loops, two plastic tabs and a rubber grip. There are two loops on the tabs which held the terminal of the shoulder restraint and two lap straps. The two plastic tabs are fixed in the middle of the rubber grip. The rubber grip is supposed to attach to a crotch strap in the lower part.

To open and close the buckle, look at the figure 4-8 below. Opening process: 1 Squeeze the grip so that the two tabs move towards to each other, until the dimension of tabs is smaller than the inner diameter of the two loops. 2 Remove the two loop parts, so that all the straps can be detached.

Enclosing process (Figure 4-8 right): 1. Hold the grip which connected to the crotch strap in hand. 2 Hold one loop which connected to shoulder restraint and a lap strap in hand. 3 Press the loop towards the grip with middle and thumb finger. 4 Hold the other loop in hand. 5 Press the second loop towards the grip so that the two tabs can lock the loops.

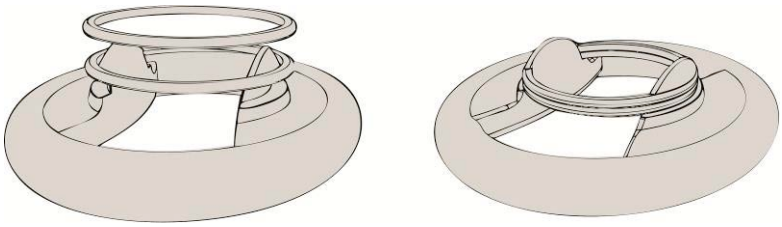


FIGURE 4-8 OPENING PROCESS AND STRUCTURE OF OHO

COMPARISON

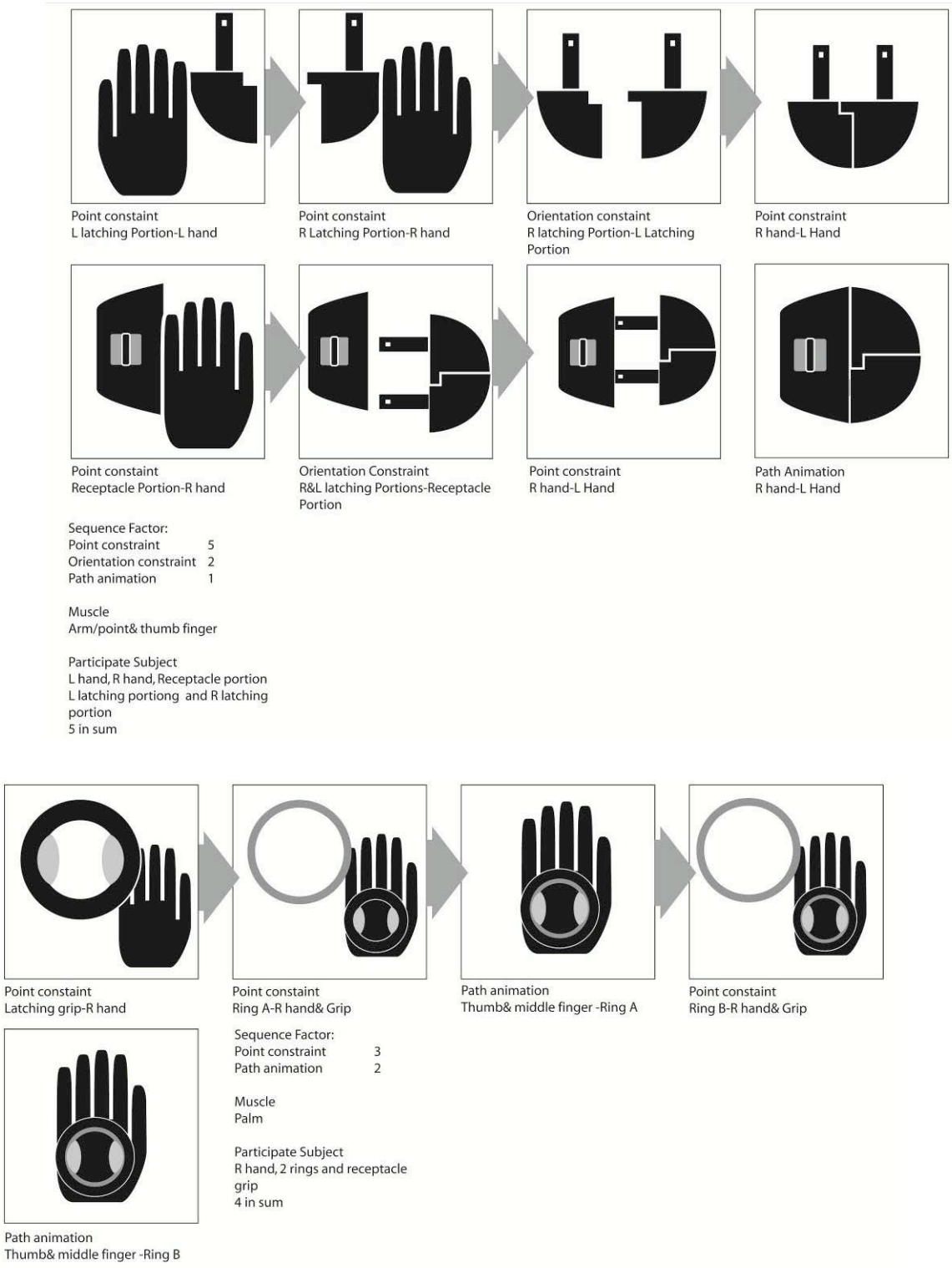


FIGURE 4-9 COMPARISON OF CLOSING PROCEDURE

The OHO buckle is improved a lot (Figure 4-9), compared with an existed stroller buckle, in enclosing procedure. In term of sequence steps and number participates, the OHO buckle has improved 37, 5% (8, 5) and Participate object: 20% (5, 4). In term of muscle application, the OHO buckle is palm and arm,

rather than fingers. From the perspective of human beings, one hand is left unused. At last, the number of orientation constraint has been reduced to zero. After the comparison of enclosing procedure, the opening procedures are compared.

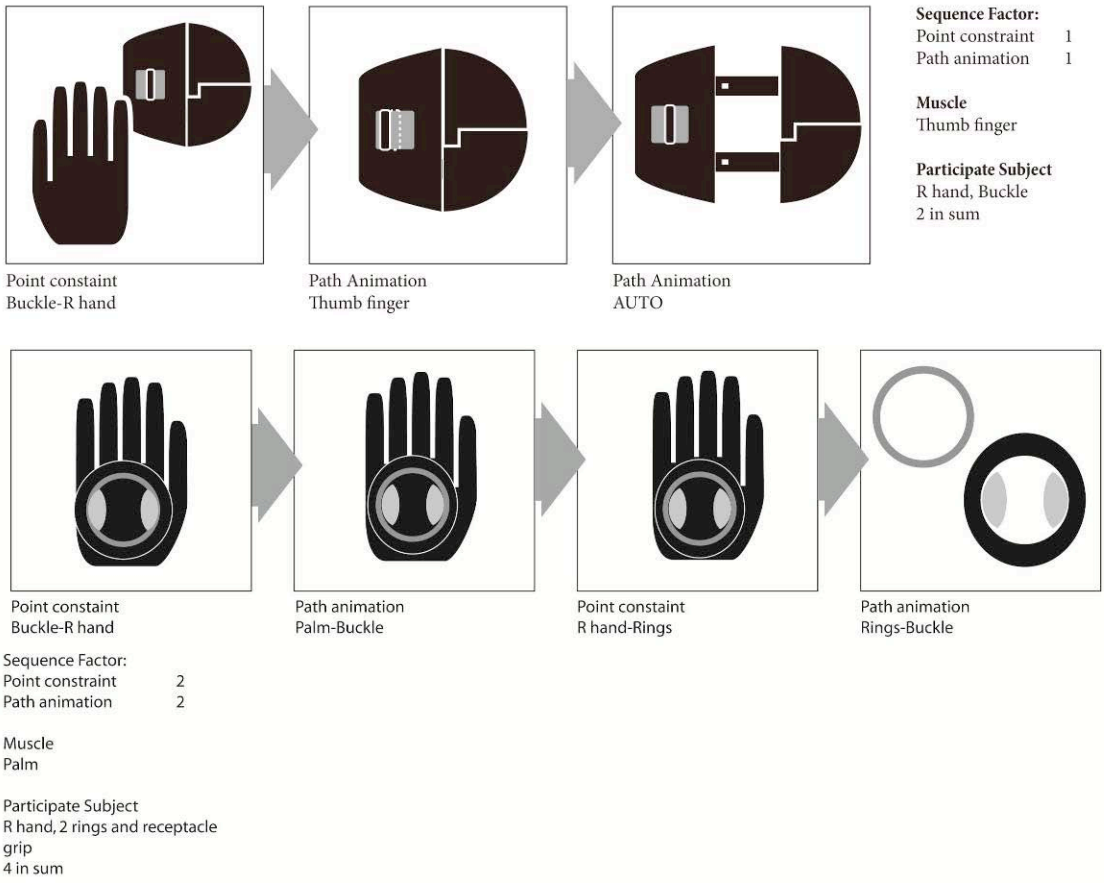


FIGURE 4-10 COMPARISON OF OPENING PROCEDURE

In term of opening procedure, the existing buckle shows advantage over the other (Figure 4-10), for its advance mechanism devices. The procedure of buckle above is automatically, while the OHO buckle requires remove the loops twice. As a result, according to these two buckles' comparison, OHO buckle is easy to be used during the procedure of enclosing, while, in the procedure of opening, it is more difficult.

4.3 OHO BUCKLE REFINEMENT

The OHO buckle is refined, in the following part, with respect to style, indication and material selection.

BASIC STYLE

Since a designer would prefer some line styles and these line styles would determine the style of the product, different line styles are compared to select a suitable for children product. For the structure line and the outline impact the style of product to a large extend. Structure lines and outlines are researched. A form drive is established with respect to feature lines, according to tens of Scandinavian design products. Look at the figure following.

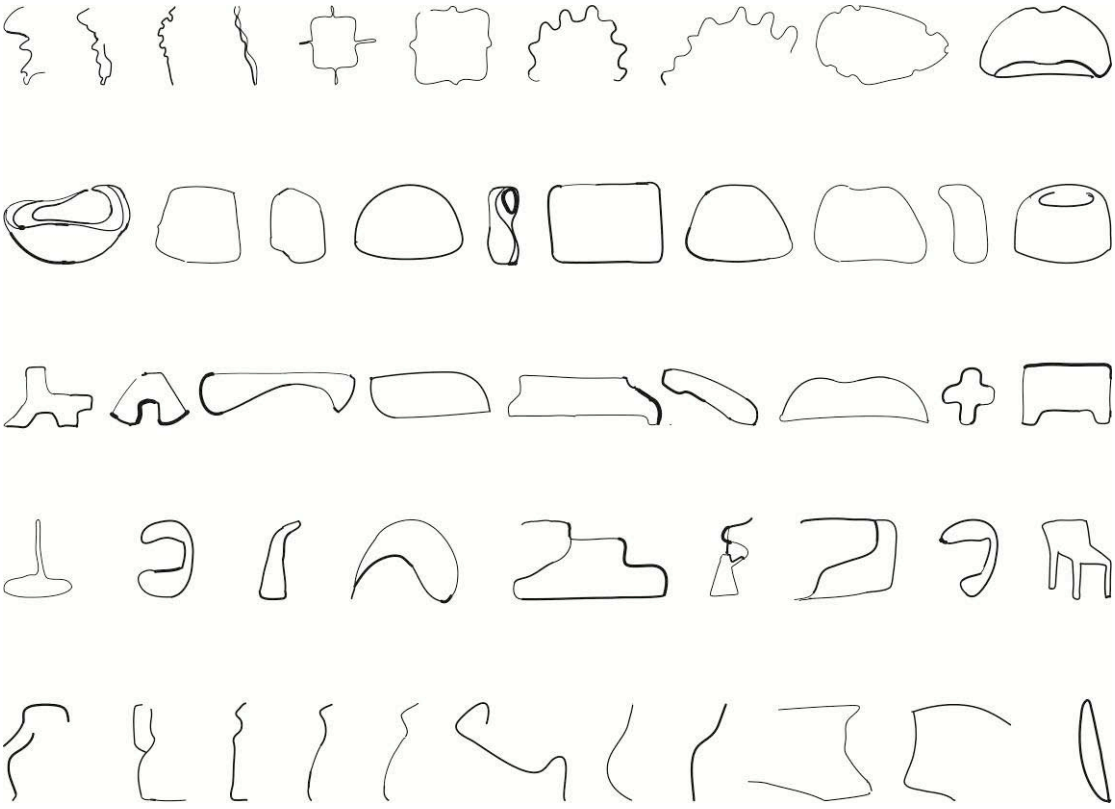


FIGURE 4-11 OUTLINES AND STRUCTURE LINES

To select a proper style, these line styles and feelings are compared. Totally straight lines and lines with sharp corner are avoided, for it is a product related to babies, while a curved and circle line style is preferred. On the other hand, a stylish line is preferred, for identification reasons. At last, the line style in the second row is determined.

GRIP SHAPE

The basic shape is designed with respect to indication, style and functionality. First, according to Norman's descriptions, a designer should lead a user to control a product in the right action effortlessly. A successful product in term of indication could be approached from making control easy to be seen, coordinating function and control and making smart use of constrains. (Norman, 1988) Second, it can also impact product feelings, which influence target market

strategy. At last, the section shape could influence the opening strength. As a result, a number of shapes have been compared, so that a suitable shape could be found, with respect to indication, target market and functionality (Figure 4-12).

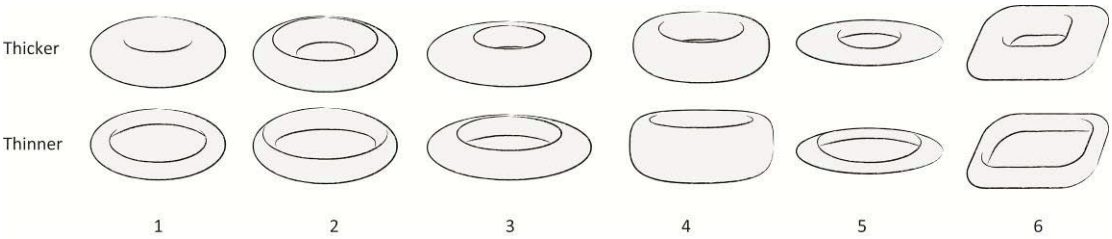


FIGURE 4-12 DIFFERENT GRIPPING SHAPES

In figures 4-12 above, shapes has been compared in two different dimensions, thicker and thinner. Relatively, the thicker dimension of shape 1 communicates childish and raw-designed feelings, while the thinner size of it looks low-quality. On the other hand, in term of indication, it can hardly indicate opening direction clearly. From the perspective of function, the section of it requires higher force to deform it.

The second shape shows a sharp feeling. In term of indirection, it provides confused opening direction, for it has a sharp corner inside, which also requires higher force to open it. In chart 3, the shape of it shows feelings of security and high quality, for it consists of various types of lines, smooth and sharp, while all sharp edges are inside. This section shape also indicates opening direction relatively clearly. Compared with all the forms in the chart, the outer part of the shape shows a comfortable and safe feeling of touching. The inner part is totally flat so that it could show the direction of deforming.

Look at the fourth figure. It provides quite positive section shape in term of function, for it would prevent the grip from camber bending during the process of opening. The fifth shape provides an ellipse outer part and a circle inner part. This shape can hardly perform functions well, for the shape prevents the grip from deforming in opening direction. The last shape feels like a candy. It provides quite an uncomfortable feel of touching, for its square outer shape, which is also hard to control, with respect to function performing.

After analyzing, the second shape in thinner dimension is selected as the basic shape of the grip. It looks high quality. The outer part implies a feeling of safety

and comfortable and the inner totally flat part provides a positive section shape of deforming.

ORGANIC SHAPE

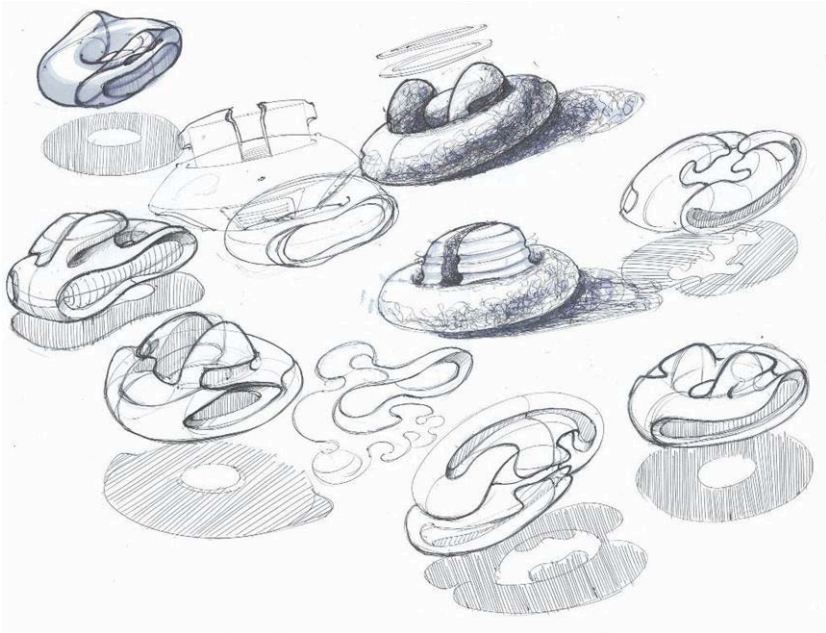


FIGURE 4-13 ORGANIC STYLE

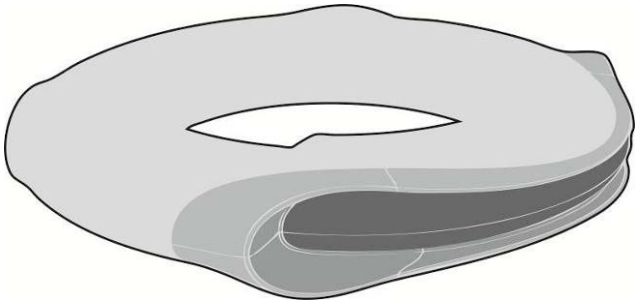


FIGURE 4-14 SELECTED ORGANIC STYLE

Numbers of styles have been sketched (Figure 4-13), and after evaluation, an organic style has been selected for indication and marketing reasons (Figure 4-14). On one hand, thin organic flanges are designed on each side of the grip, which provides flexible and soft feelings, so that a user would like to touch it. Furthermore, an adult caretaker would recognize that it is a flexible grip, so that the new buckle structure could be understood clear and easily. On the other hand, a new material can also identify the buckle, which helps brand identification establishing.

INDICATION OF TAB

Tabs are designed as an arrow in both opening and enclosing direction. Look at the figure 4-15 below. The shape of tabs helps a user to understand how to open and close the buckle.

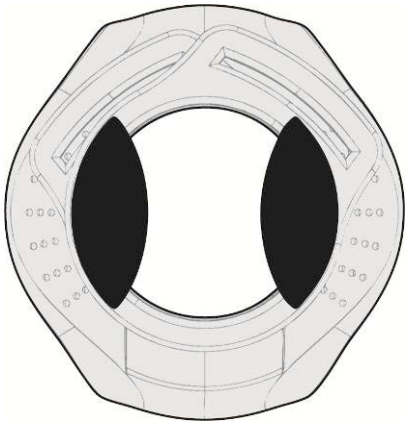


FIGURE 4-15 INDICATION OF TAB

MATERIAL SELECTION

Material selection is preceded by defining the application requirements in term of mechanical, thermal, fatigue, as well as special needs. In term of mechanical, the buckle should be opened ranged from 45 to 75N and the open travel is around 6mm. on the other hand, in term of thermal, the buckle should be reliable with in the temperature of –35 to 40 degree centigrade. In term of fatigue, the strain-life should be over ten years, 50000 times. At last, outdoor UV exposure, resilience, toxicity and oxidative ageing should be taken into consideration.

Nitrile, Silicon, Viton, Natural rubber and HNBR and Ethylene propylene are compared. Nitrile, Silicon and Viton meet most requirements as far as being mentioned last paragraph. The advantage of Nitrile is long strain-life, good resilience, while the disadvantage of it is relatively low thermal performance and weathering fatigue. There is a critical disadvantage of Silicon that it has poor bonding properties to rigid material. For the rubber parts should be bonded to plastic parts, it can hardly meet this requirement. The advantage of Viton is excellent oxidation, weathering, and thermal performance, while the disadvantage of it is strain-life and resilience are uncertain. At last Nitrile and Viton are candidates for further texting. (Huntingdon Limited, 2010)

4.4 Final Results of OHO Buckle

Figure 4-16 final result of OHO buckle

After visualization and prototype testing, the OHO buckle is described with respect to details, dimensions and failure modes. The details and failure mode of opening travel, force, cost and reinforcements are discussed below. A FMEA was applied to evaluate failure modes as far as being mentioned above.

Rationality of Opening Travel

The opening travel is decided by the radius and width of tabs, and it should be less than the distance of the two tabs and the total gap between outline and tabs. The tab outer diameter is 44mm, while the loop inner diameter is 38mm, which means the loops could not be released unless a 6mm deformation. However, the real opening travel is 8mm, rather than 6mm, since the width of tabs is oversize, which is another influence of opening travel. On the other hand, the opening travel should be less than distance of the two tabs, 20mm, and the total minimum gap between outline and loops, 4mm, or interferences would be caused when opening. At last, the opening travel contributes to the opening force directly. A smaller opening force causes accidental opening, while larger forces cause inconvenience. As a result, with respect to these influences, limitations and safety reasons, the opening travel are suggested around 8mm. The interference problem would be solved in following development.

Safe but Convenient Opening Force

According to open force research in research phase, the opening force should be ranged from 80N to 150N. A comparision has been made by figue following. It shows that the opening force of the weakest woment users is 230 newton. Meanwhile, a baby cannot hold the grip in one hand and it requires higher coordination ability to open it by squeezing. As a result, since a larger opening force causes operation inconvenience, camber bending and twisting, the suggested maximum opening force is 150N. On the other hand, considering the suggestion from the EU safety office and opening travel, the suggested minimun opening force is 80N (Figure 4-17).

Figure 4-17 comparison of grip strength between adult and children

Economical Processing Costs

Processing costs are reduced by fewer molds and applying rubber injection molding process. On one hand, since tab part and loop part are totally symmetrical, during the whole manufacturing process, only three parts would be produced, a rubber grip part, a tab part and a loop part. Fewer parts call for fewer molds, so that cost could be reduced. On the other hand, since the grip would be assembled during the rubber injection molding process automatically, no additional labor cost is required. As a result, the processing costs of a OHO buckle could be as economical as those of a side release buckle.

Camber Bending Resistant Zone

To prevent the grip from camber bending during opening and enclosing process, two bending resistant zones have been added. Since opening force is not always from the ideal angle, resultant force could cause deformation in different directions (see figure 4-18). Additional material is added to change the shape in weakest section, which would prevent the grip from camber bending. Reinforcement ribs could be another solution to this problem. However, the bending resistant zone is not included in the test prototype. Further tests are required (Figure 4-18).

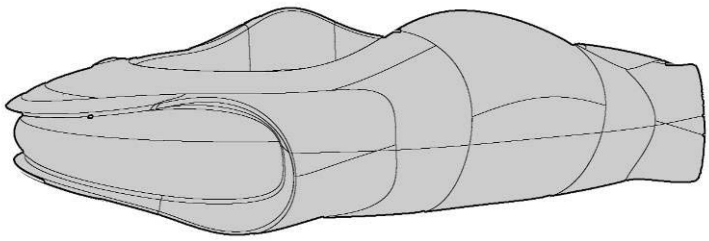


FIGURE 4-18 CAMBER BENDING RESISTANT ZONE

TOLERANCE BETWEEN TABS AND LOOPS

There are two tolerances between tabs and loops, vertical and horizontal. On one hand, the two tolerances impact adjustment and rotation of the loops. On the other hand, a larger vertical gap between tabs and loops increases the danger of accidental opening. The buckle was designed to resist the force paralleled horizontal plane, rather than other directions. A larger vertical tolerance causes loop tilt and resultant forces which results in protection failure. Current vertical tolerance is 0.4mm, which seems oversize after first prototype testing. The horizontal tolerance, 0.3mm, seems sound. Further tests are requested.

MINIMUM DIMENSION OF LOOPS

The minimum dimension of loops impacts strength and dimensions of the buckle. On one hand, dimensions of loops should be enlarged. Since loops are the weakest parts of all, which means when incident occurs, they would break first. On the other hand, a thicker loop causes reduction of immobility of the buckle, since it results in longer arm of force and the grip which provides lock force should be increased correspondently. Therefore, the diameter of loops decides the dimension of buckle and should be larger than weight of the straps, 25mm. As a result, with respect to the recommendations from engineer group, the thinnest part of loops is 2.5mm, the narrowest part is 5mm and the outer diameter is 44mm. This is a balance of limitations, and more tests are required.

ANTI-SKIDDING TEXTURE OF LOOPS

To avoid forces toward tabs, bumping texture is designed on the surface between the two rings. When upper straps are strained, loops would press the tabs towards each other, which results in buckle deformation. Though, in this case, the buckle would not open accidentally, to meet high degree of quality philosophy anti-skidding texture is designed to solve this problem. The rings are symmetrical in the horizontal plan, so that assembling sequence of the two

loops is not required. The contacting edges have been chamfered, so that no additional adjusting task is required (Figure 4-19).

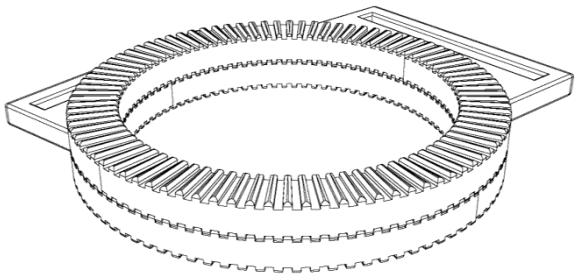


FIGURE 4-19 ANTI-SKIDDING TEXTURE OF LOOPS

FAILURE MODE AND EFFECT ANALYSIS

Failure modes are summed and evaluated by FMEA method (Figure 4-20). All the failure modes mentioned above are listed, as well as effects, causes, current controls, recommendations and actions. All the failure modes are evaluated by four ratings, severity, occurrence, detection and risk priority. Failures without action taken should be tested in following research by engineering group.

Function	Failure mode	Effects	Severity rating	Cause	Occurrence rating	Current controls	Detection rating	Critical Characteristic	Risk priority number	Recommended actions	Responsibility and target completion date	Action taken
Releasing the loops	Interference of two tabs	Loop removing failure	8	Distance of two tabs was less than open travel	5	Opening travel in sum is 8mm, while tabs interval is 20mm	7	N	420	Keep distance of tabs lager than opening travel	Chen Zheng, 2010-08	Done
Releasing the loops	Interference of hand and slots	Loop removing failure	6	Distance between outline and tabs was less than open travel	9	Distance between outline and slots is 4mm in sum, while the opening travel is 8mm	3	N	162	Enlarge dimension of the grip to 75mm, or reduce open travel	Engineer group, 2010-02	
Releasing the loops	unexpected deformation	Grip camber bending	2	Resultant opening force	10	Bending resistant were added	8	New rubber material	160	Add reinforcing rib in the grip	Engineer group, 2010-03	
Lock	Accidental open	Protection function failure	10	Tolerance between tabs and loops was oversize	1	The tolerance between tabs and loops is 0,4mm	1	Safety	90	Increase locking overlap and decrease the tolerance between tabs and loops	Engineer group, 2010-03	
Production	Production failure	Ungraded production	10	Thin-walls were designed	8	The thinnest part is 0,45mm	9	N	7200	Avoid thin-wall and small radii	Chen Zheng, 2010-08	Done
Adjustment	Adjustment fail	Strap tangling	2	Tolerance between tabs and loops was oversize	4	Gap between tabs and loops is 0,3mm	9	N	50	Keep the gap between loops and tabs aroud 0,2mm	Engineer group, 2010-03	
Attachment	Loop break	Protection function failure	10	Thickness of loop was undersize	2	Thickness of loop is 2,5mm	8	Safety	1600	N	Chen Zheng, 2010-08	Done
Lock	Accidental open	Protection function failure	10	Forces towards tabs deformed grip	1	Anti-skidding texture was added.	1	Safety	10	Text the anti-skidding texture	Engineer group, 2010-03	

FIGURE 4-20 FMEA FOR OHO

5 DESIGN PHASE II

Compared with the first design I, in this phase, concepts have been generated according to convertibility, press-opened buckle and application of differences between age groups to avoid unauthorized opening. First, brainstorming was used to generate an idea drive according to the specifications. Second, after choosing and combination, three concepts were formed. Third, with method of decision analysis, ROTO was selected to be further refined. In later parts, ROTO concept has been refined and visualized.

5.1 RESULTS OF BRAINSTORMING

Idea drives have been generated according to security, convertibility press-opened and shape. First, since security and press-opened are both related to opening process, an idea drive combined these has been formed. The second idea drive is about convertibility. Shape of buckle has been also taken into consideration and generated the last idea drive. These three drives contain different ideas which are from Innovative and inspiring thoughts to feasible solutions. Some ideas are summarized (See figure 5-1). More details and descriptions about each idea were in Appendix F.

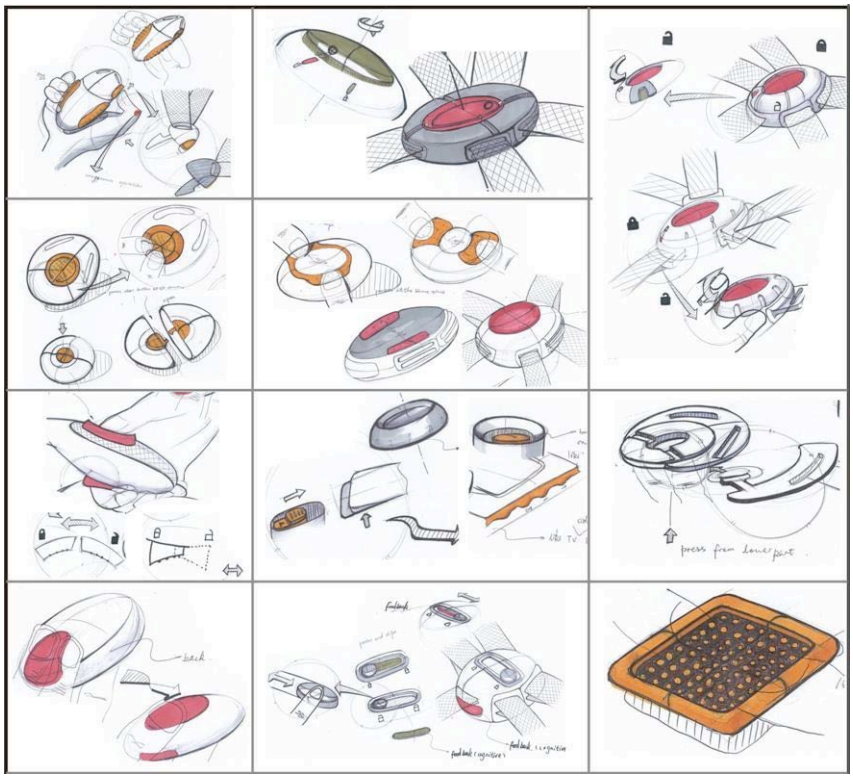


FIGURE 5-1 IDEA DRIVE CREATED BY BRAINSTORMING

5.2 Concept Formation

Three concepts were formed after idea choosing and combination. Since the idea drive needed to come up with as many ideas as possible in brainstorming process, there were not too many restrictions. First, some ideas were far from feasible and have been eliminated. For instance, some could not be operated in correct ergonomic way and some were not clear to use. Second, the rest of solutions from three drives were combined together. At last, three concepts were formed (Figure 5-2 to 5-4).

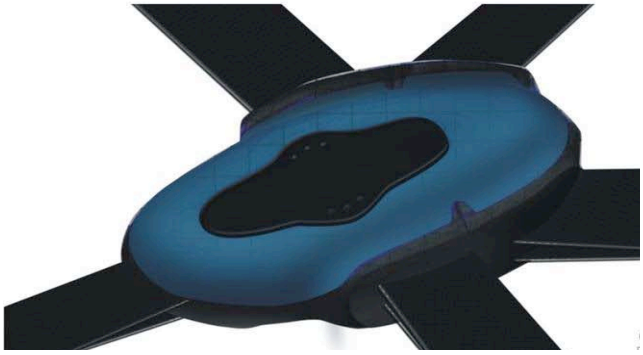


Figure 5-2 BUCKLE OYTT

Buckle OYTT provides both 3 and 5-point-harness, it could be opened by pressing button with two thumbs together. However, it requires two hands' operation.

Figure 5-3BUCKLE SLIDER

There is a safety button on the bottom of buckle "slider". The steps of opening are, sliding bottom button to unlock the buckle, then pressing top button to release latching parts. However, it is not clear to use in the first time.

FIGURE 5-4BUCKLE ROTO

Buckle ROTO equips with a secure ring which could be rotated to unlock the button. The steps of opening are, rotating secure ring, and then pressing big button to release latching parts. Feedback is on the top of the buckle which is clear to use. It provides 3 and 5-point-harness.Logo could be etched or screen printed on button.

5.3CONCEPT SELECTION

These three concepts were checked with decision analysis against specifications (Appendix G). Decision analysis was used to distinguish each character and dismiss concepts. ROTO is clearer to use and could not require two hand for releasing compared with OYTT. OYTT must be opened with two hands together and with lower security. Concept Slider is relative more secure, however it is not clear to use. These can be seen in the summary of the decision analysis in table 4 below.

objectives	Score	OYTT	ROTO	Slider
A harness providing both 3 and 5-point is preferred.	7	10	10	10
A one hand operation solution should be found if possible.	7	2	4	5
Press opened buckles have more advantages over pinch opened ones.	8	8	10	10
Reducing cost by reduce number of components.	10	2	2	2
Application of differences between age groups is recommended.	8	4	9	9
Clear how to operate	8	6	6	2
Total		248	318	293

TABLE 4 SUMMARY OF DECISION ANALYSIS

5.4 ROTO REFINEMENT

In this chapter, ROTO buckle has been refined in term of outlook. First, shape of slot has been analyzed and redesigned. Then heritage of Holmbergs AB was discussed, in term of color.

SHAPE OF SLOT

Slot of shoulder restraint has been redesigned outside the cover rather than inside and the angle of it is 77 degree. On one hand, inside slot is hard to thread belt and may increase difficulty of manufacture as well (Figure 5-5a). Revised slot is easy to thread belt and reduced cost of manufacture. On the other hand, according to shoulder slot angle analysis in 3.2.3, shoulder slot angel of buckles providing multi-utility modes should be between 75 and 82 degree. At last, 77 degree shoulder slot was chosen from perspective of aesthetics (Figure 5-5b).

FIGURE 5-5 SLOT ANGLE MODIFICATION

COLOR HERITAGE

After analyzing safety seat buckles from Holmbergs, it is found that heritages are not significant and strong in term of shape features, but the color heritage is relatively strong. Holmbergs Childsafety AB is a supplier of buckles for child safety seats and red buttons are required by child safety seat standards, so black color and red button are applied widely (Figure 5-6 a). As a result, this color heritage could be applied in stroller buckle design.

ROTO buckle consists of main black body and red circle with a bulge, in term of color design. First, black and red colors are heritage from previous product, as far as being mentioned. Second, since majority of stroller straps are black, the main body color is also designed black. Third, some new features have been introduced in stroller buckle design, red circle with a bulge, which could be a good indicator to show how to operate (Figure 5-6 b).

FIGURE 5-6 COLOR HERITAGE

5.5 Final Results of ROTO Buckle

ROTO includes two shoulder latching parts, two waist latching parts and a receptacle part (Figure 5-7). Shoulder latching parts and waist latching parts could be disassembled and assembled easily by sliding. Thus, it is possible to provide both 3 and 5-point-harness systems. Slots for shoulder latching part and waist latching part are suitable for belt of 25 mm wide straps. A large space of buckle offer enough place for stroller logo which could be etched or screen printed. Four screws are mounted on the bottom to protect ROTO well and make it durable throughout using.

Figure 5-7ROTO

The receptacle part is equipped with a secure ring and a big button (Figure 5-8 left). When an adult caregiver opens it, they could rotate secure ring to unlock buckle and then press the button. The force responded for pressing the button is around 44 N according to security analysis in4.3.2. Lock and unlock indication are etched on the surface of receptacle part (Figure 5-8 right).

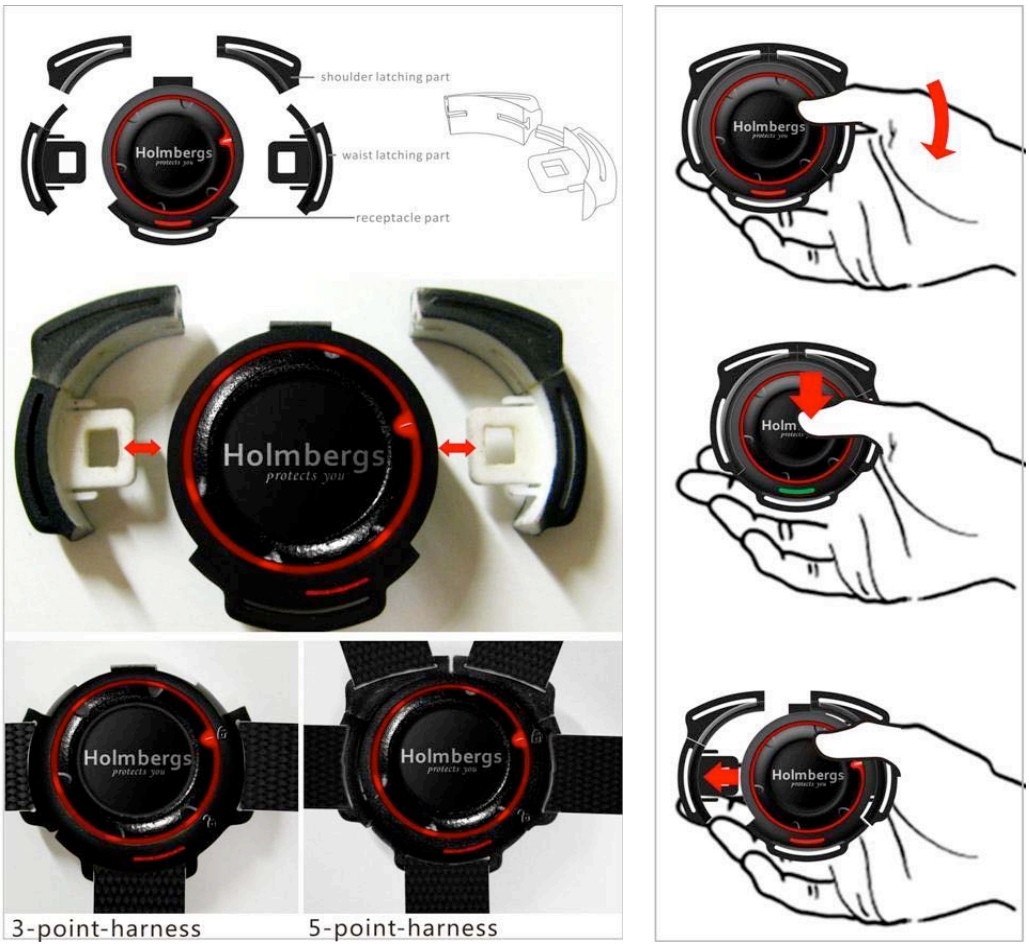


FIGURE 5-8 ROTO AND OPERATION

ROTO SECURE RING

ROTO equipped with a secure ring to avoid children unbuckling. When the latching parts are engaged, they are locked automatically, so that the latching parts could not be opened accidentally. When an adult caregiver wants to release the ROTO, the process is rotating the ring by 45 degree in clockwise direction until the indication shows green and then the button could be pressed down. After the latching parts release, the ring turns back to pre-position which is prepared for the next locking operation (Figure5-9). This device avoids adult caretakers to rotate the ring again after closing buckle, in other words, it reduces sequence of operation and protects children from forgetting to lock the buckle.

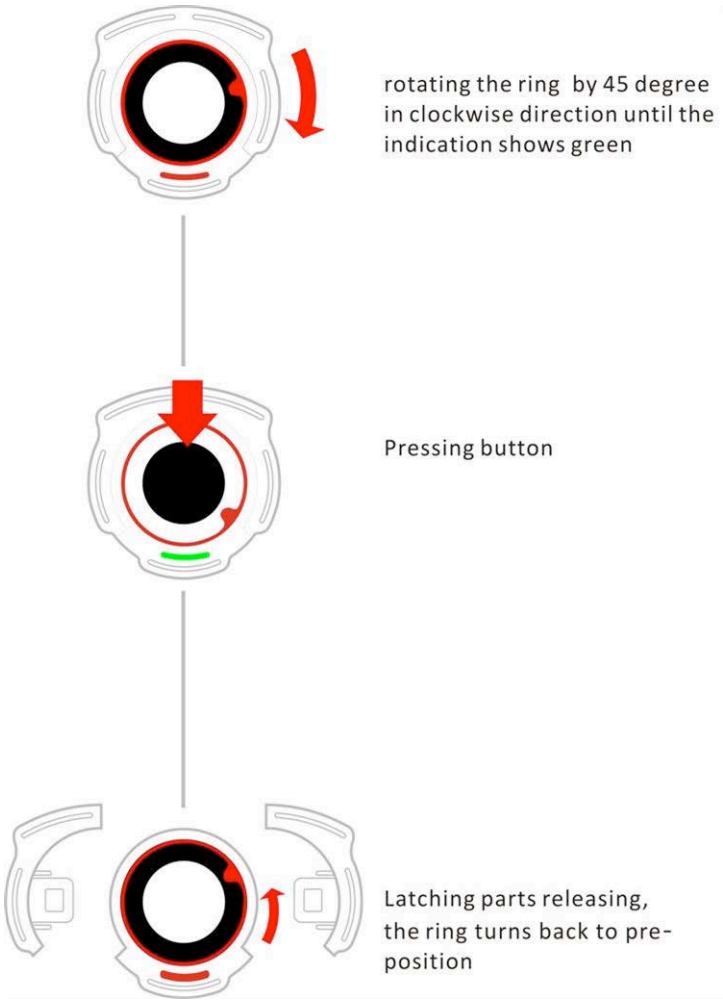


FIGURE 5-9 SECURE RING

FEEDBACK ON COVER

A feedback is provided to show whether the buckle is in lock mode. When ROTO is locked and could not be pressed, the indication is red. When the buckle is in unlock mode, the color turns green (Figure 5-10).

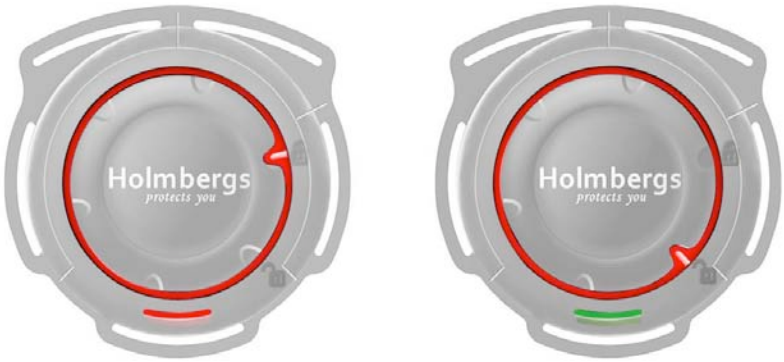


FIGURE 5-10ROTO COLOR FEEDBACK

RECEPTACLE PART STRUCTURE

The receptacle part comprises following parts: secure ring, button, upper and lower portions, rotatable member, lever, projection, lower portion, 3 springs and 4 screws. Upper portion and lower portion are covers of buckle, they enclose and locate other components, at the same time provide protection. The screws are mounted to protect ROTO and make it durable throughout using (Figure 5-11).

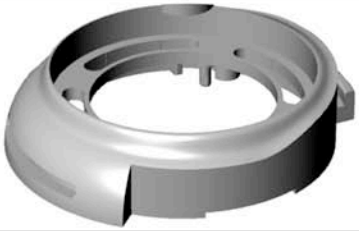
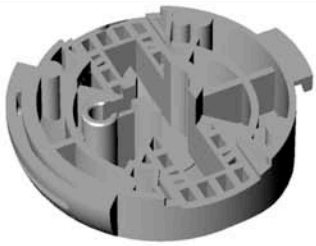
Name	Component	Function Description
Secure Ring		Secure ring has six grooves on the top for finger and four notches to connect with rotatable member.
Button		Button is designed for work veritable (go up and down) through rotatable part and it could press lever to release latching parts.
Upper Portion		
Rotatable Member		The rotatable member provides function of locking and unlocking buckle by rotating, since there is a hole in the center with special shape which make button to adopt or not. It connects with feedback to show different modes for adult caregivers.
Spring 2		A tension spring 2 is capable of repositioning the rotatable member to locking mode.
Lever		Lever is for hooking or releasing latching parts.
Spring 1		Spring 1 is under lever and button and supports them.
Projection		Projection is supported by spring 3 and it could stop the rotatable member to return back.
Spring 3		
Lower Portion		
Screws		

FIGURE 5-11 STRUCTURE OF ROTO RECEPTACLE PART

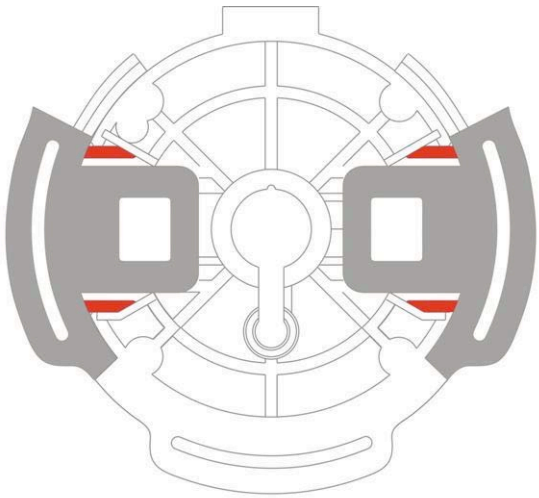


FIGURE 5-12TONGUE JUMP OUT WHEN RELEASING

There are two spheres in the middle of the lever which make it into a “seesaw”. This kind of structure could avoid one side tongue engaging while the other side is not inserted. With the two spheres, the buckle only locks when all parts are engaged. When latching parts are engaged, there will be small elastic deformation on them. After releasing, they come back to original shape and make both sides tongue jump out when the releasing button is operated (Figure 5-12).

WORKING PRINCIPLE

Look at the figure 5-13. When adult caregivers rotate secure ring, the rotatable member would rotate with it and when it rotate to a certain place. The hole on rotatable member makes projection to bounce to stop rotatable member turn back. There is a spring under projection. When the rotatable member is in this position, the button could be adopted to shape into hole which is on rotatable member, and then button could be depressed. The button is adopted to not rotate but to be capable of moving vertically (up and down) relative to the secure ring and the rotatable member. The button will depress lever to release tongue from the launching parts. The depressed lever will press the projection, and subsequently the projection would release the rotatable member which could turn back to pre-position.

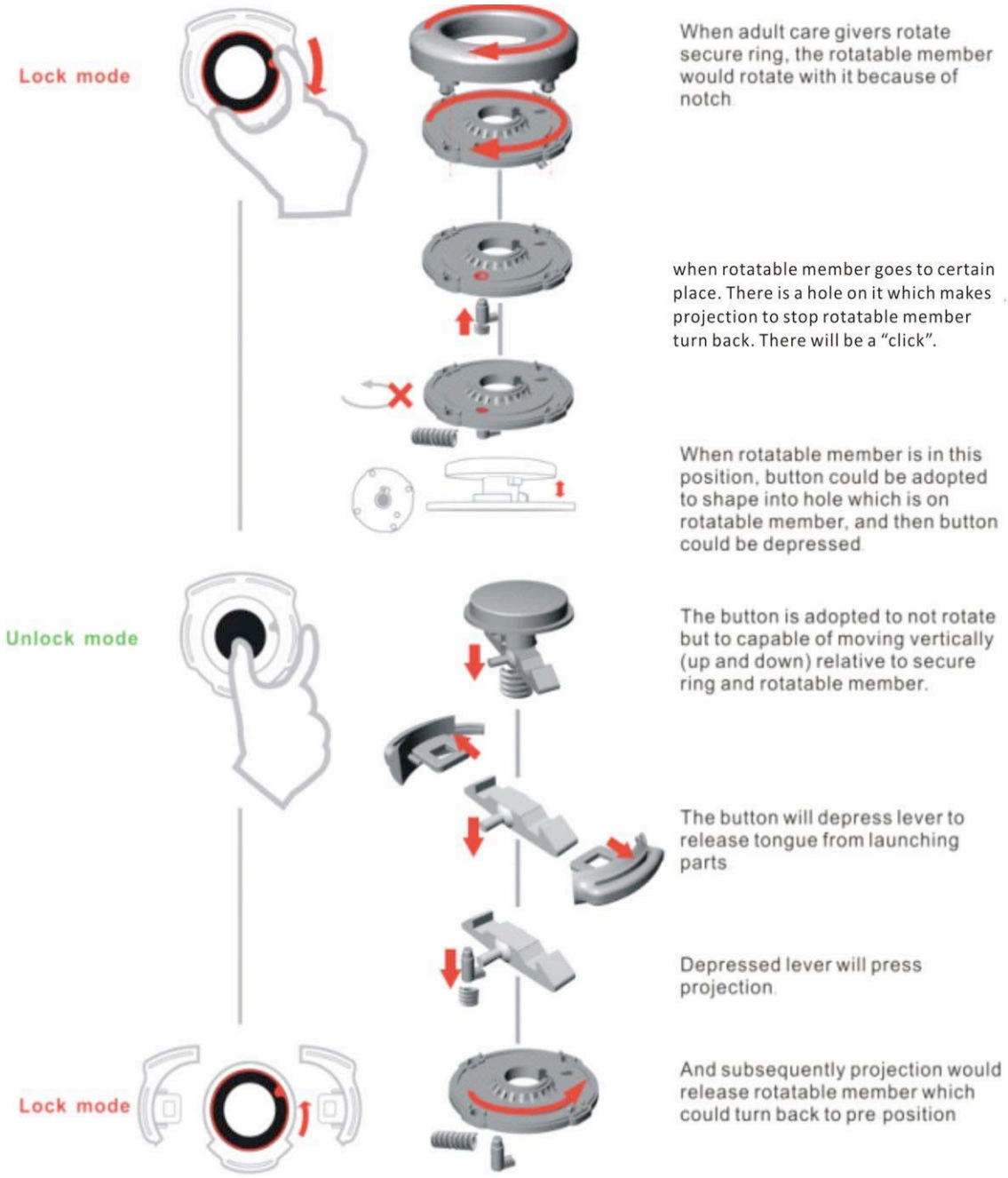


FIGURE 5-13WORK PROCESS OF ROTO RECEPTACLE PART

6 DISCUSSION

Constraint-based theory has been introduced from computer animation field for the first time, so the effect and if it could be applied further should be discussed. On one hand, in this report, the result of OHO buckle proves that it could be used to analyze buckling motion. On the other hand, for those assembling tasks which are related to the motion of human being, this method could also be applied. This method could be used during analysis phase and the advantage of this method is that movement could be analysis objectively. However, the delimitation of this method is that human movement could be too complicated to analyze with simple imitation.

There are two final results in the report and the two solutions are totally different, so it is necessary to discuss what is the reason for two solutions rather than one. On one hand, two results have been approached due to two processes applied and both of them have unique pros. According to Lawso (Lawso, 2005), application of process and methods would impact the final result to a large extent. Two processes are selected in the beginning of design phase, one mainly basing on operation and the other concerning on mechanism structure. The OHO buckle could be operated by one hand and is low cost, while the ROTO is convertible and safer.

On the other hand, the two solutions could not be comprised together. First, the pros of each design are conflict. Press opened buckle and convertible buckles require more components, so the cost is relatively high. Second, since the solution has been expected to be more creative and inspiration for further development, but a comprised could hardly contain all advantages well, two featured concepts are preferred. Third, strollers and buckle are various on the market. To meet demand of more target group, featured ones are selected.

First, in term of cost, OHO buckle cost lower. There are 5 parts in OHO buckle and 4 molds are required for OHO manufacturing. As a result, cost for OHO buckle is low which makes it competitive. On the other hand, number of ROTO components is 14 which may raise cost.

Second, both these two buckles perform well in term of work load. Force for releasing loop is recommended at minimum 80N and it is designed by griping. On the other hand, opening force for ROTO is recommended at minimum 44N and it is designed by pressing the button.

At last, from perspective of security, ROTO has more advantages over OHO. On one hand, OHO buckle mainly applies differences of hand size between two age groups which lead to different hand gestures. An adult would open the buckle by gripping while children can hardly hold it with a small hand. However, the security mechanisms are exposed, which may lead to accidental open. On the other hand, ROTO mainly applies intelligence and coordination differences between these two age groups. With secure ring mechanism, it needs to be opened by technical skill and hand strength together so that unauthorized open could be avoided. And the security mechanisms are covered inside.

7 CONCLUSION

The final results fulfill most of goals and of the project. Both OHO buckle and ROTO are able to fit 5-point-restraints. Several slots were provided to fit crotch strap, lap straps and shoulder straps. For OHO buckle, there are 5 components in it, thus this result fulfills the goal of low cost. Safety was also considered and solved in process of development. The opening posture is griping which is more comfortable than side release buckle. ROTO equipped with safety mechanism which could reduce opportunities for unauthorized open to a large extent. Posture for opening ROTO is close to hand functional resting position, thus it could be open in ergonomic way. Although its cost is not as low as that of OHO buckle, the number of component for ROTO has been reduced in development process as well. Compared with existing buckles with safety mechanism, there is no additional cost for ROTO. A solution that fulfills all the requirements had not been found during the development work. The two final concepts fulfill the majority of technique requirement and specifications at the same time. They have a great diversity. Hopefully they could be sources of inspiration and contribute to further development within stroller restraints buckle area!

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8.6 PERSONAL CONTACT

Wilson, Therése Product Manager, Holmbergs Childsafety AB, several times

Johansson, Claes Product Engineer, Holmbergs Childsafety AB, several times

APPENDIX A INTERVIEW I

In what situation do you use your stroller outside?

What is the frequency? (E.g. once a week, 3 time a week, everyday etc.)

Where do you often to go? (E.g. forest, park, shopping mall, supermarket etc.)

What are you going to do there? (E.g. shopping, sports, travelling etc.)

How do you prefer to get there? (E.g. tram, bus, car, walking, jogging etc.)

Where do you usually use the buckle of stroller?

(E.g. in the opening, at home, walking, on the bus/tram etc.)

In what situation do you usually take your baby out from the stroller?

If the baby is crying.

If the baby is hungry or thirsty.

If the baby was in need to be translated from inside the stroller.

Others

What do you go with when you use the stroller?

(E.g. pet, friend, couple etc.)

What do you usually bring with you when you use your stroller?

(E.g. bag, shopping package, glove and hats of baby, your own gloves and scarf etc.)

What do you think that the baby tends to open the buckle by itself?

Do you mind that we make a video to record your procedure of usage?

		User1	User2	User3	User4	User5	User6	User7	User8	User9	User10
Background	Gender	Female	Female	Female	Female	Female	Female	Female	Male	Female	Female
	Age of child	8 months	15 months	13 months	16 months	5 months/ 17 months	6 months	20 months	2 months	5 months	5 months
1	Frequency	Everyday	Everyday	Everyday	Everyday	Everyday	Everyday	Everyday	Everyday	2 and 3 times a week	Everyday
	Location	Forest park mall supermarket	Anywhere	Anywhere	Anywhere	Anywhere	Anywhere	Anywhere	Anywhere	Anywhere	Anywhere
	Aim	go for a walk shopping	All reasons	All reasons	All reasons	All reasons	All reasons	All reasons	All reasons	All reasons	Shopping
	Transportation	Walk	Walk bus tram train	Walk bus tram train	Walk bus tram	Car	Walk bus tram train	Walk bus tram train	Walk bus tram train	Wal k	Wal k
2	Reason of taking baby	—	Baby crying	Play walking	Crying hungry want to walk	—	Crying hungry	—	Crying	Crying hungry	Don' t often take out since too cold
3	Companion	By self with friends	Husband children by self	Families friends	—	Husband	Families friends husband	—	Famili	Families friends	Along
4	Belongings	Bag change clothes	Bag, napptine water, food	Gloves Rain cover blanket scarf	Bag, napptine water, food	Jacket things for shopping	Package glove food	All the things need	All the things need	All the things need	All the things need
5	Children Unbuckling trends	No	Yes sometimes			Not in this age but thinking		No, trying	No, too small	No, too small	No, havn' t use it
	Harness	Nonuse	5 points mode	3 points mode	Nonuse	Nonuse	Nonuse	5 points mode	Nonuse	Have 5 point harness but don't use, since the belt is hard to use, problem is belt not buckle	No, havn' t use it

Questions		I1	I2	I3	I4	I5	I6	I7	I8	I9	I10	I11	I12	I13	I14	I15	Sum
Age of the child (month)		18m		12m	10m	14m		36m	12m	36m	30m	24m	30m	10m	24m	18m	
1) Do you have experience of using push chair on a bus (tram)?	Yes	o		o	o		o	o	o	o	o	o	o	o	o		12
	No		o					o								o	3
2) When you use a pushchair on a bus, in which way do you prefer to use?	3 points						o				o	o				o	4
	5 points	o			o				o					o			4
	2 points														o		1
	nonuse harness					o				o			o				3
Why do you prefer so?	Old enough, harness is					o				o		o	o				4
	child feels uncomfortable						o										1
	It is really hard to operate												o				1
	others								o								1
	Hard for parents																
3) What do you think the strength when you open your buckle?	Easy for parents, hard for							o	o	o	o		o				5
	Parents can, children cannot			o	o							o		o	o	o	6
	Easy for parents, possible		o														1
4) Do you think the buckle is uncomfortable for the child?	agree					o											1
	disagree	o	o	o	o		o	o	o	o	o	o	o	o	o	o	14
Reason	others					o											1
5) To what extent, do you prefer one-hand-operating when you use the buckle?	not possible	o															1
	not at all										o	o					2
	a little							o									1
	OK													o	o		2
	Very much		o	o	o	o	o		o	o			o			o	9
6) What do you have with you by hand?	Hat														o		1
	shopping bag		o	o				o		o					o		5
	clothes for the baby		o	o		o	o			o					o		6
	others			o	o		o		o			o	o		o		7
	none	o															1

7) Who do you go with when you use the stroller?	friends		o	o					o	o	o		o			o	7
	couple	o	o			o	o	o	o		o		o			o	9
	others				o		o					o					3
	on my own													o	o	o	3
8) To what extent, do you think the baby can take care of itself on the bus (tram)?	not at all		o	o	o	o	o	o		o		o	o	o		o	11
	just so	o															1
	OK										o				o		2
	good	o							o								2
9) How often does the baby tend to open the buckle?	Never			o	o	o		o	o			o	o	o	o	o	10
	seldom						o			o	o						3
10) To what frequency can you seat yourself on the bus (tram) with a stroller?	Never				o												1
	seldom											o	o				2
	sometimes					o			o	o							3
	often	o		o			o	o			o			o	o		7
11) In case of bus's braking or turning, to what extend do you worry about the baby's safety?	somehow	o		o		o			o	o	o			o			7
	OK						o										1
	serious							o				o	o		o		4
	quite serious		o		o												2
12) How often will you have your gloves on your hands on the bus (tram)?	never				o					o							2
	seldom											o	o		o		3
	sometimes	o				o	o	o						o			5
	often			o					o								2
13) In what situation do you have to take the baby out of the stroller?	If the baby is crying		o				o	o	o	o	o		o	o	o		9
	if the baby is hungry or						o										1
	others			o		o	o					o					4
14) Hard to operate when the bus is swaying.	Agree					o		o					o		o		4
	partly agree				o						o						2
	hard to agree								o	o				o			3
	disagree			o								o					2
One hand is engaged to operate the buckle.	Agree	o		o				o	o				o	o			6
	partly agree				o					o	o	o			o		5
Have to lean on a wall when operate.	partly agree				o			o	o	o	o			o	o		7
	hard to agree												o				1
	disagree			o													1
When the child wears heavier coat, the difficulty of operation would be increased.	Agree	o			o		o		o	o	o	o			o		8
	partly agree			o				o									2
	hard to agree												o				1
	disagree													o			1

APPENDIX C PERSONA

Elin is 30 years old and she is a mother of two daughters, Rosa and Sofia. Rosa is 3 years old and Sofia is 10 months. Elin is a freelance designer and designs children products. Being a mother gives tremendous inspirations for her design. She and her husband lean how to look after children who make them feel really happy. She needs to prepare children's food, washing their clothes and reading stories for the two little princesses. The families enjoy going out together. Sometimes they go shopping or just go for a walk. There is a stroller for two children in their home that she could take them together. She thinks the buckle is a little hard to open and the interference of straps is annoying when lifting child out and inside.

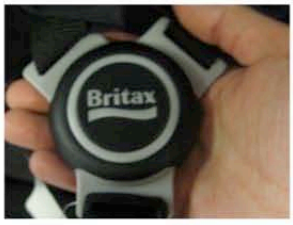
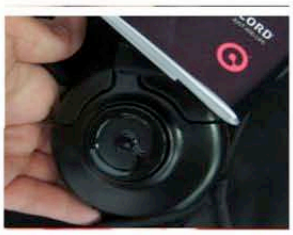
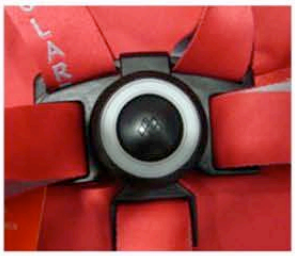
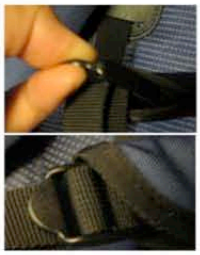
Anna is 13 months old. She is an active girl, likes animals and chocolate, and enjoys outdoor playing. She is developing motor skills, enjoys going out with her parents, for instance shopping, traveling especially sitting in shopping cart with some fruits when go to supermarket. She like cartoon but can’t understand SpongeBob. She dislikes carrot, broccoli and afternoon nap. She is pleased with vivid color and interesting sound, begins to have interest on people especially contemporary. Sometimes, she uses mouth to explore the world and usually puts toys or other stuff in her mouth. Because of the temper tantrums, Anna tends to have temper tantrums because she has such strong emotions, but do not know how to express themselves. Now Anna gets a new hobby which is catching goldfish with her cat.

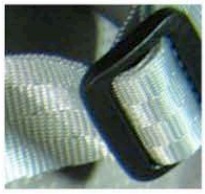
APPENDIX D SCENARIO

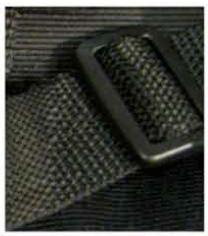
In winter, Patrik has to face to all kinds of situations when using stroller, but handling the stroller on a shaking bus/tram is the most difficult. Because in winter he has to bring quite a lot of clothes for his baby and himself, and the baby has to use number of daily use. On the other hand, he would have shopping bags. And when he is taking a bus or tram, he has to show his ticket, keep balance, and take care of the babies and so on. However, the baby cannot keep silence during the entire trip, so the he has to get it out and hug it until its being silent. And for the baby has heavy clothes on itself, Patrik has his gloves on, the buckle is such a problem to operate.

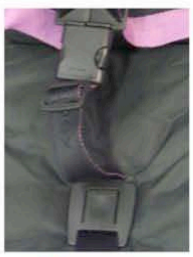
APPENDIX E BENCHMARKING

Buckle

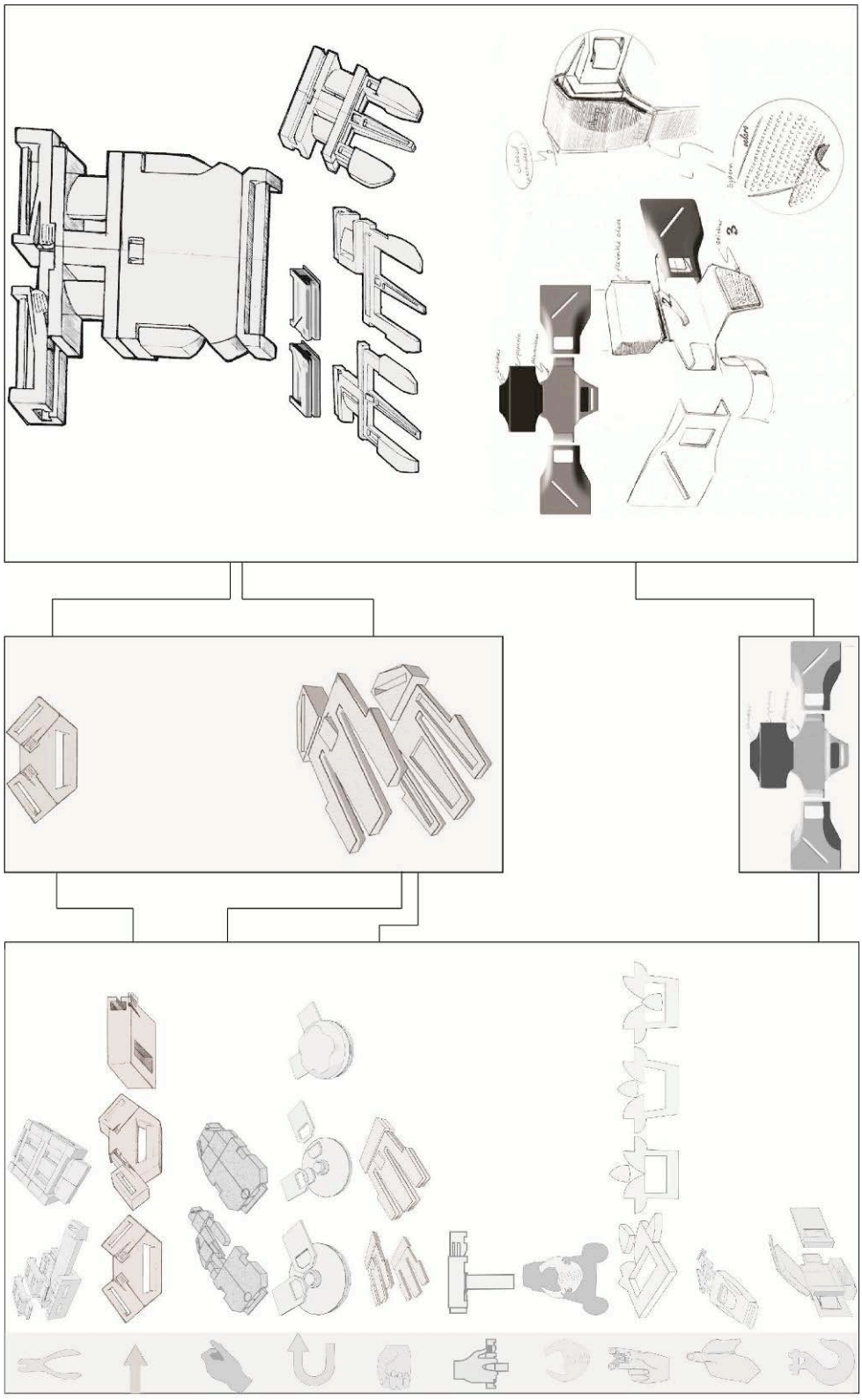
Brand	Look	Adjustor	Description
Britax			It could be opened by pressing dig button on the top and it provides 5-point-harness.Adjustor is hard to use. Logo is etched on the button.
CONCORD		 	The buckle is with safety mechanism which is on the back and could be rotated to unlock the buckle. After rotating the safety mechanism, user could press button to release latching parts. However, it is not clear to use. LOGO is both on the top and bottom of the buckle. It provides 5-point-harness and adjustor is hard to use.
Emmaljunga 			this buckle provides 3 and 5-point-harness, but "hook" is hard to use. It could be open by pinching. The bog size buckle make it relative better than small size buckle. The adjustor could be operated by one hand.
MACLAREN 			This buckle is with safety mechanism and could be opened by pressing top and bottom buttons together to release latching part. Shoulder strap and lap strap could not be adjusted together. adjustor for lap strap combines with buckle together and not easy to use. It provides 5-point-harenss.
mountain buggy 			This buckle is with safety mechanism and could be opened by pressing safety button and pinching side latching parts together to release buckle. It provides 5-point-harness. The adjustor could be operated by one hand and it is easy to use.
Silver Cross 			This buckle requires low finger strength to open. However, it is easy for children to open as well. It provides 3 and 5-point-harness and easy to remove and assemble shoulder straps.

Brand	Look	Adjustor	Description
GRACO			It could be opened by pressing dig button. It provides 5-point-harness. Adjustors combined with buckle together and could be adjusted by pulling strap and pressing button on adjustors.
Quinny 			This buckle could be opened by pinching receptacle part. It provides 5-point-harness. The adjustor is not easy to use. Logo is equipped on the cover of receptacle part.
phil&teds 			this buckle provides 3 and 5-point-harness, but shoulder strap and lap strap could not be connected together which increase assemble procedure and cause inconvenience. The adjustor is not easy to use.
			This buckle is with safety mechanism. It need to press a certain place to release latching part, otherwise it will require higher open force. Hook for conversion is not easy to use. Adjustors combine with buckle together.
ESPRIT			This buckle provides 3 and 5-point-harness. It could be opened by pressing but it is easy for children unbuckling. Type for removing shoulder strap is relative easy to operate. Adjustors could be operate by one hand.
BRIO			This buckle requires high finger strength to open. However, it is hard for children to open. It provides 5-point-harness. Because of the shape of this buckle, it may cause resultant force. Adjustors are hard to operate.

Brand	Look	Adjustor	Description
bertini			It could be opened by pressing dig button. It provides 3 and 5-point-harness. Shoulder strap and lap strap could not connect and may cause inconvenience. Adjustor is not easy to use.
			This buckle provides 3 and 5-point-harness. It could be opened by pinchin latching parts. Type of conversion for assembling is relative easy to use. However, adjustor is not easy to use.
Britax			This buckle provides 3 and 5-point-harness. It could be opened by pinchin latching parts. Type of conversion for assembling is relative easy to use. However, adjustor is not easy to use. LOGO is etched on cover of receptacle part.
Emmaljunga 			This buckle provides 3 and 5-point-harness. It could be opened by pinchin latching parts. Type of conversion "hook" for assembling is not easy to us However, adjustor is not easy to use. LOGO is etched on cover of receptacle part.
CITY MINI STROLLERS.com Baby Jogger			This buckle requires high finger strengt to open. However, it is hard for childre to open. It provides 5-point-harness. Because of the shape of this buckle, it may cause resultant force. Adjustors ar hard to operate.
STOKKE 			this buckle provides 3 and 5-point-harness, but "hook" is hard to use. It could be open by pinching. The bog size buckle make it relative better than sma size buckle. The adjustor could be operated by one hand.

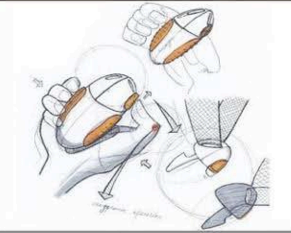
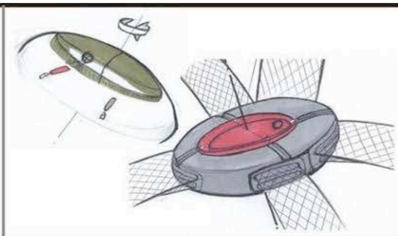
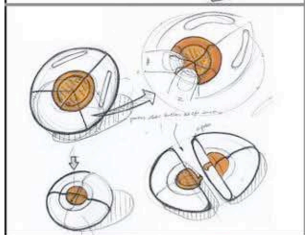
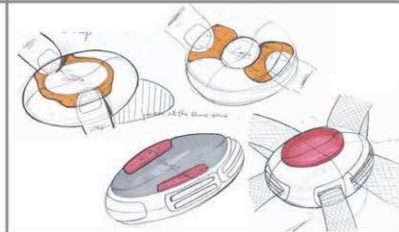
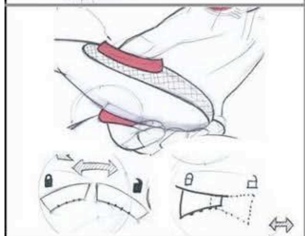
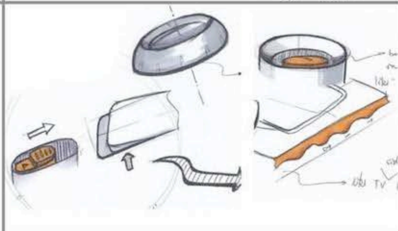
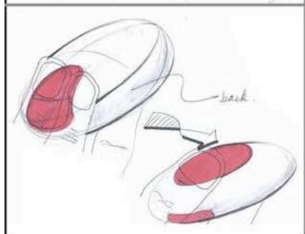
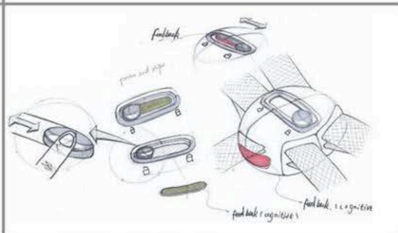
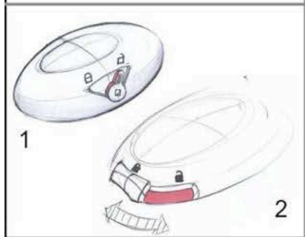
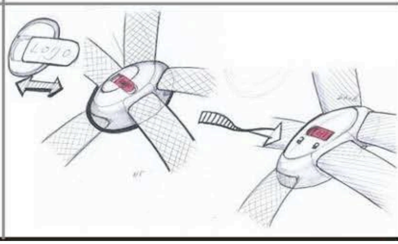
Brand	Look	Adjustor	Description
			the buckle could shut finger around corner. 5-point-harness pinching-opened adjustor is not easy to use
Baby Jogger 			The stroller s restraint buckle could break or unlatch allowing the child or infant to fall out which leads to callback. 5-point-harness pinching-press opened adjustor is not easy to use
			Pinching-opened 5-point-harness Adjustor could be operate with one hand.
iCandy			3 and 5-point-harness pinching-press opened adjustor is not easy to use
cybex			Pinching-opened 5-point-harness Adjustor is similar with adjustor for child safety seat that could be pulled and pressed by one hand
			Pinching-opened 5-point-harness Adjustor could be use in one hand.

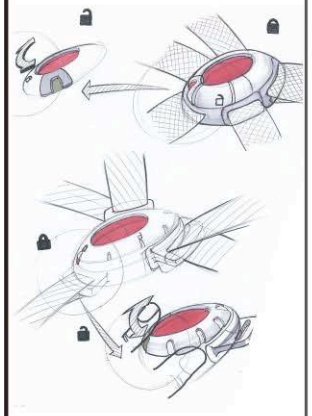
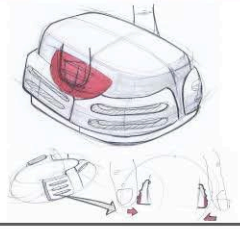
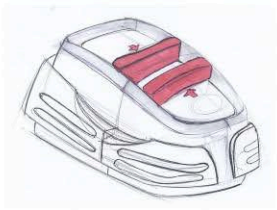
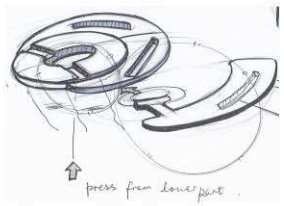
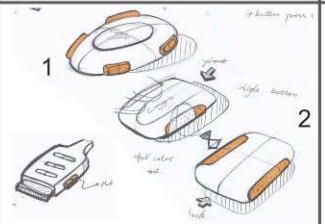
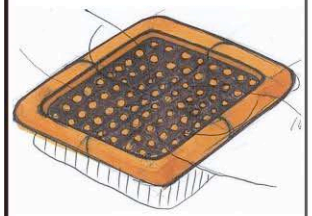
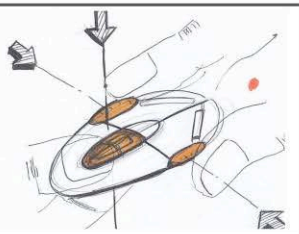
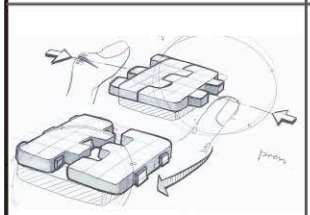
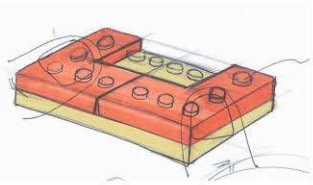
APPENDIX F MECHANISM DEVICES GENERATION



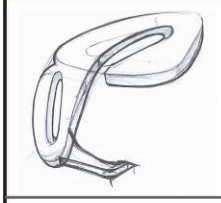
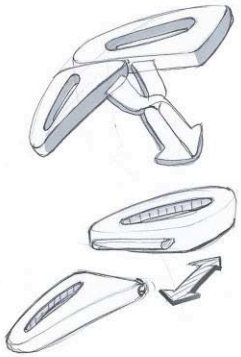
APPENDIX G IDEA DRIVE

IDEA DRIVE 1

	This buckle could be opened with one hand and it is with a safety button. But the operation is in incorrect ergonomic way		This buckle could be opened by rotating button to a certain palce to open it.
	This buckle could be opened by using two thumbs together.		These buckles need to be opened with two thumbs together.
	This buckle is with safety mechanism. it could be opened by one hand. Open steps are sliding safety button on the bottom with forefinger and pressing top button with thumb to open buckle.		These are several ideas about safety mechanism. For instance, hiding buttons or making it into neutral-colour.
	This buckle could be opened by pressing buttons on the top and bottom together.		This buckle is with safety mechanism in the bottom of the buckle and it could be unlocked by sliding button.
	This buckles are with Safety mechanisms. Buckle 1 requires fine finger movement which need to be avoid.		The safety mechanism could be slide to open the buckle.

	These two buckle are with safety mechanism. Operation for mechanisms are rotating it to certain place to inlock the buckle.		This buckles with two side buttons, user press particular place in order to open it with low finger strength, otherwise it need high strength to open.
			This buckles could be opened by pinching button in the middle of buckle. But operation is in incorrect position.
	Opening for this buckle does not depend on deformation but depend on friction.		Buckle1 could be opened by two hands pressing four buttons. The buttons for the second buckle hide in the bottom of the buckle that children could not find them easily.
	This buckle was inspired by guessing game. Only adult caregive know where to press to open the buckle. But this buckle is not clear to use.		This buckle is with two safety buttons and it could be opened by two hands.
	The aim for this idea is to generate a new mechanism for buckle.		The aim for this idea is to generate a new mechanism for buckle as well, inspired from Lego.

Idea drive 2

<table>
<tr>
<td>  </td>
<td rowspan="3">There is a small opening in shoulder slot to remove or assemble shoulder trap</td>
<td rowspan="2">  </td>
<td rowspan="3">Some ideas about sliding to assemble and remove</td>
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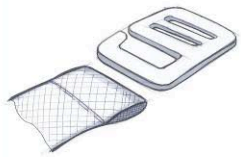
<td>  </td>
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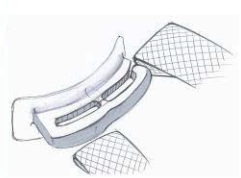
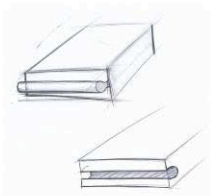
<td>  </td>
<td>  </td>
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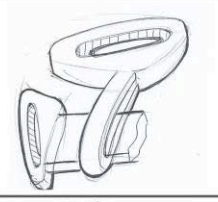
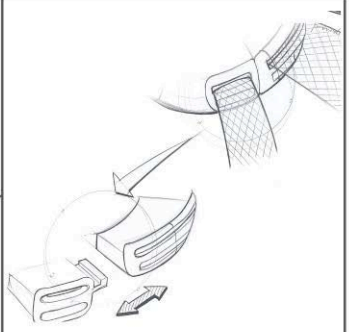
<td>  </td>
<td>It is an idea to assemble shoulder strap part and lap strap part.</td>
<td rowspan="2">  </td>
<td rowspan="2"></td>
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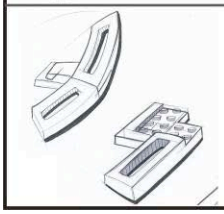
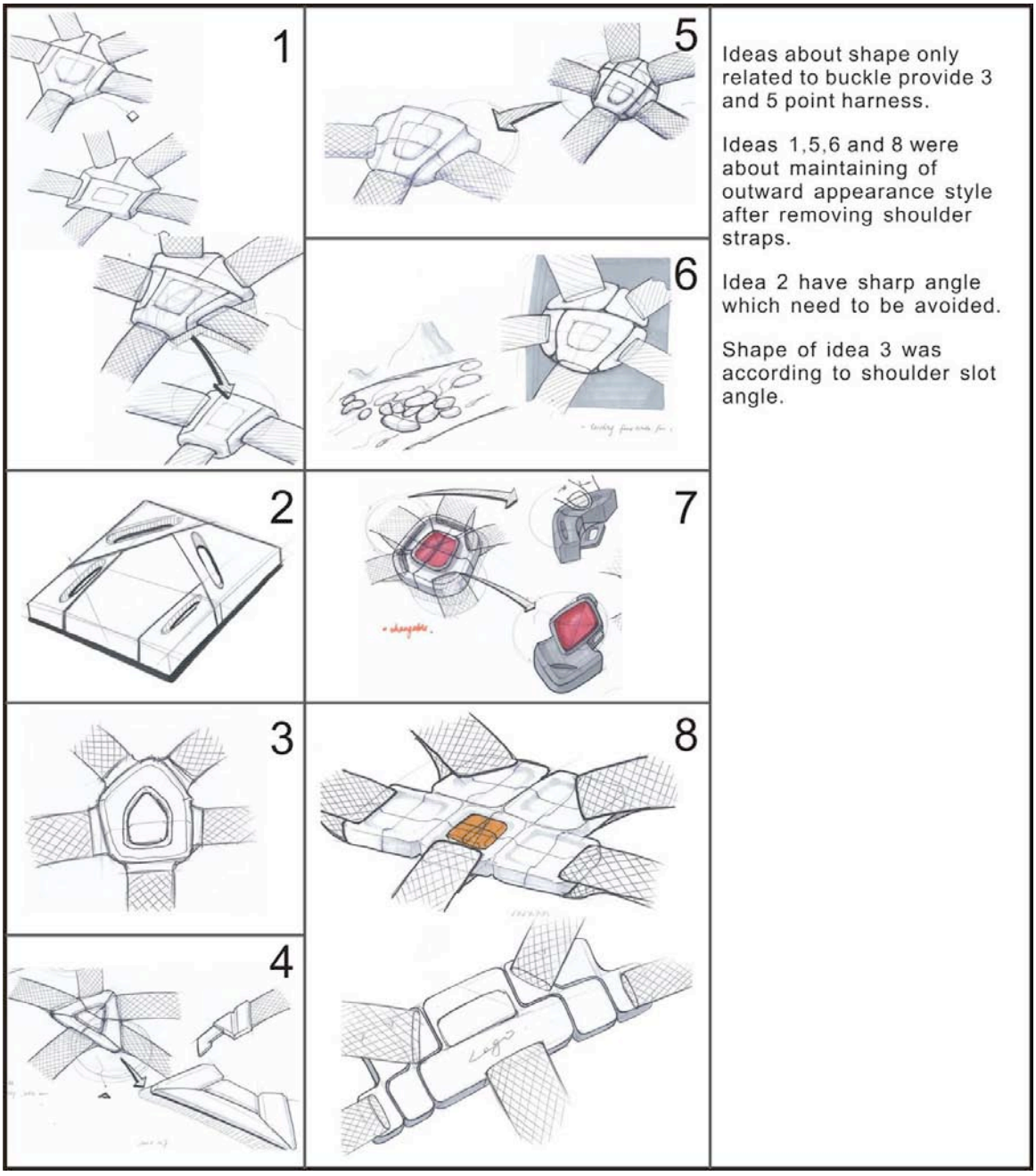
<td>  </td>
<td>It is an idea to assemble shoulder strap part and lap strap part.</td>
</tr>
</table>

Idea drive 3



Ideas about shape only related to buckle provide 3 and 5 point harness.

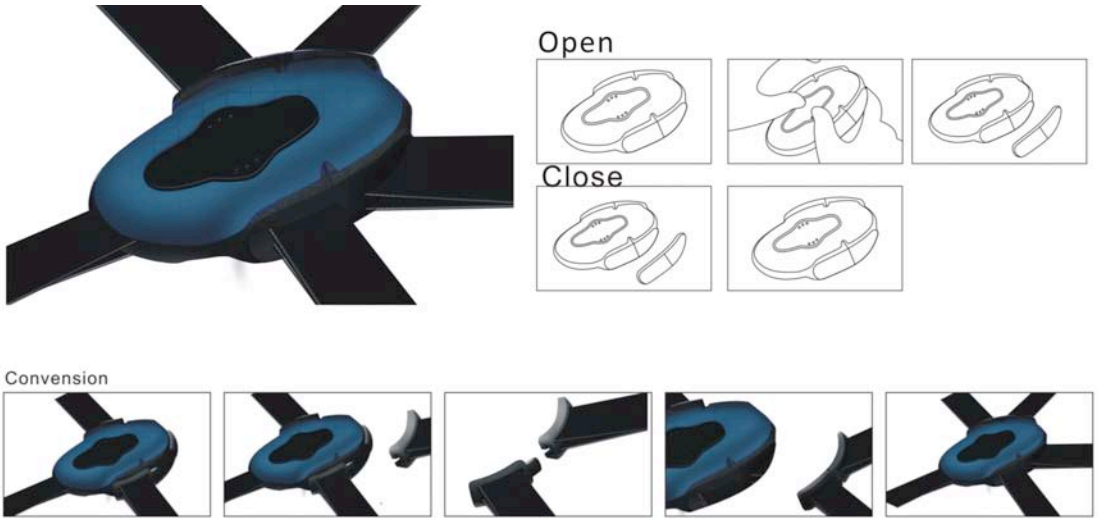
Ideas 1,5,6 and 8 were about maintaining of outward appearance style after removing shoulder straps.

Idea 2 have sharp angle which need to be avoided.

Shape of idea 3 was according to shoulder slot angle.

APPENDIX H CONCEPTS

OYTT



Buckle OYTT provides both 3 and 5-point-harness, it could be opened by pressing button with two thumbs together. However, it requires two hands' operation.

Slider

There is a safety button on the bottom of buckle "slider". The steps of opening are, sliding bottom button to unlock the buckle, then pressing top button to release latching parts. However, it is not clear to use in the first time.

ROTO

Buckle ROTO equips with a secure ring which could be rotated to unlock the button. The steps of opening are, rotating secure ring, and then pressing big button to release latching parts. Feedback is on the top of the buckle which is clear to use. It provides 3 and 5-point-harness.Logo could be etched or screen printed on button.