Process report

Hydra

Hydraulic Tool Support System

MA4-ID1 Fall 2009 | Andreas Hammershøj Olesen

Title page

Master thesis

Industrial Design

Institute of Architecture & Design

Aalborg University

Title

Hydra

- Hydraulic Tool Support System

Themes

Semi-technical products

User Centered Design

Functionality and ergonomics

Project period

September 2009 – January 2010

Supervisor

Christian Tollestrup

Andreas Olesen

Synopsis

This 4th semester master project concerns the design of a support system for hydraulic rescue tools used by firemen to free persons trapped in cars in automotive accidents.

The research and analysis phase contributes to the foundation of the project through the use of situated interviews, observing drills, analyzing theoretical training manuals and DVDs etc.

On the basis of the research and analysis, a problem is stated: How are the tools supported and procedures improved resulting in higher performance, more precision and less physical strain?

In the concept generation phase, a concept based on integration of known proven technologies is formulated on the basis of a sketching workshop and further investigations.

The concept evolves in the concept development phase by the use of sketching in combination with 1:1 working models that validate and explore design proposals through and empirical approach. The concept is detailed and documented by means of 3D modeling.

As a result, Hydra - Hydraulic Tool Support System is presented. A support system that through a harness in combination with a load-bearing arm relieves the operator of physical stress. With Hydra, the operator is able to work faster, more precise and with more endurance.

Preface

"The final semester of the master programme sets the stage for a manifestation of the student's abilities. With a point of departure in a problem defined by the student himself/herself, the student is given the opportunity to display the ability to achieve a combination of design and technical solutions in an integrated whole." (Studyguide 2009)

This is it

The master thesis is not just a manifestation of my abilities as a student. It is the final option to try out new methods and tools and thereby supplement and obtain new skills before I enter the professional world. A world where questions regarding jobs, profile, competences and life itself are suddenly increasingly pertinent.

I do not have a clear understanding of what my answers would be to all those questions, but since the master thesis is imminent, the project scope will be defined from what areas my current personal interests cover.

Products?

I see myself as a product designer with a focus on products on several different technical scales, but I have found myself more enthused with the design of semi-technical products (il. 0.2.) with a focus on user interaction such as functionality and ergonomics.

I enjoy solving actual problems through design where the resulting improvement is easily tangible. Focusing on aesthetics and styling is interesting as well but not as the sole foundation of a project, but rather as a "form follows function" (or ergonomics) approach.

What?

After having defined "sort of" what I want to learn, the next issue surrounds what I actually want to work with. The obvious answer would be to work in the area that I expect to be working on in the future, but this question is not yet clearly answered.

Out of personal interest, I researched working with products for use by firemen. A target group that has high requirements to functionality and ergonomics but also an area where I suspect integrated design to be able to solve substantial problems.

I hope you will enjoy the tale of my project!

Technical (engineering)

Excavator

ill. 0.1. Illustration - 2nd semester Master project.

Semi-technical

Wheel chair accessories

ill. 0.2. Bachelor theisis.

Non-technical (art)

Fire wood bucket

ill. 0.3. Project elaborates at architectural office.

Appreciation

Several people have been involved in the process of developing this project whom I would like to thank.

Thanks to Bernhard Obermayr from Weber-Hydraulik for providing user manuals, books and DVDs which have been especially useful during the analysis phase.

Thanks to Centervall.dk for allowing the use of high resolution pictures.

Thanks to Kim and others at the fire station showing me around and letting me observe a drill.

Thanks to Mikkel Heilmann for aid with the physical model.

Thanks to my girlfriend Gitte for continuous support and help with the project.

Reading guidance

The project is documented in two reports; a process report and a product report. The reports can be read in either order.

The process report contains five chapters matching the five phases of the process.

Phase 0

Project planning

Phase 1

Research and analysis

Phase 2

Concept generation

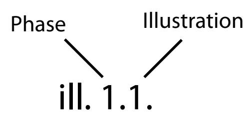
Phase 3

Concept development and detailing

Phase 4

Reflection/reaction

Harvard style is used for referring to all sources and the lists of references and illustrations are located in the back of the report. When referring to appendix and illustrations the following format will be used:



ill. 0.4. Illustration numbering diagram.

DVD

The process report is supplemented by a very elaborate DVD containing further documentation on the project. The DVD contains appendixes, inspirational pictures, inspirational links, pictures from observing users, sketches, pictures of models etc. Open index.html in the root on the DVD.

Contents

ill. 0.5. Fireman in action.

Introduction

The initial frames for the project are defined by personal interest. The following describes the initial approach driven by these interests.

Approach

The master thesis does not concern a predefined project/theme or a set of concrete learning goals.

The basis of the project is an area defined by personal interest. A problem field is researched and the users and context within this field are identified and explored to reveal a potential project.

Learning objectives

In a more concrete sense, the main learning objective is defined as:

- Completing an integrated design project that visually and technically supplements my portfolio (available on the attached DVD) and presents the major part of my design skills.

Through the project I should be able to present my core competences as an industrial designer and demonstrate that I individually have the competences to accomplish a design process resulting in a satisfying result.

The master thesis represents the final chance of completing a self-defined project of such a large extent before entering a professional life. This chance makes it possible to polish off existing competences as well as acquire new supplementary ones. As the project is individual, this will exemplify the need for performing all tasks that would previously have been performed by group members. This can be further specified as making it an objective to complete a successful project that is not diminished majorly in any of the important areas.

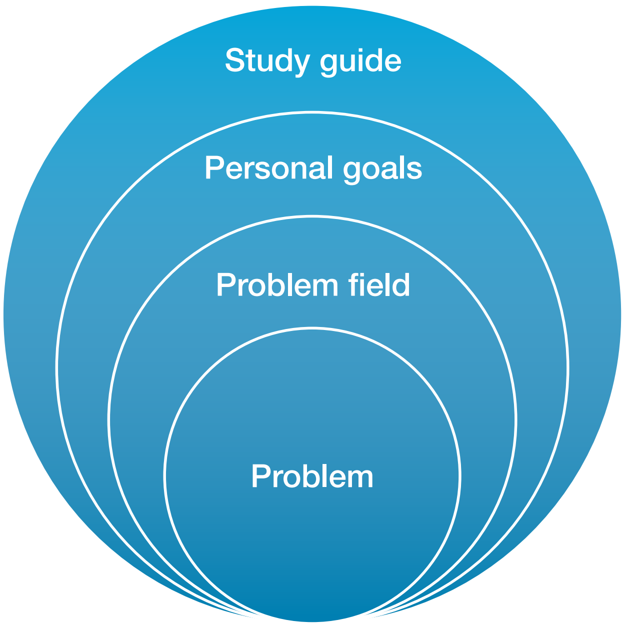
Themes

The objective of designing a”semi-technical” product will be approached under the theme “User Centered Design” and a “Form Follows Function” means of design. It is expected that basing the solution on specific user needs and context will increase the level of innovation in the project. Combined with mainly defining functions before aesthetics, should ensure a solid foundation for a successful end result. This approach should as well maintain a high level of innovation, compared to working in close cooperation with a company, a specific strategy, existing product line and production facility etc as a starting point for the project.

Planning

The planning phase of the project is initiated by dividing the project into phases and filling out a phase plan with main topics and milestones for each of these phases. The approach thereby defines what contents and focus will be included in the project.

Setting up deadlines can for the phase plan be a meticulous affair and a very useful tool for, but as a project relies on uncontrollable factors (especially during Research and Analysis), these deadlines are only seen as a guideline for the project.



ill. 0.6. Diagrammatic intrepetation of project focus.

Methods and Tools

Documentation aspects

As the project is individual, the documentation aspects of the project are believed to be a higher burden than in a group project. By means of documenting continuously throughout the project it is expected to reduce the often-heavy workload from the final period of the project. With this approach to documentation it is important to maintain focus on actual project work such as sketching, experiments etc and not let working on the computer take control of the project.

Research and analysis

In the first phase, User Centered Design methods such as situated interviews, observing actual use (real life and video) will provide a solid understanding of actual user needs on which to build a solution.

As the project is individual, a dictating machine, camera and video camera will be used when observing and interviewing users, with a reflecting transcription and observing pictures/video.

Concept generation

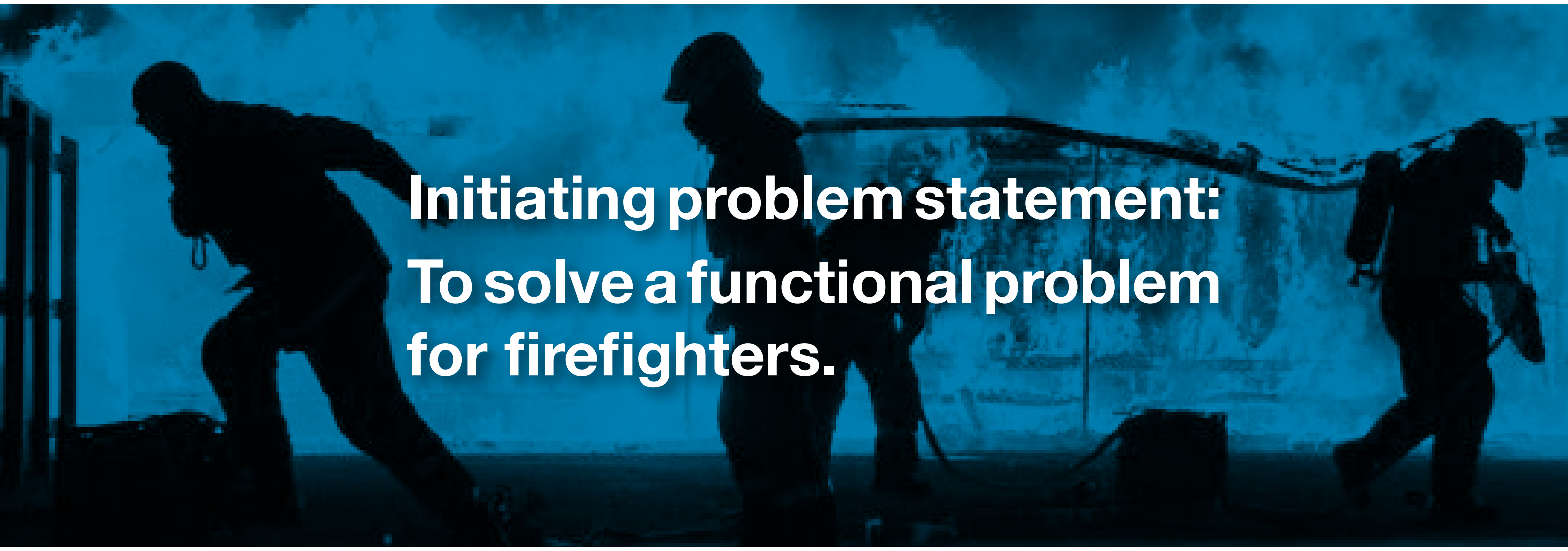
Sketching workshops with volunteers will be used to provide a collaborative synthesis effect for generating ideas as well as articulating the project.

The resulting functional principles will be evaluated and validated through experiments, which will be used to define the specifications for the solution and test various use aspects.

Styling and detailing the functional principle will be carried out using mood boards, sketching and 3D modeling.

Reflection

If possible the solution will be presented to users and other actors in the surrounding system to reflect upon the project.



ill. 0.7. Firefighters in action.

Project management

The project are divided into phases which are described in the following phaseplan.

The structure of the phaseplan is based on the generic product development process of Eppinger& Ulrich (Eppinger&Ulrich p.14). The phases of the model are interpreted to fit the focus of the semester and the time frame for the project.

The content of the phases are adjusted throughout the process as the focus of the project is specified.

Phase 0: Planning

(1/9 - 14/9)

Objectives/activities:

Articulate project

Project overview and themes

Project planning (phases)

Locate external contacts

Methods & tools:

Timetables

Milestones

Learning objectives

Output:

Phaseplan/weekplan

Initiating problem statement

14/8: First visit at Beredskabscenter Aalborg

Phase 1: Research and analysis

(14/9 - 12/10)

Objectives/activities:

Define problem areas

Usecases

Methods & tools:

Situated interviews

Going native?

Brainstorming

User investigation

Contextual analysis

Usecases/Storytelling

Problem exploration & delimination

Output:

Understanding of products and context

An overview of problem areas and focus

8/10 Hydraulic Tool Drill at Rørdal training facility.

Phase 2: Concept generation

(12/10 - 2/11)

Objectives/activities:

Create and select functional principles

Evaluate principles according to users

Benchmark products/market

Formulate principles into concepts

Develop concepts

Mature concepts

Choice of concept for further development (or derived concept)

Methods & tools:

“Crazy Idea Week” (5 min sketching)

Technology scanning

Market registration

“Three Ideas Week”

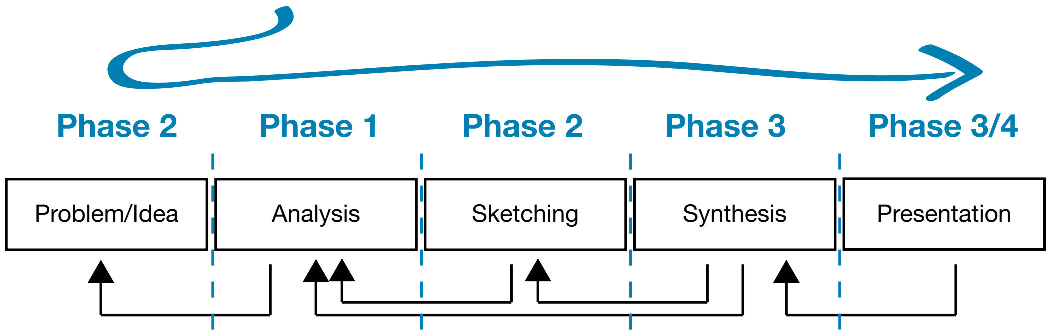
Moodboards/Shapeboards

Design scenarios

Output:

A concept containing a functional principle, form and expresseion.

ill. 0.8. Phase diagram.



ill. 0.9. Design process with added phases. Based on Knudstrup 2005

Phase 3: Concept development and detailing

(2/11 - 4/12)

Objectives/activities:

Product architecture

Main and detailed layout

Definition of materials

Styling

Methods & tools:

SolidWorks

Photoworks and Photoview 360

Output:

Graphical representation of the concept

SolidWorks model of concept

Phase 4: Reflection

(7/12 - 18/12)

Objectives/activities:

Documentation of the process

Process reflection

Documentation of the product

Rendering product

Methods & tools:

Adobe suite

SolidWorks (Photoview, PhotoWorks)

Output:

Process report

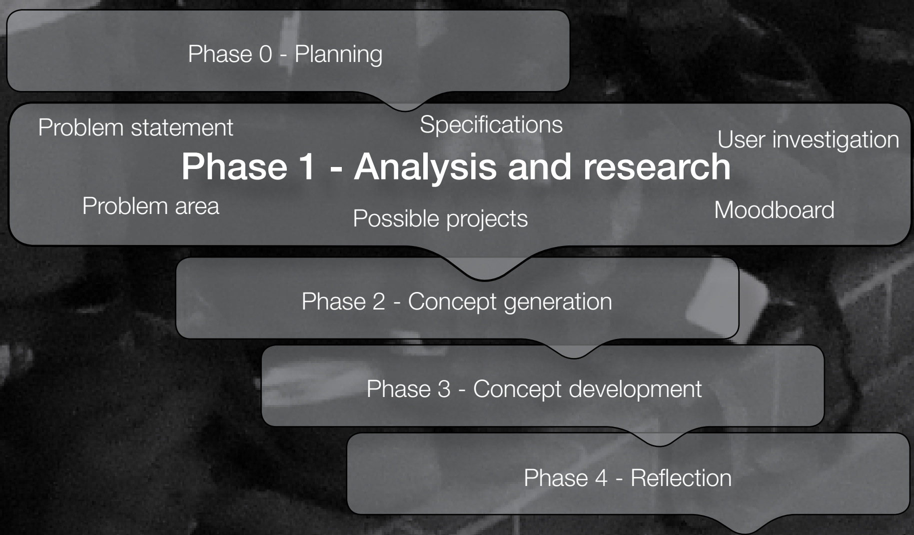
Product report

30/12: Printing

06/01: Project hand-in

ill. 1.10.   Coat rack at firestation.

Phase 1 - Research & analysis



Phase 1 contains the preliminary research and analysis of the project. Based on the initiating problem statement, firefighting and its aspects are explored through research online and by visiting a fire station. Various projects are considered and the initial analysis results in a problem statement.

By observing a drill at a training facility and through analysis of user, product and processes, phase 1 results in a set of specifications and a moodboard.

Research & analysis

Following the initial problem statement, the approach to research and analysis is described.

The use of firefighter products and their context is observed through a visit at fire station and through various other resources to be able to determine problem areas and opportunities for improvement of products or processes.

Kim, Beredskabsmester (Chief Firefighter) at the fire station, Oluf Borchs gade gave a personal tour of the fire station and an introduction to all of the products and how they are used.

Before the visit, information about the fire station and its activities were researched through their website and statistics (Aalborg 2009). Every incident of emergency responses is documented and briefly described which provides a simple overview of the number of and types of deployments that the fire station cope with.

Internet resources

Amateur photographers post their vivid photographs online which provides a good source for photographs of fires, firefighters and the use of their products. Online resources such as Centervall.dk (Centervall 2009) and DenErNem.dk (DenErNem 2009) provide these photographs.

ill. 1.11. Notepad.

ill. 1.12. Camera.

ill. 1.13. Dictating machine.

Notepad

The most important information such as contact information or future meetings is noted in the notebook for later use.

Camera

The camera is used for visual documentation (photographs and video) of products, processes and the context.

Dictating machine

The dictaphone is used to document the entire visit at the firestation. The recordings are analyzed to reveal important comments and details.

YouTube

As it is not possible to observe the products in actual use and context as an onset YouTube is used as a quick research tool for the various products and processes. The videos accentuate the photographs and exemplify how the products are used with motion pictures. The videos clarify the problems that arise when actually using the product. (Links available on DVD)

ill. 1.14. YouTube logo.

Other resources

Firefighter communities like Firetactics.com (Firetactics 2009) and FireRescue1.com (Firerescue 2009) describe in detail how complicated firefighting techniques work and contains several articles on the more theoretical aspects of firefighting such as “The basics of Ventilation” [Firerescue1 2009] as well as the more practical reviews of products. The methods described mainly focus on the American standards for firefighting, but are still useful for research.

The Danish “Beredskabsstyrelsen” (Beredskabsstyrelsen 2009) also feature technical documentation and use manuals for several different products such as the “Overtryksventilator” (smoke ejector) ranging from theories as well as how to use the pressure ventilator in practice.

ill. 1.15. Hydraulic tools.

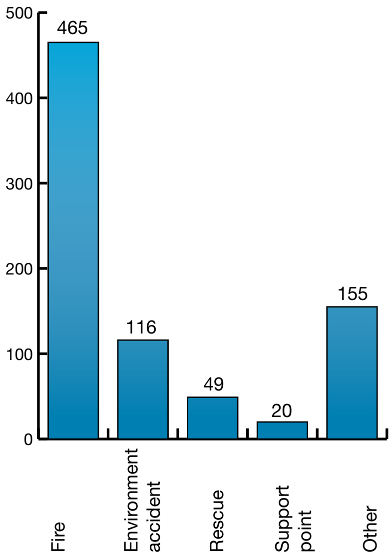
ill. 1.16. Preassure ventilator [Centervall 2009]

ill. 1.17. FireRescue1.com - a useful resource for firefighting tactics.

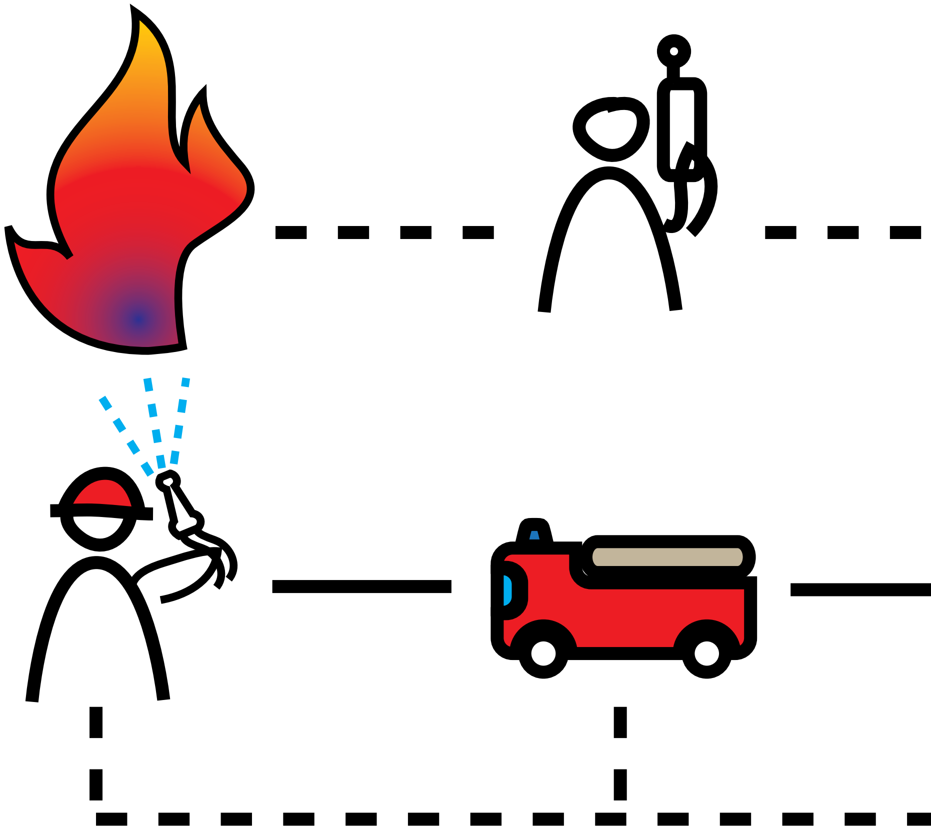
Oluf Borchs gade Fire station

On the following pages, the fire station at Oluf Borchs gade will be presented.

The deployments from the fire station are very different ranging from fires and environmental accidents as the two major to rescue operations and supporting operations as some of the minor deployments. There are also a large amount of “fake” alarms (other). Although the jobs of a fire fighter are very different (Christensen 2009) communication flows through the same system.



ill. 1.18. Deployments from fire station.

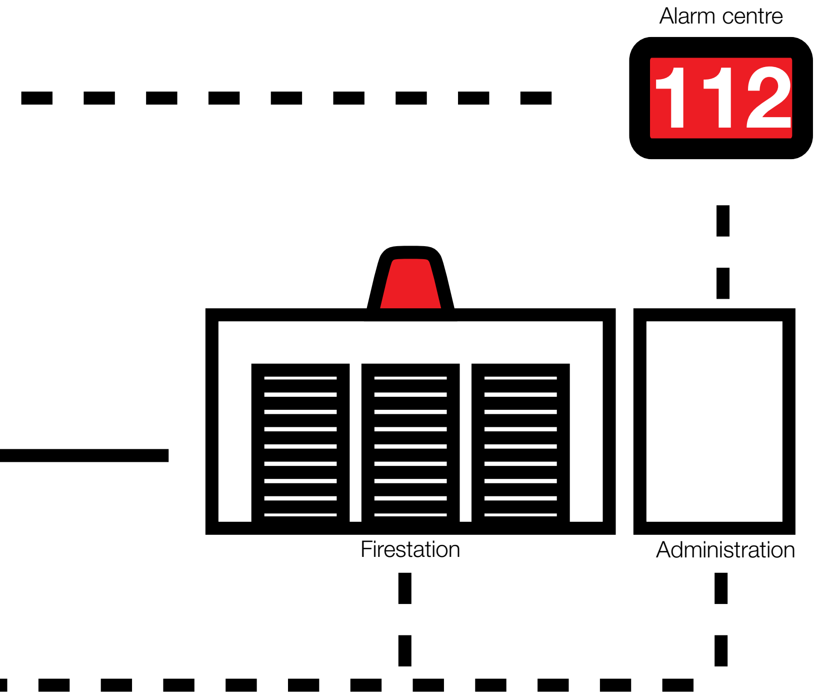


ill. 1.19. Deployment flow system.

ill. 1.20. Year report 2008, Aalborg Firestation.

ill. 1.21. Smoke diver radio with a modified button to make it possible to operate with large gloves.

ill. 1.22. Adress information is sent to an in-car GPS-unit automatically.



Visiting the fire station

In the following pages, the most important products and aspects revealed when visiting the fire station are highlighted and commented including quotes from Kim the chief firefighter.

Kim introduced the entire fire station, all of the equipment and explained how all of the products and processes work.

Obviously it is impossible to document every small aspects of the visit but the most relevant are included in the chapter. Additional pictures, observations and a sound recording from the visit are available in appendix on the attached DVD.

At the fire station, Kim introduced the waiting area, the dressing hall, the garage, storage facilities and maintenance department. The pictures and corresponding comments have been arranged into groups of similar application.

ill. 1.23. Information about the task is posted on big screens thereby making the firefighters aware of what to prepare for.

ill. 1.24. One of the various different vehicles available at the firestation. Many of the vehicles have multiple functions to be able to ahandle the various different tasks.

ill. 1.25. Kim, The chief firefighter at the fire station, demonstates the fire helmet and protective gear (headmounted flashlight, eyeshield etc.).

Possible projects

"I think that some sort of carrying harness or similar would be a great product and a large aid in using the tools."

- Michael Klausen, former fire fighter

Several problematic products and procedures were realized based on the visit at the fire station. Ranging in complexity and relevance, two possible projects stood out featuring viable problems. The choice of a project direction is based on a brief reflection upon the two projects and their contents (table ill 1.28.).

The smoke ejector

The smoke ejector consists of an engine and a propeller housed in a steel frame. It is a fairly low tech solution for moving large quantities of air and thereby controlling fire development and smoke.

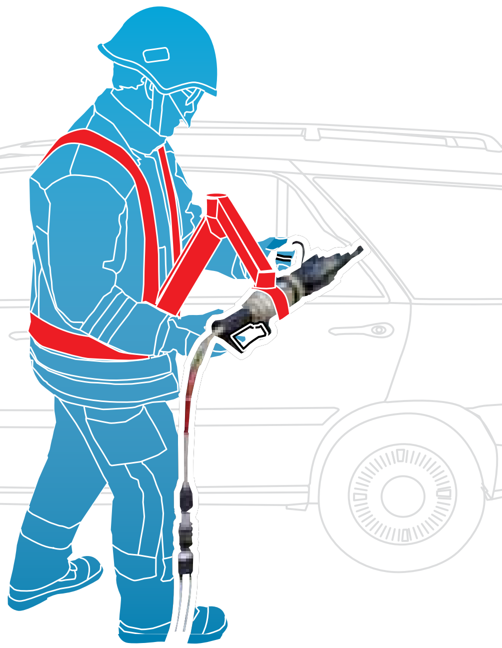
A project surrounding the smoke ejector is in most aspects a redesign with several possibilities for innovation on a fairly low level.

A project could consist of redesigning the main construction as well as rethinking the overall layout, dealing with ergonomics and muffling engine noise. The benefit is quite clear both on the short-term as well as long-term. The product is used frequently and an improved product will have a noticeable impact.

Hydraulic tools support

Hydraulic tools consist of a hydraulic piston that through a gearing mechanism operates a cutter, spreader or various other tools. The system relies on oil pressure created by a pump that transfers pressure to the tool via high-pressure hoses. The tools are heavy, difficult to handle and require high precision.

ill. 1.26. Smoke ejector.



ill. 1.27. Hydraulic support system.

The hydraulic support system is a new product that addresses the physical stress of using the tools. The project could consist of generating a concept that provides support of the tools by transferring the load to user torso/waist. The functional elements for this support system will incite a "Form Follows Function"-process.

Although the tools are not used as frequently, the improvements during use and on a long-term basis will be significant.

Where to go?

The hydraulic support system fulfills both my personal learning goals and the initial stated purpose of the project. It presumably contains aspects that are interesting and a fitting level of complexity.

	Benefit (short term)	Benefit (long term)	Frequence of use	Innovation	Complexity	Fit my profile
Smoke ejector	*****	***	Daily	**	****	****
Hydraulic support system	*****	*****	Weekly	*****	***	*****

ill. 1.28. Diagram summing up and camparing pros and cons for the two objects in relation to: Benefit (short term), Benefit (long term), Frequance og use, Innovation, Complexity, Fit my profile, Using plastic.

Problem statement

Handheld hydraulic equipment used by fire fighters to liberate restrained passengers in automotive accidents is heavy and difficult to handle.

How are the tools supported and procedures improved resulting in higher performance, more precision and less physical strain?

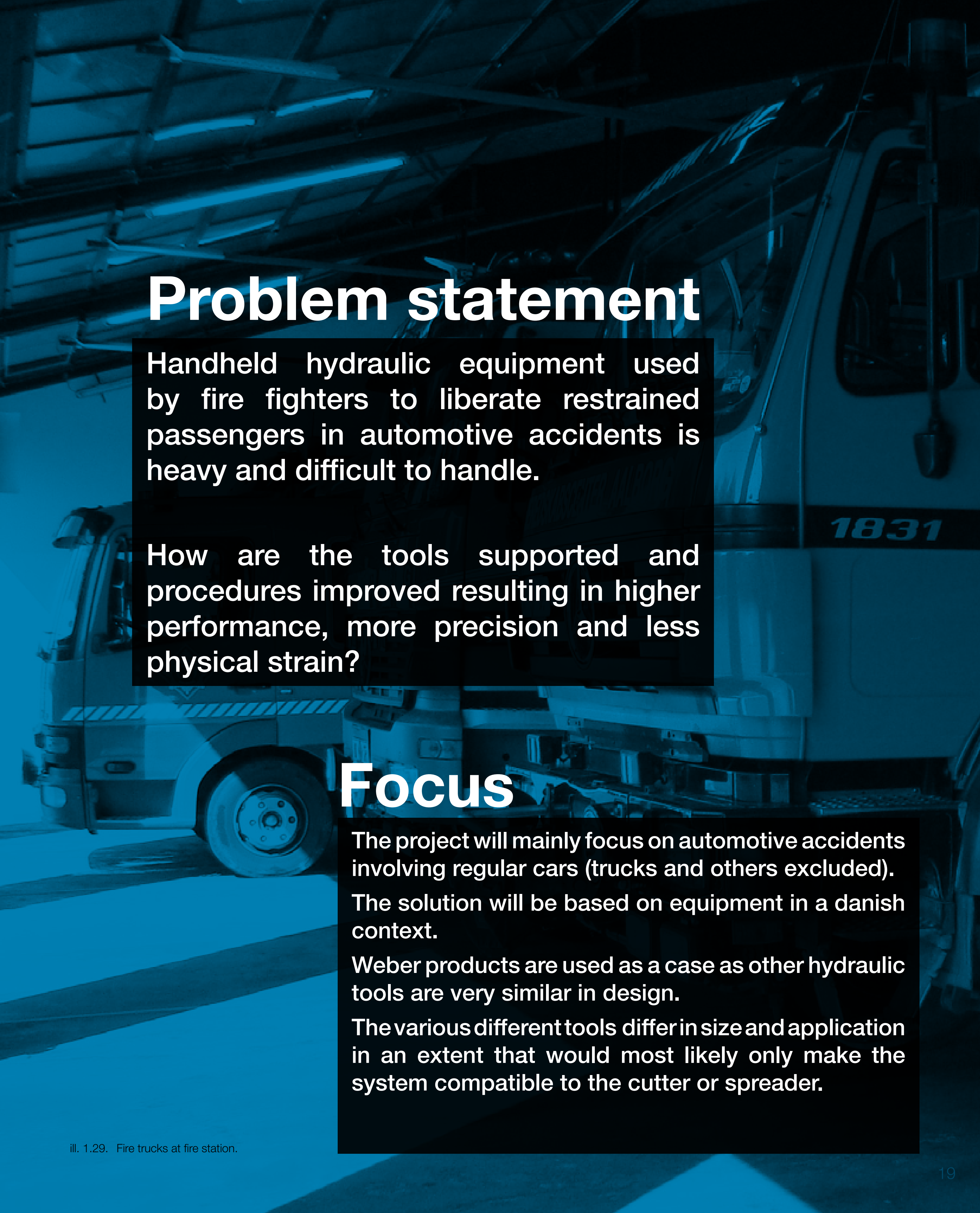
Focus

The project will mainly focus on automotive accidents involving regular cars (trucks and others excluded).

The solution will be based on equipment in a danish context.

Weber products are used as a case as other hydraulic tools are very similar in design.

The various different tools differ in size and application in an extent that would most likely only make the system compatible to the cutter or spreader.



ill. 1.29. Fire trucks at fire station.

Hydraulic tools analysis

Hydraulic systems

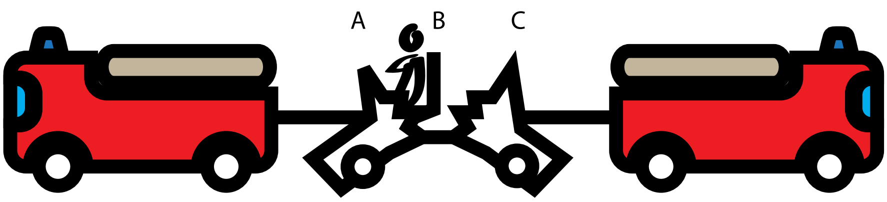
Hydraulic tools work through the use of oil pressure. A pump is able to generate the required pressure to several tools simultaneously (typically two or three). The pump is typically driven by electricity from the fire truck, but smaller and more mobile editions are available. When using two or more tools simultaneously, the pump performs slower as the power is divided between the tools. When using only one tool, the pump must be manually switched to provide pressure only to one channel for maximum power. The pump is controlled through a panel in the truck.

ill. 1.30. Weber Power Unit E 50 - T + SAH 20

Hoses

The pressure is fed to the tools through hard plastic hoses that are very stiff and difficult to handle. The hoses do not easily kink, but are relatively fragile against sharp edges, vehicles driving over them etc. If a hose is penetrated, the complete hose must be replaced.

The tools mount to the hoses via a quick-disconnect valve, which makes it easy to switch to another tool.



ill. 1.31. Advanced car opening.

Use

There are many different approaches to retrieving trapped patients in car accidents. The processes sometimes require the use of several different tools. As an example, removing the roof by cutting the door posts with the cutting tools and using chains connected to two fire trucks, a car can be pulled open like a clamshell (ill. 1.33.).

In another approach, when the spreader does not extend far enough, an extension cylinder is attached to the hoses (via quick-disconnect) and pressures the dashboard upwards via the doorframe (ill. 1.34.).

ill. 1.32. Advanced car opening.

The tools

A cutter and spreader of a generic size is typically standard equipment. These are typically very similar in main layout, only differentiating in opening size, cutting/ spreading force and therefore in size/ weight.

Both tools are operated by a hydraulic cylinder, which is encapsulated in a steel shell. The cylinder drives the cutter/ spreader blades through a gearing mechanism. Oil is provided to the cylinder through the parallel hoses on the back of the product which are covered by a flexible spring to protect the fragile hoses.

The cutter functions like a large set of scissors with an offset cutting mechanism driven by a hydraulic cylinder. The cutting blades are designed so that they pull the object closer when cutting.

The spreader functions similarly to the cutter, but the main force is applied to spreading instead of cutting although the tool is also able to squeeze objects with a large force.

Ergonomics

The cutter includes a handle towards the front of the tool and one on the back whereas the spreader incorporates two handles around the center of mass.

Both of the tools feature a push-through button just in front of the rear handle, which operates the opening/closing-mechanism. The button can be pushed either way with a corresponding action.

Accessories

Various accessories are used in combination with the hydraulic tools such as door inlays (ill. 1.32. previous page), cloths with magnets (to protect against sharp edges) and other non-hydraulic tools like saws, hammers etc.

ill. 1.33. Weber RS 165-65 Cutter

ill. 1.34. Weber SP49 Spreader

Rescuephases

Weber-Hydraulik

At the fire station they primarily use hydraulic tools and accessories from Weber-Hydraulik. When contacted, the Austrian company provided several sources of information and notified me of their interest in the project.

Weber-Hydraulik provided training manuals for several of their products as well as books and DVD's on rescue procedures and hydraulic tools.

In Norderstedt, the 9. – 11. October, Weber-Hydraulik hosted the Rescue Days 2009. Rescue Days feature several different rescue situations involving automotive accidents. Live video is available including explanatory dialogue and discussions of the rescue workers as they carry out the job. (Google Videos 2009.)

From the DVD-set, two main subjects are of relevance for the project. Standard operation procedures divided into phases (ill. 1.37. – 1.43.) and "Working areas" (ill. 1.44.).

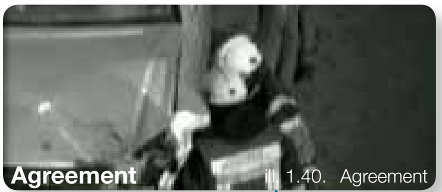
ill. 1.35. The Rescue Days logo

ill. 1.36. Books and dvds.

ill. 1.37. Approach

ill. 1.39. Situation report

ill. 1.38. Reconnaissance



ill. 1.40. Agreement

The approach must be coordinated and calculated. A falsely parked vehicle can hamper the rescue.

The reconnaissance is made by the officer in charge. He gains an important overall view of the accident area.

A situation report must follow from the police, medical and fire service requiring all technical as well as medical rescue measures that are required to be put into action.

Agreement takes place between the officer in charge and the emergency doctor. They discuss in a dynamically changing interplay what further action to take in the interest of the casualty.

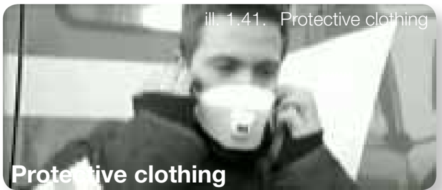
Working areas

The incident area is arranged into two working areas. The inner working area applies for the officer in charge, emergency doctor, paramedics or one crew member responsible for casualty care, and an operational crew, who are to pay attention to the following points: Type and construction of the crashed vehicle, possible leaking of flammable liquids and dangerous goods and the means of access into the car.

Adjacent to the inner area is the outer working area, applies for support crews, ambulance crews and police. Important points for them are: Observation of traffic, preventing the spread of danger and carrying out inspection of the surroundings.

It is important for everyone to keep to his or her own working area; thoughtlessly leaving the area can result in serious accidents.

ill. 1.44. Standard operation workingareas.



ill. 1.41. Protective clothing

ill. 1.43. Batteries

ill. 1.42. Extinguishing media

Personal protective clothing and equipment is to be worn in accordance with health and safety regulations do not jeopardize yourself and others with carelessness.

Two independent extinguishing agents and if necessary special extinguishing media are available and in readiness, they should be constantly manned throughout the incident.

Locate the batteries. Disconnect both battery cables on all batteries, negative terminal first and tjeck that the vehicle is voltage free.

WEBER-HYDRAULIK

ill. 1.45.

Weber-Hydraulik is a leading and innovative international company that implement hydraulic drive and control engineering. The range of products extends from components to systems for mobile and stationary applications. Weber-Hydraulik also equips fire services and emergency management bodies throughout the world with rescue equipment.

(Weber 2009)

Hydraulic Tool drill at Rørdal

To fully understand the use of hydraulic tools, a drill is observed. The drill is performed on a regular passenger car.

The vehicle is approached in several different positions: on the side through the rear window, flat on the ground through the driver side door and a “third door” approach.

Regular use

The standard approach of opening a door involves a lesser strenuous approach, where the tool is not put to far reach positions. The immediate problem observed was when the operator used his weight to cram the hydraulic spreader between the door and doorpost to open the door. The operator leaned over the tool, into the dangerous area of flying shrapnel and suddenly protruding sharp edges as observed by the supervising fireman.

ill. 1.46. Regular use.

ill. 1.47. High reach situations.

High reach situations

If the driver’s feet are possibly trapped underneath the pedals, an inspection opening is made beneath the front door. With the car on the side, the opening is made in a high reach position. The operator is almost unable to lift the tool while positioning it for an optimum cut which is necessary for a successful entry. The problem is further enhanced by the fact that the button on the tool is placed even higher than the cutting point. To succeed another fireman is required to support the tool as well. Alternatively a lifted stage construction is available, but setting up the support is a lengthy process.

Low reach situations

Reaching a cut lower on the car challenges the operator for instance when kneeling or lowering the tool. The strain on the operator’s back is increased and the cuts or spreads are similarly to other far reach positions difficult to carry out with high precision. In these far reach positions; the operator also quickly becomes tired, requiring a break, help or substitution from other firemen.

ill. 1.48. Low reach situations.

ill. 1.49. Confined spaces.

Confined spaces

With the door on the side, the easiest entrance is through the rear window hatch. The hatch was removed allowing an operator to enter the vehicle through a very narrow opening. The tight space barely allowed a person to enter which made it a challenging task to operate the heavy equipment in such a confined area. With the hatch removed, the operator cut out the seats allowing a stretcher to enter to the trapped persons. A fireman secures the passengers neck during the operation.

Switching tools

The processes involve two primary tools: the cutter and the spreader. These tools are used extensively and simultaneously and therefore require their own set of hydraulic hoses. The quick-disconnect hose plugs allow the hoses to be fairly easily attached to a third tool, where the longer extending cylinder is often used. The cylinder is for instance used to press open a doorframe with the help of precise and tactical cuts from the cutter tool and the use of a relief bar.

ill. 1.50. Switching tools.

ill. 1.51. Switching tools.

Reflections

The observations result in several clearly defined requirements for a support system, which will be specified on the following page. Some of the main observations and considerations are noted below.

Preparing

When the fire truck drove close to the scene, it backed up within few meters of the damaged vehicle. The hydraulic tools and control station is placed in the rear of the truck. The cutter and spreader was carried close to the damaged vehicle and put on the ground. The vehicle was then supported to be stable on the side. When tipped over for other exercises, the wheels where punctured to increase the stability of the vehicle.

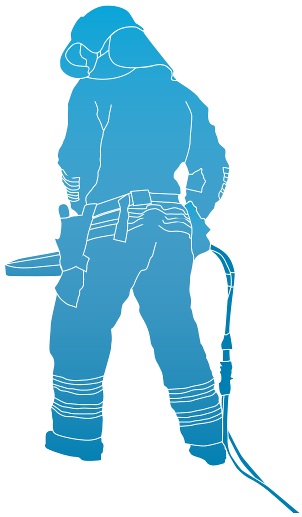
ill. 1.54. Low reach position.
In this position, the firefighter experiences a moderate level of physical stress, but not significantly more difficult than regular positions.

Working

The uses of hydraulic tools are very different in approach and involve high requirements for the agility of the user and flexibility of moving the tool around. The tools themselves are very heavy and bulky, making the difficult to handle – especially in far reach positions.

The firemen use the tools for an extended period of time ranging from a few minutes to 20+ minutes with tool changes (e.g. the “third door” approach, where an entire door opening is made).

The firefighters work in teams of 5-6 and they switch the operator relatively often (3-5 minutes) to maintain high performance. During the entrance through the rear window hatch, the operator was required to work without a substitute. The look on his face illustrated the intense and exhausting job.



ill. 1.52. Regular position.
In this position the tool less difficult to carry. The position is quite often used for the more ”regular” car crashes.

Other aspects

To protect their eyes from flying shrapnel, the firemen used their flip down safety goggles in their helmets.

The firemen did not access any pockets or use their uniform in any other way than for protective means. It did not seem like any special considerations to layout on the fireman should be taken if a design was to include sort of harness or some other kind of relief system that could inhibit access to pockets etc.

The cutter and the spreader are very similar in design and resemble each other in dimension, weight and application, where the extension cylinder differentiates in both of these areas.

ill. 1.53. High reach position.
This position is more seldom, but very difficult. The higher reach positions increase physical stress to an exhausting extent.

Specifications

A set of criteria for the hydraulic support system is listed.

The specifications for the hydraulic support system are derived from the analysis and observation of the use of firefighter products.

Although the support system does not compete with other systems, its aspects can still be regarded via Kano's model of must-be, performance and excitement factors. The main competitor of the system is not using it at all. The system must improve on several aspects such as ergonomics, functionality and performance.

Primary requirements:

The system (must be) able to:

- Support the hydraulic tool in most positions.
- Provide relief to the physical strain of the user.
- Be operated using wearing thick protective gloves.
- Make it possible to work at least as precise and fast as without the system.

Important aspects:

A reasonably high level of (performance) is required for the product to be successful in its use and thereby succeed in any regards. It would be favorable if the system:

- Supports the cutter and spreader interchangeably.
- Supports in very high and very low reach situations.
- Enables the tool to rotate for all cuts/spreads.
- Is very compact to be able to be used in confined spaces.
- Retains a high degree of mobility and agility.

Excitement factors:

The system may appeal to the (excitement) of the user if it makes it possible:

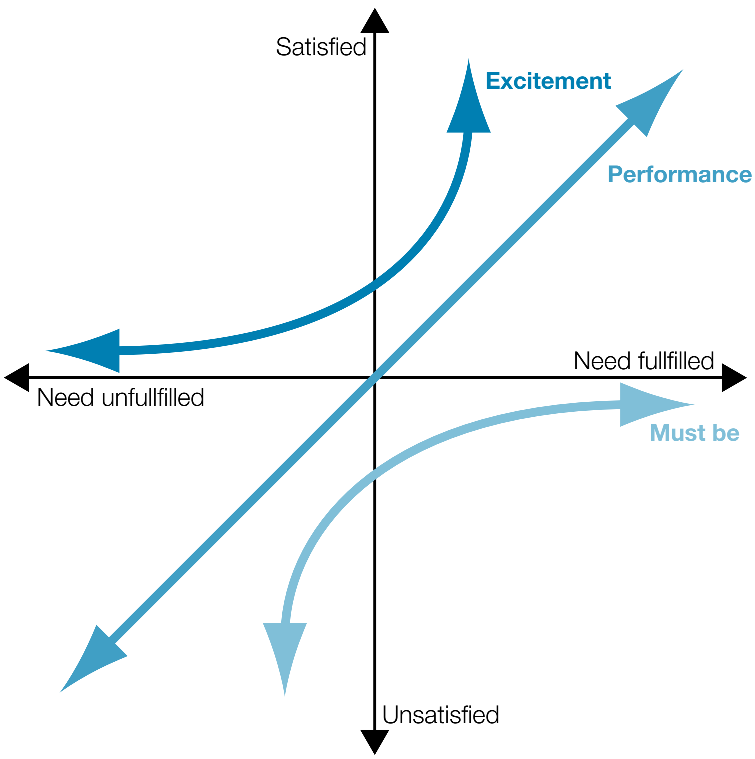
- To detach from and attach to the support system very quickly in situations where the system is too bulky or another tool is required.
- To detach the hydraulic tubing while the tool is still in the system whether it is attached to an operator or not.
- The specifications will be detailed and reflected upon throughout the process.

Contextual requirements

The system must be low-maintenance and be highly durable. It must be designed with the wear and tear in mind both through use of durable materials as well as clever design solutions.

The system should attach to the firefighter in a way that maintains access to important functions on the uniform such as the radio, important pouches etc.

The system should easily be removed from or placed in the firefighter vehicle before or after use.



ill. 1.55. Kano's model.

Moodboard

A firefighter...

...is well prepared.

...is a team player.

...is very strong through regular physical workout.

...could be considered a combination of an auto mechanic and a paramedic.

...is very calm and patient.

...deals with accidents very reasonably with a large overview.

...is very dedicated and serious about his job and solving the task at hand.

...will choose the easiest and most efficient solution disregarding ergonomy and physical wear and tear.

ill. 1.56. A firefighter.

ill. 1.57. Moodboard.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01

Phase 2 - Concept Generation

Based on the analysis of Phase 1, a concept generation process is initiated. The process is initiated through a sketching session with the purpose of creating principles.

The principles are evaluated according to the set of initial specifications and a principle or a combination of principles are formulated into an initial concept which will be verified and detailed in the concept development phase.

ill. 2.1. Set up for test.

Creating principles

A sketching workshop initiates the second phase.

To initiate the concept generation, a sketching workshop is carried out with a couple of volunteering industrial designers. The collaborative synthesis effect that appears in groups can be difficult to replicate as an individual.

Besides providing plenty of paper and pencils, the workshop is prepared by printing out outlined drawings of a fireman opening a car door with the cutting tool. The drawings provide a simple way to sketch “in context”.

Large photographs of the products in use and video material as well as spec sheets and other relevant information were prepared for the workshop.

Procedure

As an introduction, the project is briefly explained by means of photographs and video material. The purpose is to explain the problem at hand; its context and circumstances to the workshop participants. This articulation of the project and discussion of further questions increases the awareness of important project aspects from several points of view.

A series of short 10-15 minutes sketching sessions is performed. Ending each session, the sketches are presented and discussed in collaboration in order to grow the group synergy effect.

The following sessions built upon the existing ideas as well as produce new ones.

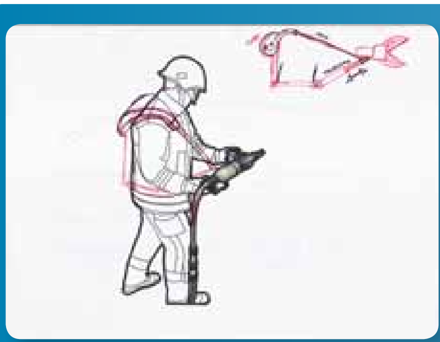
The duration of the workshop is around an hour of sketching and discussions regarding the sketches and the project. To increase creativity, very few negative opinions are allowed, although, necessary to guide the process to maintain focus on solving the chosen problem (ill. 2.3.).

Results

As a summary, the ideas are grouped as many of them are variations of the same basic idea. The ideas are then analyzed verbally.

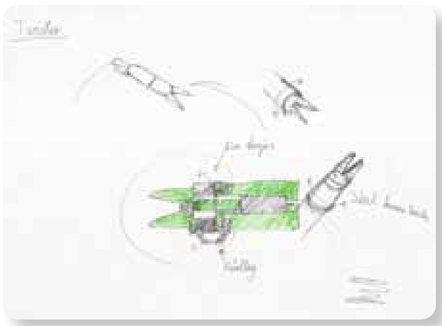
The main interesting ideas were further evaluated through positive/negative aspects.

ill. 2.4. Sketching on the tripod.



ill. 2.5. Sketching the suit.

ill. 2.2. Big Dog robotic dog.



ill. 2.3. Tool sketch. One of the ideas that goes beyond the project focus (changing the tool itself).

ill. 2.6. Sketching the monopod.

ill. 2.7. Sketching on the tripod.

The Tripod

The tripod concept works through supporting the tool via a tripod or a clamp that can be mounted onto the vehicle. It removes almost all of the load-bearing aspects from the firefighter, but will require special situations surrounding the setup such as enough space around the vehicle as well as limited reach.

+ Supports the entire weight
+ Is seperated from the operator(s)
+ Is very stable

- Is complicated to set up and move
- Requires a lot of room
- Is complicated

ill. 2.8. Sketching the suit.

The Suit

The tool is supported by a structure that is attached to the operator. Through this structure, weight is transferred to larger muscles, while operation of the tool itself is controlled by the arms.

The use of the tool will mostly remain unchanged, but physical wear and tear will be diminished.

+ Transfers weight to larger muscles
+ Retains mobility
+ Works in cooperation with the operator

- Is fairly complicated
- Increases total size
- Is operator dependant

ill. 2.9. Sketching the monopod.

The Monopod

A simplified system, where a height adjustable monopod supports the weight of the tool and the operator controls the tool itself. The monopod will obviously not support in all situations, but the idea is that it in its simplicity will support in most situations and relieve physical stress.

+ Is very simple
+ Is easily detached
+ Easy to move around

- Supports in fewer positions
- May be difficult to handle
- Tool must be supported continuously

Concept main layout

The results from the sketching workshop are developed into an initial concept.

Sketching on concept

Of the three resulting principles “The Suit” is chosen as the most solid concept. The concept realizes many of the requirements laid out in the initial specifications (pp 26-27).

The system will fulfill the primary requirements such as supporting the tool in most positions, relieving physical stress thereby increasing precision and performance etc.

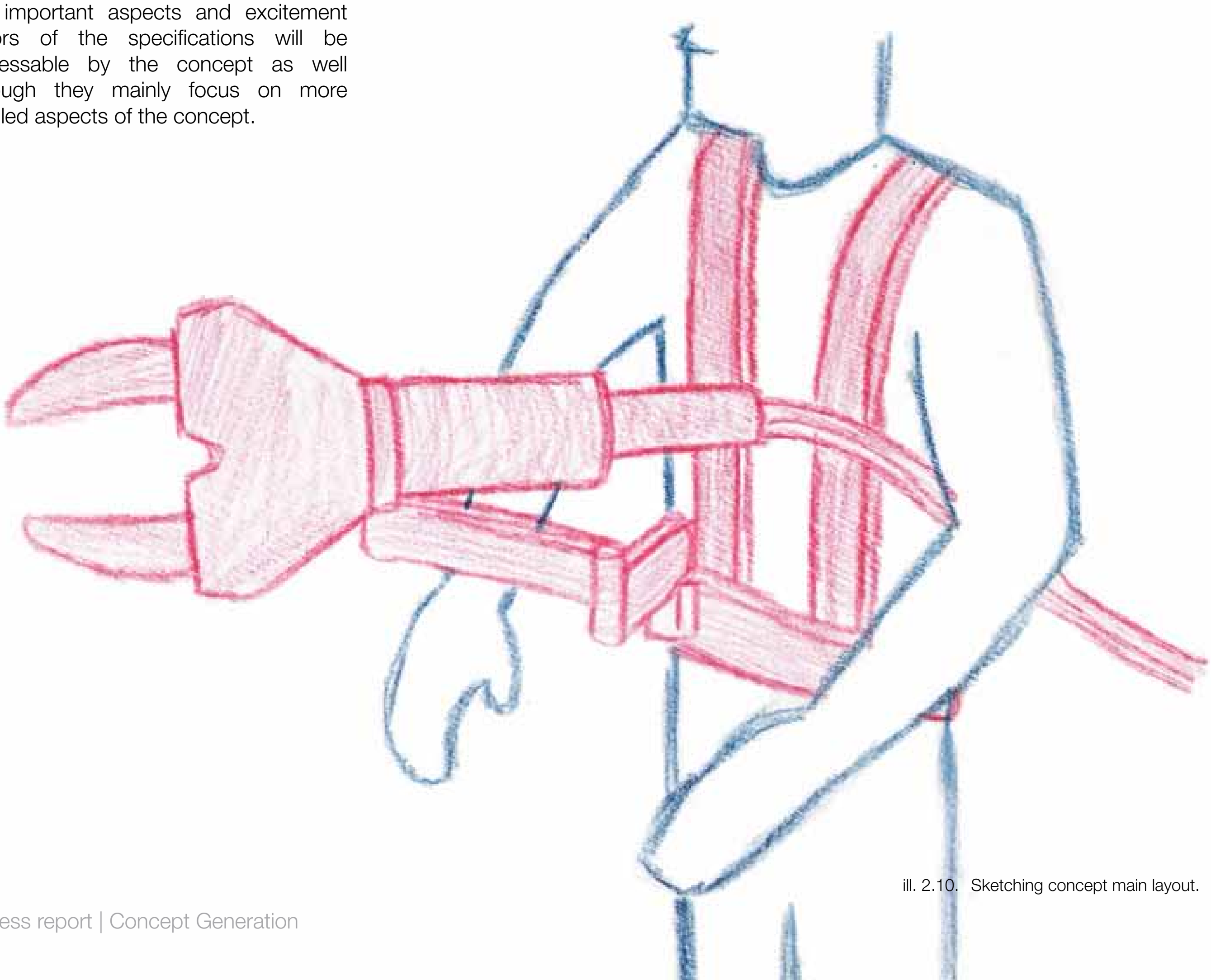
The important aspects and excitement factors of the specifications will be addressable by the concept as well although they mainly focus on more detailed aspects of the concept.

”The Suit” consists of two major parts; a harness system and a supporting arm. The arm supports the tool by transferring the weight onto the supporting structure attached to the torso of the operator.

The concept is divided into three major focus areas; the harness, the arm and the joints:

The harness

The harness consists of a stiff structure, which transfers the weight onto the torso of the operator. The stiff structure will divide the forces onto different areas of the upper body.



ill. 2.10. Sketching concept main layout.

The supporting arm

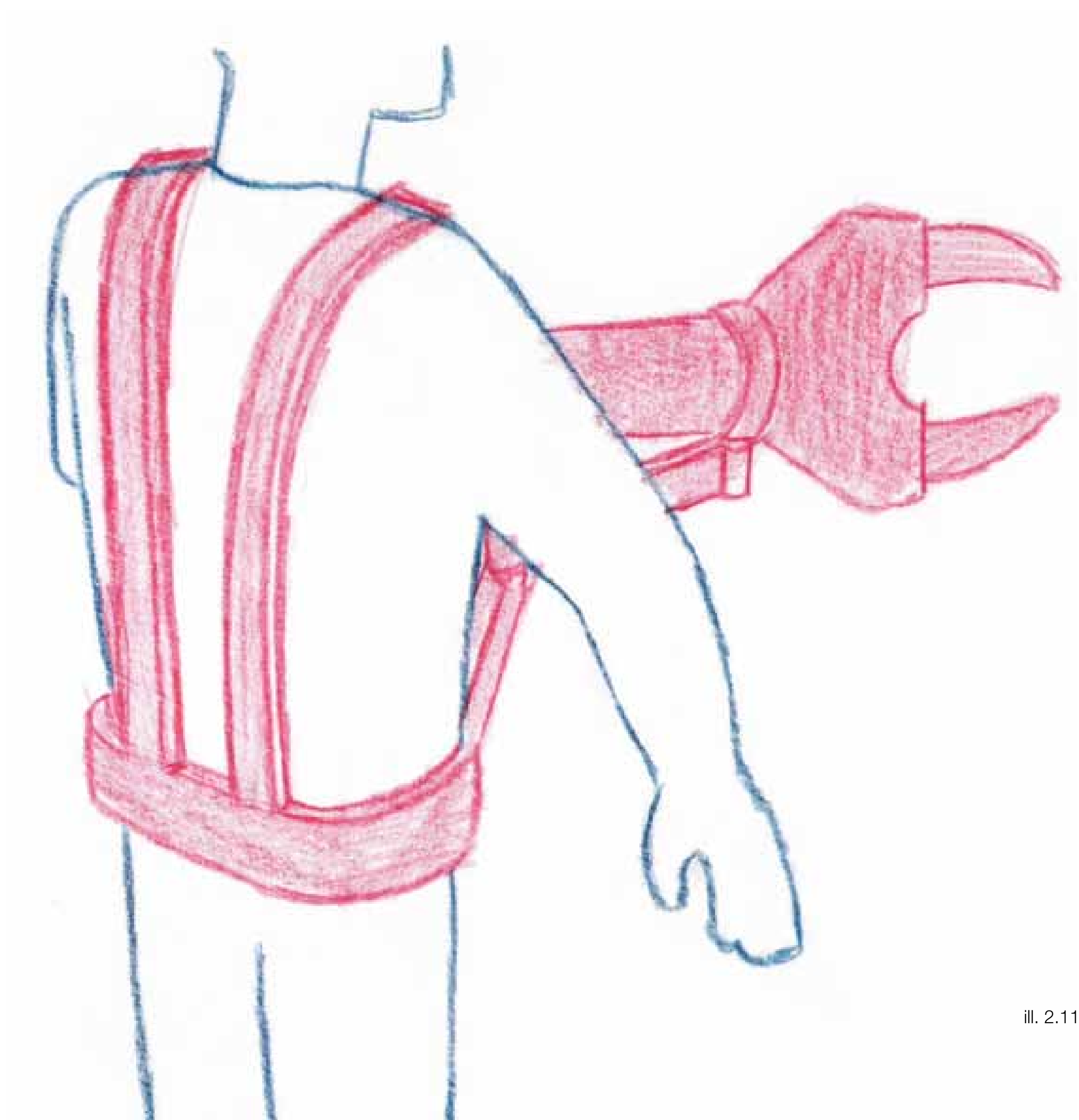
The arm consists of a series of beams, which are connected through joints. The arm will provide vertical as well as horizontal movement of the tool. The arms must integrate some kind of spring system to provide support for the tool to carry its weight.

Joints

The tool attaches to the arm via a joint. The joint must provide the necessary movement and rotation of the tool as well as provide options for removing or changing the tool.

Use

When using the tools, the system should be usable for most situations. To provide maximum flexibility, several harnesses can be incorporated to make it possible to switch operator and/or tool rapidly. In situations where the system is unusable or too bulky, it will be able to be removed quickly.



ill. 2.11. Sketching concept main layout.

Concept development

Initial concept development and inspirational sources are articulated.

Before generating ideas for the harness, arm and joints, research is carried out to find inspiration for the technical and functional parts and thereby defining main layout and functionality.

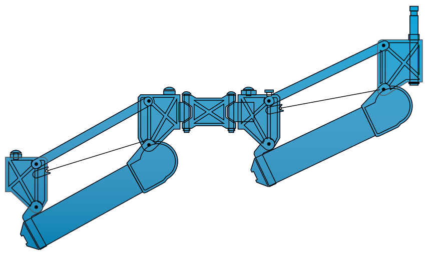
Inspiration

During the workshop, steadicams has been mentioned and studied several times.

As the name implies, steadicams are developed to minimize the jolts that footsteps sends through the body which result in shakes and shocks in video footage. Steadicams consist of three major elements: An articulated iso-elastic arm, a specialized ”sled” for camera equipment and a supportive vest. (HowStuffWorks 2009)

Although Steadicams were developed mainly to improve camera balance, to minimize shakes and shocks it does perform another function of relieving the pilot of physical stress which is similar to the physical stress experienced by a fire fighter when using hydraulic tools.

The ”sled” is mainly for storing batteries and an LCD-screen and is very specific for shooting video, but the arm and the supportive vest are a very relevant source of inspiration.



ill. 2.12. Sketching concept main layout.

The supportive vest

The vest consists of a stiff exoskeleton structure that transfers weight onto the shoulders and front waistline of the operator. The pressure areas are padded while the weight-transferring structure is relatively bare.

The vest is closed by using a series of buckles and Velcro to ensure an optimum fit.

The arm

The articulated arm provides a sort of “self-levitating” system similar to a spring-loaded swing arm lamp (an architect’s lamp). It consists of two arm segments connected through a pivoting hinge (ill 2.12.).

Other similar products are used for inspiration to the arm and joints as well, such as the JB Medico Armstrong arm, which is able to support a large amount of weight using a similar system (ill. 2.15.) and joints for camera equipment (ill. 2.16.).

More inspirational material is available on the DVD.

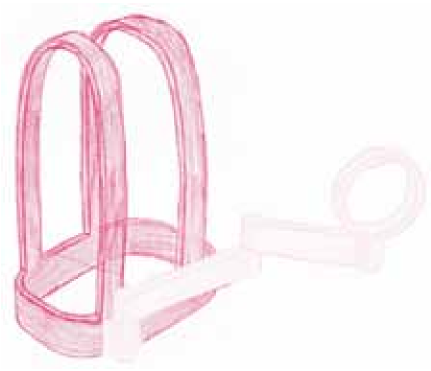
As a result of this inspirational research and thoughts on application, several design problems are revealed.

ill. 2.13. A modified steadycam from the movie ”Aliens”, used to control an otherwise impossible to carry machinegun.

ill. 2.14. Studiecam supportive vest.

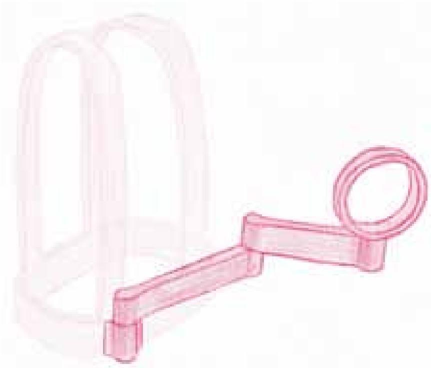
ill. 2.15. An architects lamp.

ill. 2.16. Joint for camera equiptment.



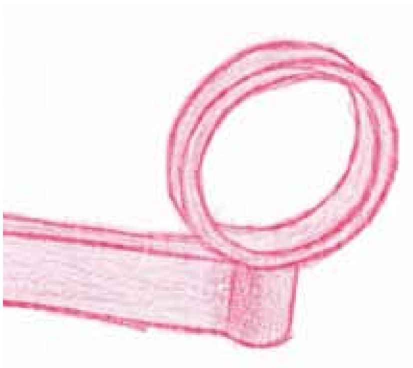
ill. 2.17. The supportive vest.

Design problems:
Enter/exit
Buttons
Ergonomy/stress
Centre of mass changes
(Hoses)



ill. 2.18. The arm.

Design problems:
Range
Movement/ihibition
Hoses



ill. 2.19. The joint.

Design problems:
Rotation
Detachment/switch tool
Buttons
Placement of hoses and couplings

Physical models

A 1:1 scale model is built and used for experiments.

Full scale modeling

As a hydraulic tool is unavailable for testing purposes, a 1:1 scale model is built. Initial calculations made it clear that the sheer weight of the tool is too high to construct a model without using some kind of heavy material. The target weight on the selected model, the RS 165-65 (which is also used at the fire station at Oluf Borchs gade) is 16,1 kg.

As in the professional world, networking is of extreme importance and networking provided access to a steel lathe in which a slightly simplified main body of the tool was machined. The cutter seems to be used more frequently and is chosen for the model and following design phases. The cutter and spreader differentiate slightly in the main body and a corresponding attachment point would differ as well.

The front of the model is constructed in layers of MDF and painted to achieve a close resemblance to the actual product. To model the handles and hose couplings, threaded bar is fitted to corresponding drilled and tapped holes of the main body. Regular pneumatic hoses represent the hydraulic hoses.

ill. 2.20. Full scale modeling.

How much support?

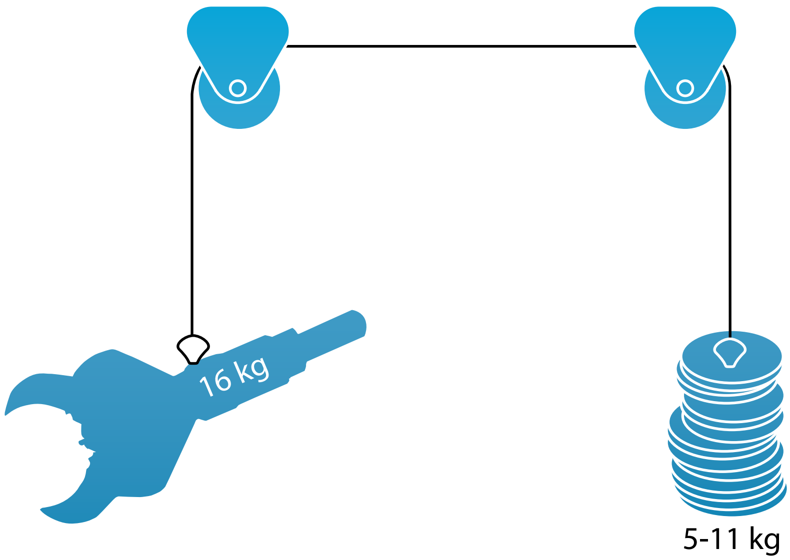
To test how support influences the experienced physical stress of the tool, an experiment is carried out.

After failing the initial simple setup (appendix on DVD: 01.11.2009 | Test 1 | Weight) a more advanced system is set up with lower resistance and lower margin of error. Using a set of trusses and steel wire, the tool is linked to a set of weights. The weights vary from 0 kg to 11 kg ranging from removing none to almost all of the weight of the tool.

The tool is then moved to four different positions; by the knees, by the hip, by the shoulders and above the head. The physical stress level is evaluated on a scale from 1 to 10 (10 being the most difficult). The scale is only relative and does not reflect upon other factors than the experienced physical stress. As the system allows the tool to move freely in a vertical direction, it also provides an augmented experience of how a proposed support system could feel.

The experiment is documented through photographs and video (ill. 2.28. following spread) (appendix on DVD: 05.11.2009 | Test 2 | Weight).

ill. 2.21. Full scale model of the cutter.



ill. 2.22. Diagram of full scale model test setup.

Results

Without adding any supportive force to the system, it is clear that when carrying the tool at the waistline or below is not stressful compared to lifting the tool to the shoulders and above. When lifting the tool higher, different muscle groups in the upper back and shoulder area are activated compared to being able to use the larger muscles of the legs and lower back in regular and low reach positions (ill. 2.23. – 2. 24.).

When adding weight to the system (and subtracting corresponding weight from the tool), carrying the tool becomes substantially easier (ill. 2.28.). The largest difference is in the initial 5-8 kg, where the perceived physical stress is suddenly diminished to an extent where a highly prolonged operating time is expected.

As the supporting weight increases towards the weight of the tool, the experienced physical stress is diminished to an insignificant level.

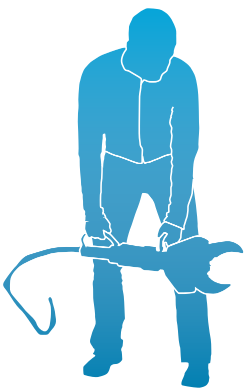
Specifications

The continuously evolving specifications and considerations are modified according to the results and findings of the experiment.

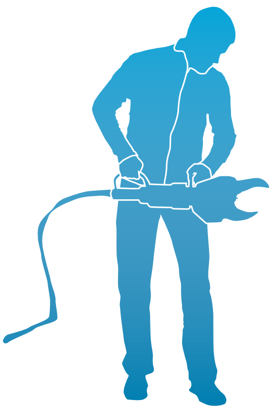
It is not necessary for the system to support all of the weight of tool. A 100% supporting force is preferred but as an example, a 50% decrease of the carried weight will still make the system superior to the alternative - no support at all. Supporting a fraction of the weight would require considerations on what would happen if the tool was accidentally dropped.

It is necessary to consider the total system weight as it must not add excessive physical stress to the operator. As a comparison, the vest and arm of the Ultra 2 steadicam weighs 9 kg and supports equipment of up to 22 kg (Tiffen 2009). As the periods of time using such camera equipment surpasses the use of hydraulic tools, an estimated total weight below 30 kg seems tolerable.

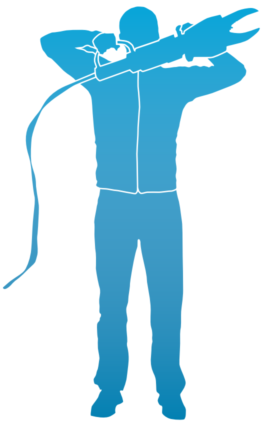
Price, although not a major design factor in this project, should stay below a reasonable level. The complexity of the system and involvement of technical solutions should be considered according to production as well as maintenance cost.



ill. 2.23. Position knee.



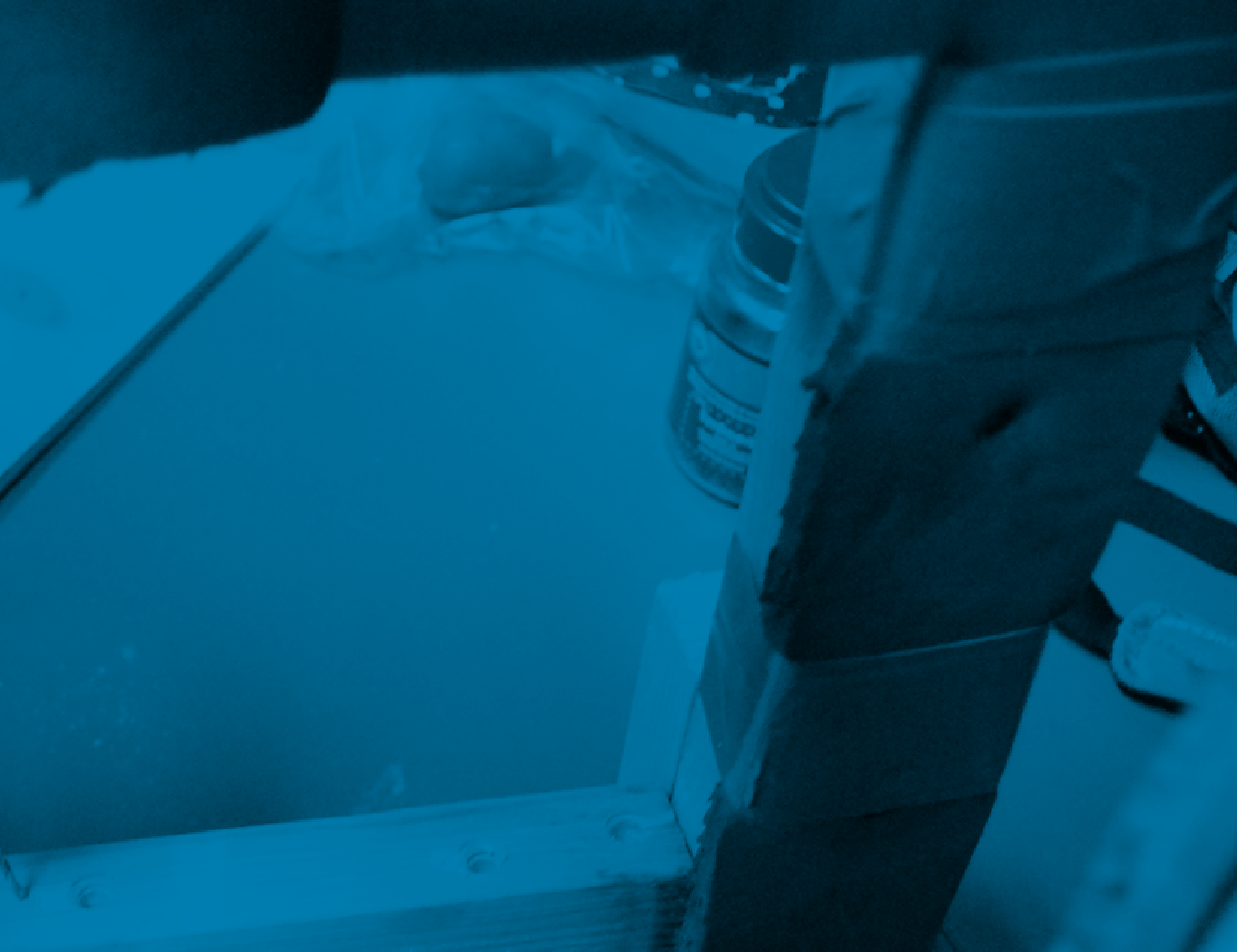
ill. 2.24. Position hip.



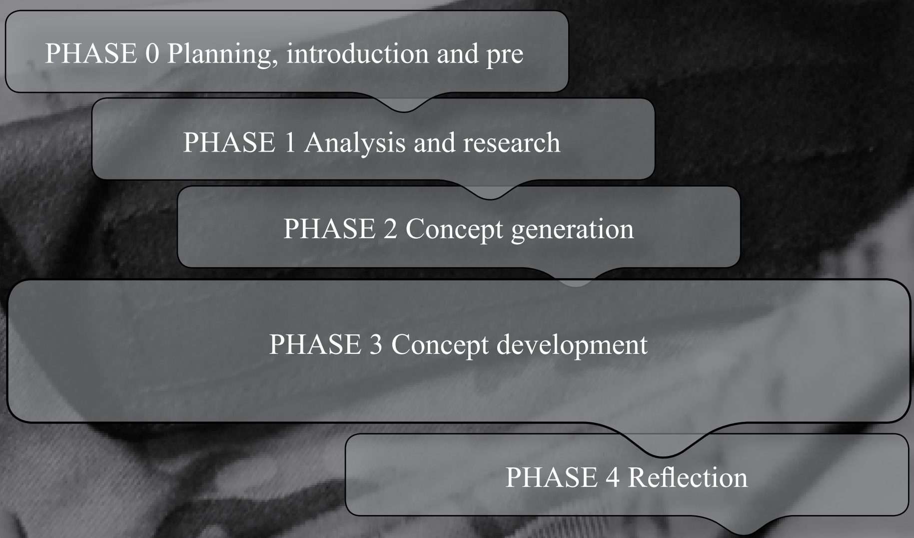
ill. 2.25. Position shoulder.

ill. 2.27. Scale of experienced physical stress. Dark color equals high level of stress.

ill. 2.28. Pictures from full scale experiment.



Phase 3 - Concept Development



The concept of phase 2 is detailed by defining a layout and elaborating details. The process is divided into harness, arm and details. The concept is detailed in a process by "quick and dirty" sketches, followed by validating through full scale modelling.

Documentation is carried out through 3D modelling, renderings and technical drawings.

ill. 3.1. Picture from experiment.

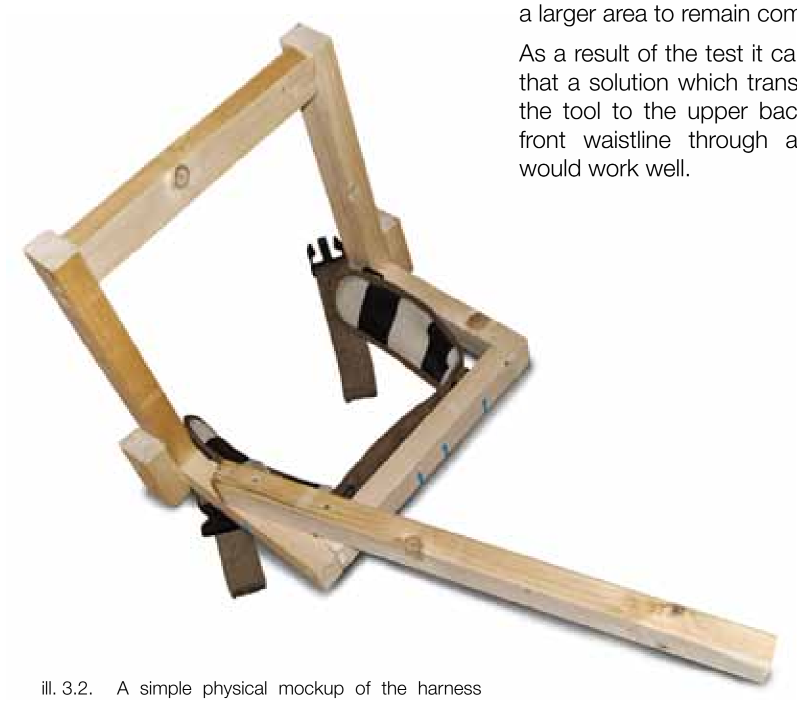
Harness

The process of designing the harness is initiated by considering the load transferring elements of the system.

Mockup

The purpose of the harness is to transfer weight onto the upper body of the operator. A situation is tested by using a simple physical mockup made of regular wooden beams (ill. 3.2.).

A stiff structure in combination with a wide padded belt creates the ”wearable model” used to test the weight transferring capabilities. The downwards force from the tool will be converted to pressure on the upper back at the shoulder blades and front waistline by the hips. The pressure on the upper back and front waistline in combination with the padded belt create enough friction to prevent the assembly from moving downwards.



ill. 3.2. A simple physical mockup of the harness made of regular wooden beams.

Results

With the tool resting most of its weight in the outer most position, the centre of gravity is moved forward (ill. 3.4.) and the posture is slightly angled to compensate (ill. 3.6.). The altered centre of gravity does not decrease control as the changed posture feels very natural and stable.

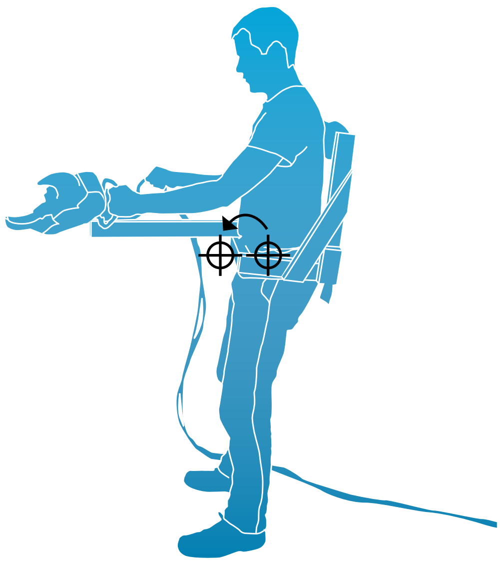
Larger, stronger muscle groups (thigh muscles, lower back and upper back) are activated and weaker ones more relaxed.

Although the intention of the model is not to test sideways stability, it does seem quite steady even when tilting the body slightly towards either side.

As the pressure points consist of rectangular beams without further ergonomic considerations, they are quite uncomfortable even for short term use. The pressure is quite intense and requires a larger area to remain comfortable.

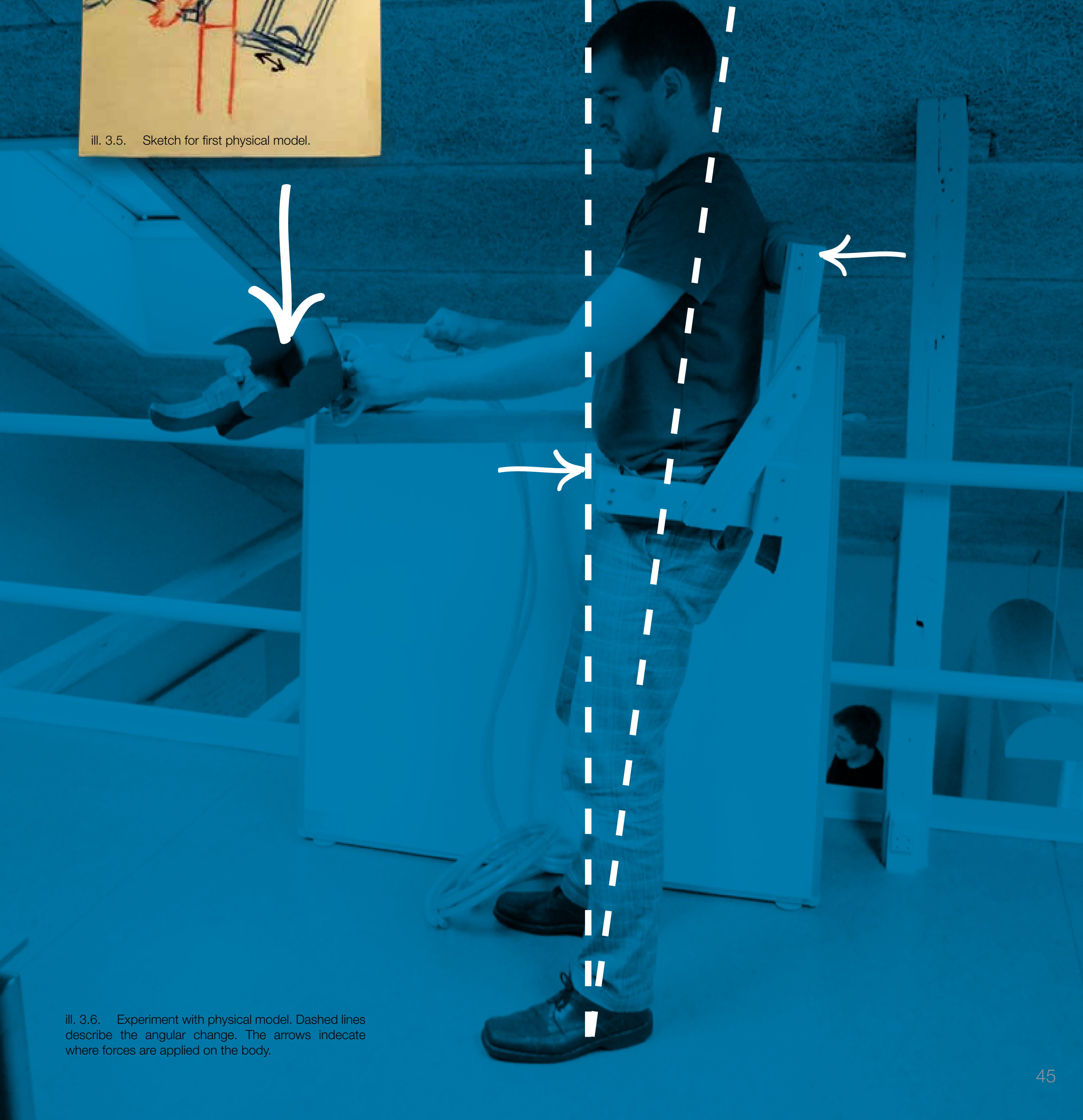
As a result of the test it can be concluded that a solution which transfers the load of the tool to the upper back area and the front waistline through a stiff structure would work well.

ill. 3.3. The simple physical mockup is tested.



ill. 3.4. Tool resting in the outer most position

ill. 3.5. Sketch for first physical model.



ill. 3.6. Experiment with physical model. Dashed lines describe the angular change. The arrows indecate where forces are applied on the body.

Arm

As well as the harness, the process of designing the arm is initiated by creating a mockup model.

Mockup 2

The arm must provide adequate freedom of movement both in the horizontal and vertical directions. The load-bearing structure of the arm is too massive to replicate in a simple model, so the purpose of the model is mainly to analyze movement and range. The proposed arm is mainly derived from Steadicams and flat screen mounting solutions.

Initially the arm (although the test was carried out with the arm mounted to the waistline-position) was meant to be mounted approximately 10 cm above the waist. The modeled arm extends to a maximum length of approximately 70 cm.

The mockup is first done in 3D (ill. 3.7.) to approximate total reach and then a wood model is made to test the actual experience of moving around the arm. A simplified foam model of the tool (without hoses) was mounted to the arm for reference.

The arm features a double joint between the two major parts which allows the two assemblies to fold flat against each other.

Results

Freedom of movement seems only slightly inhibited. The arm folds to most positions easily. In some situations it gets in the way of the leg when kneeling which is solved by shifting the weight to the other leg. When using the tool in close perimeter of the mounting point for the arm, the arm did seem to protrude in a manner where it could be in the way for some obstacles (the side of a car, another firefighter etc.).

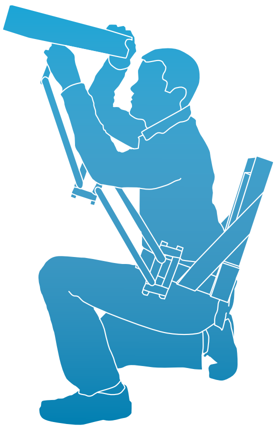
Considering the arm being mounted approximately 10 cm lower than intended, it provided an almost complete vertical range from below floor level to above the head (appendix on DVD for photographs from the process: 09.12.2009 | Test 4 | Model 2 | Arm Range).The horizontal range is not inhibited either indicating that a higher mounting point in combination with a shorter arm could be a favorable solution.

ill. 3.7. Sketch of the arm for mockup model in 3D.

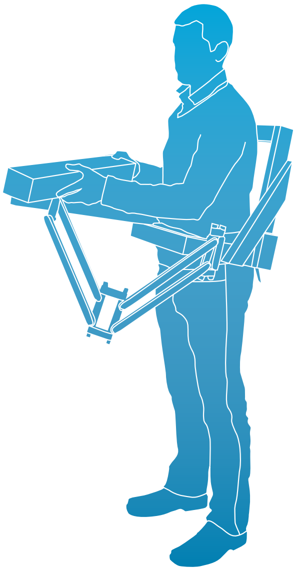
A shorter arm would not protrude as much and the full range of the arm could be made possible through several individual mounting points or a movable mounting point for the arm.

Minor problems with the tool inhibiting arm movement in low reach situations is experienced.

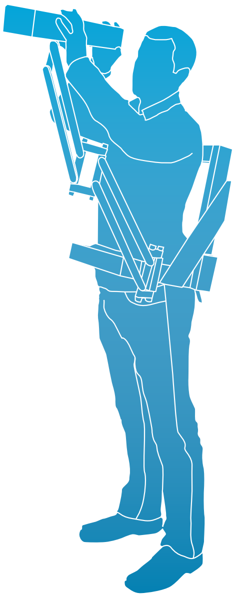
ill. 3.8. Kneeling down position.



ill. 3.9. Kneeling up position.



ill. 3.10. Normal position.



ill. 3.11. High reach position.

ill. 3.12. Sketch for model of arm.

ill. 3.13. Testing the simple physical arm model.

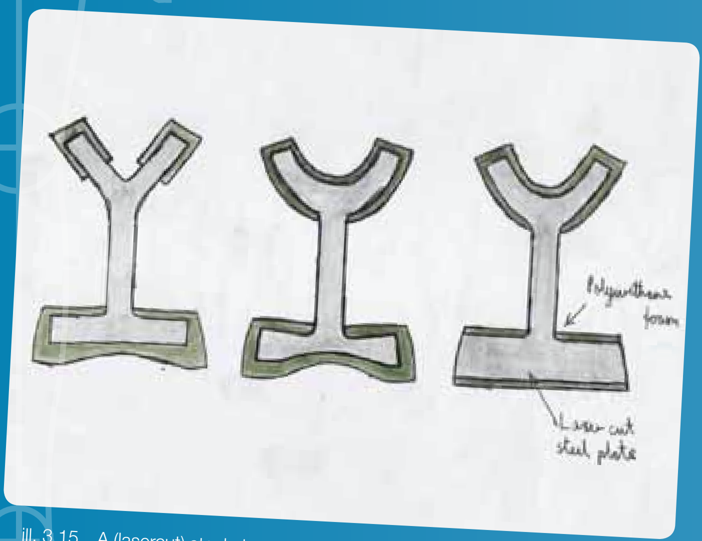
Sketching

The initial sketches describe an idea of a stiff external structure (ex. steel plate) placed on the front of the operator, which transfers the weight of the tool onto the shoulders and front waistline similar to Steadicams (ill. 3.15.). Although the sketching process is extremely iterative, a linear description is sought after.

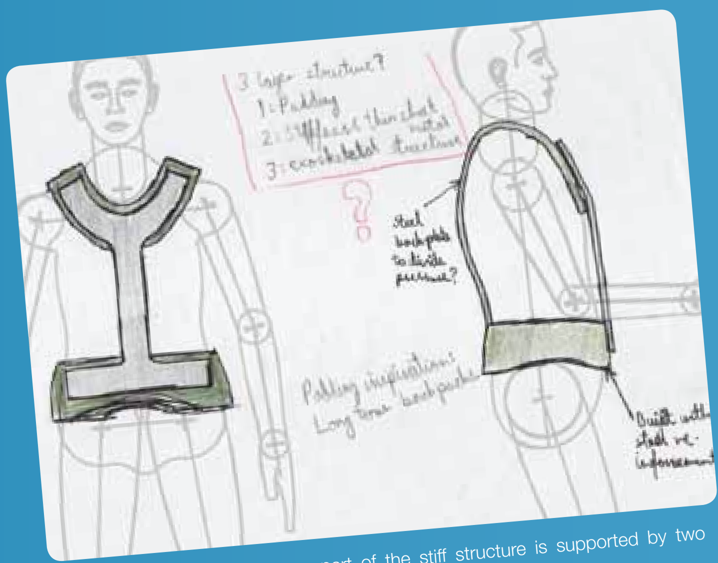
Anatomy

Sketches are based on orthographic views (front and side) of a 50-percentile man (Tilley 1993). The 50-percentile (18-65 years) does not reflect upon the actual user group and a final solution would have to reflect further upon the topographical anatomy of firemen. A following adjustment is not perceived to modify the final solution majorly.

ill. 3.14. Initial sketches to consider expression.



ill. 3.15. A (lasercut) steel plate is used to create the external stiff structure which is then padded using soft foam. The coherence between expression and function is investigated.



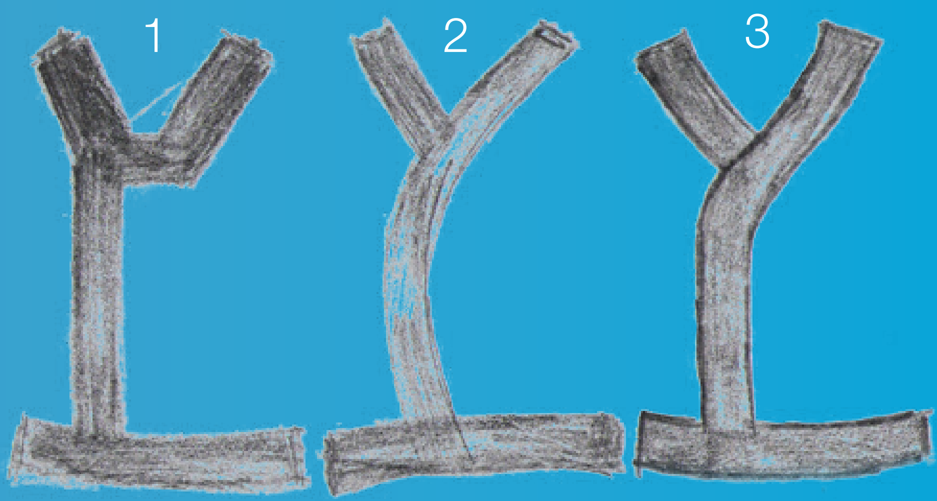
ill. 3.16. The Y-shaped upper part of the stiff structure is supported by two parallel soft straps around the back of the operator.

Arm mount

During the various trials, it was considered to create a moveable or several mounting points for the arm to achieve a large working area with a short and less obtrusive arm. Point 1 and 2 (ill. 3.18.) would be able to provide ambidextrous use while a third point provides high reach range.

As an alternative, a moveable mounting point featuring an offset rail could be integrated to make moving the attachment point easier and more fluent. Although firemen never work alone a solution that could be operated as an individual is preferred as it is more flexible (it is assumed that ill. 3.18 would require a supporting fireman to switch mounting point).

The rail is offset from centre to keep the arm out of the way of the operator (ill. 3.17.). When observing video material of the side-mounted arm of Steadicams, it seemed an advantage to mount the arm offset.

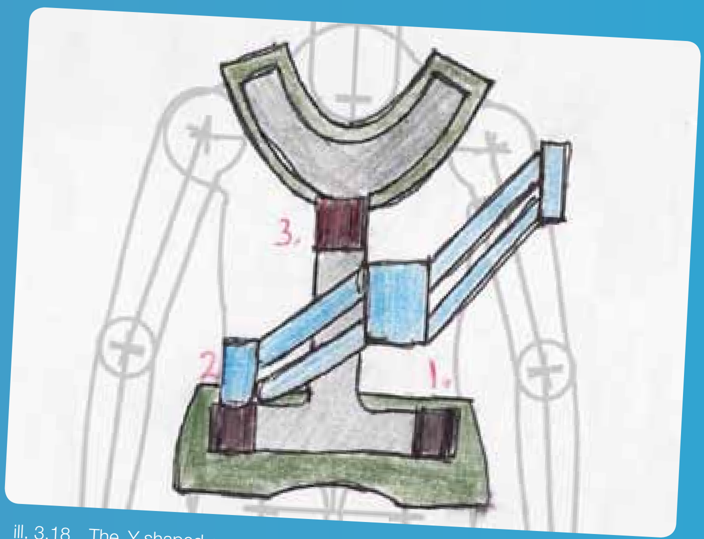


ill. 3.17. Initial sketches to consider expression.

A sliding mount would be able to further address anatomic differences and possibly provide a more fluent operation.

To integrate the offset rail, the centre support is offset revealing new aesthetic problems.

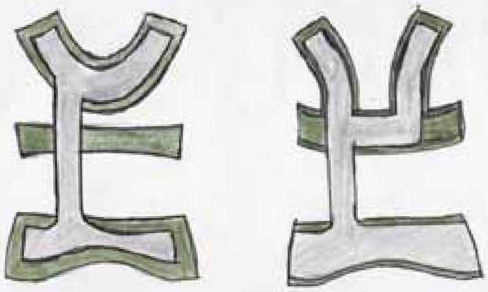
Sketch #3 (ill. 3.17.) provides a harmonic expression which is deemed inappropriate and "too elegant" for the rough use of fire fighter products.



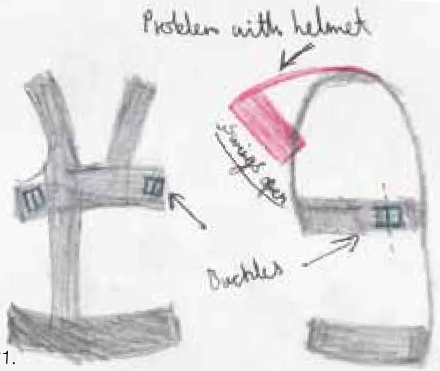
ill. 3.18. The Y-shaped upper part of the stiff structure is supported by two parallel soft straps around the back of the operator.

ill. 3.19. A trip to "Toursport" - observing hiking equipment - inspired the shape of waistband and tightening straps.

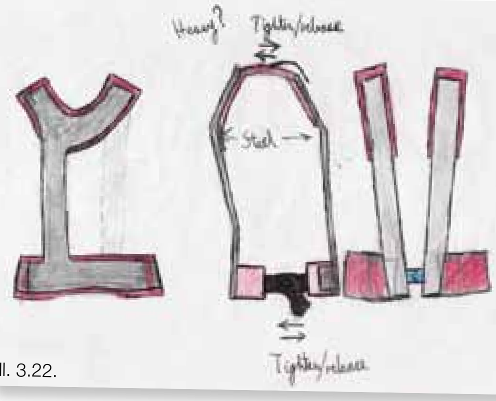
Harness development



ill. 3.20.



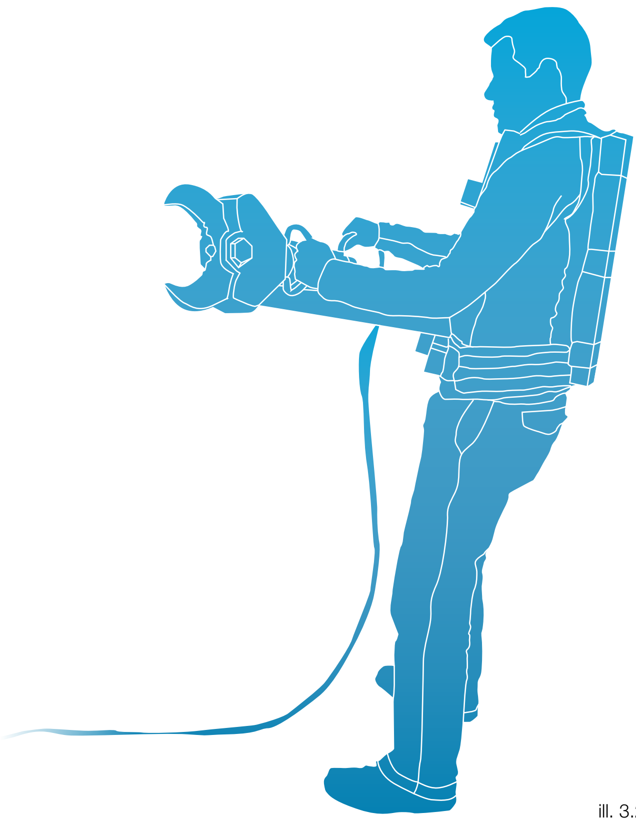
ill. 3.21.



ill. 3.22.

To simplify the overall complexity of the harness, the chest belt of the Steadicam units is initially omitted. Entering the harness should be as simple as possible, but on the contrary, omitting the chest belt could imply unwanted stress to the neck area during side lifts and perhaps provide discomfort. Closing the chest strap on the back is not possible, requiring a more complicated side entrance. A side entrance requires a side entrance on the shoulder strap and waist band as well.

Several methods of designing a simulated chest belt support are considered, but the arguments quickly become speculation. A simple model is constructed by use of a load-bearing waist belt, wood and foam sleeping mat for simple padding to simulate the support system. The sketch consisted of the stiff front with padding and two straight stiff straps on the back. The stiffness of the back straps is expected to divide the pressure on the back evenly. (Appendix on DVD: 20.12.2009 | Test 5 | Trial Model).



ill. 3.23.

ill. 3.24.

ill. 3.25.

The largest concern with the model is to test stress to the neck area during side lifts. The shifting weight seems to be absorbed through the stiff construction through torsion in the waist belt, providing only mild discomfort to the neck area.

If properly considered in the detailing phase, the problem should diminish to insignificant by using a sideways rigid frontal construction.

The reversed waist belt inhibited movement of the hips when kneeling with a following discomfort because of the wide lower back area now being in front. A solution should take freedom of movement in this area into consideration similar to the waist belts from hiking backpacks (appendix on DVD: 14.12.2009 | Visit to Toursport for backpack inspiration).

The thick wooden construction inhibited arm movement, bringing attention to minimizing protruding elements in the upper chest area.

The stiff back straps seem to transfer pressure well, but not evenly. Considering the difference in anatomy when moving the arms or from one fire fighter to another, this solution may not be the most favourable.

Harness detailing

Following the previous model, a modified version without stiff straps is tested. The stiff straps did not seem to adapt well to the human body.

The modified version seems to be far more comfortable although a new problem occurs. When removing the stiffness of the back support straps, the rigidity of the complete system is also altered, leading to a weakening of the vertical stability of the waist belt. The waist belt tilts which lead to discomfort and the stiff front part of the construction tilting forward (ill. 3.29.).

A semi-rigid construction made out of low density (100-300 kg/m3) polyurethane elastomers is considered to provide the necessary stability in combination with a cloth outer shell.

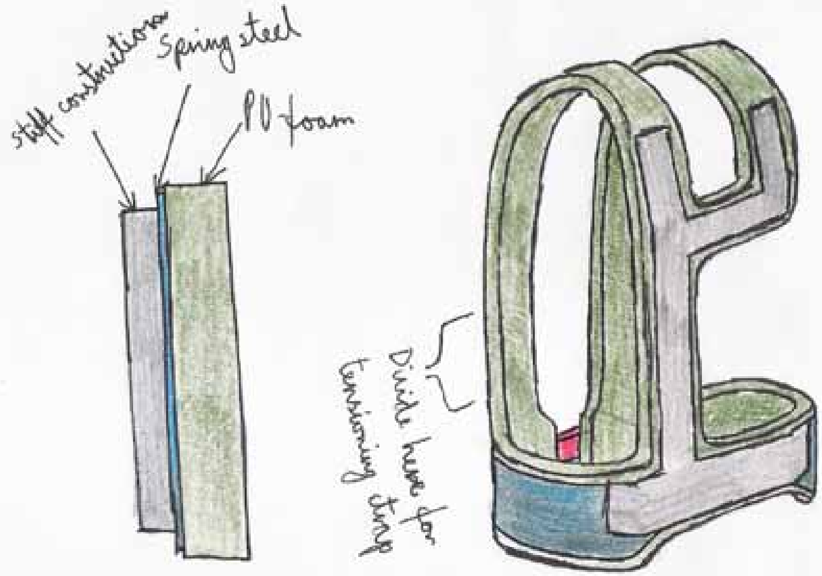
Polyurethane is easily produced and can be modified to improve fire performance, stability in chemical environments etc. Manufacturing products using polyurethane is very flexible in numbers and cost ranging from RTV silicone for thousands of casts to metal filled epoxy molds for 10.000+ parts. (Wikipedia 2009)

The polyurethane padding could be supplemented by flat spring steel reinforcements to provide stability in desired directions combining a sandwich construction of polyurethane foam, spring steel and a stiff outer frame (ill. 3.27.).

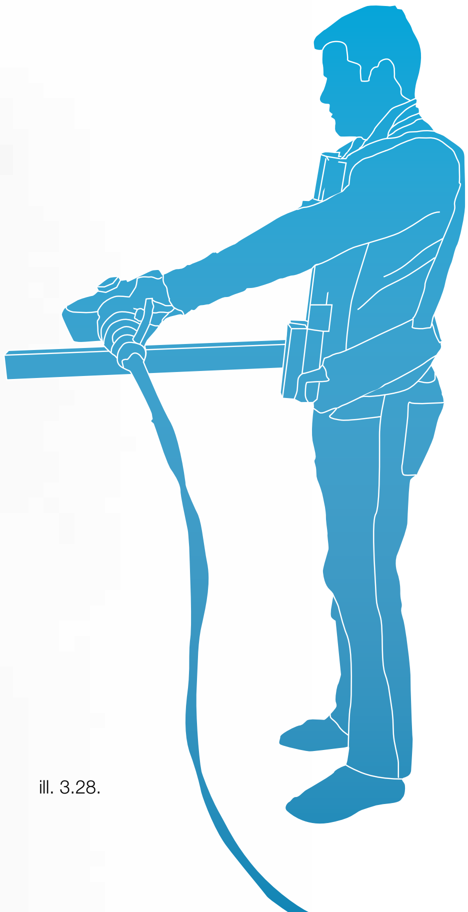
The spring steel layer would provide vertical stiffness while still allowing the waist belt to fit for various different anatomies.

(Appendix available on DVD: 26.12.2009 | Test 6 | Trial Model v2.)

ill. 3.26. A car seat constructed of polyurethane foam.



ill. 3.27. The layered construction where polyurethane foam covered in cloth (green) transfers the weight from the stiff construction to the upper body. The polyurethane is stiffened by a thin spring metal reeinforcement.



ill. 3.28.

ill. 3.29.

Principle to detail - arm

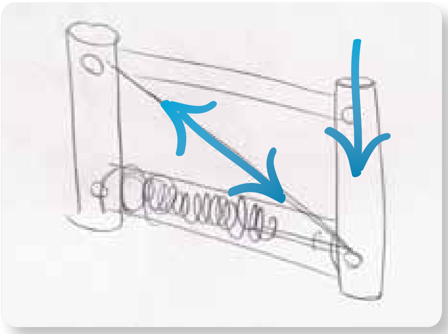
The sketched arm extensively tested via model 2 is required to feature a load-bearing element and other aspects as well. As load is applied by resting the tool on the arm, the parallelogram tends to skew. The load-bearing is carried out by a spring mounted in the parallelogram to resist this skew.

To minimize exposed elements, the spring is moved to the inside of the lower beam of the parallelogram, securing it from shattered glass or other interfering elements.

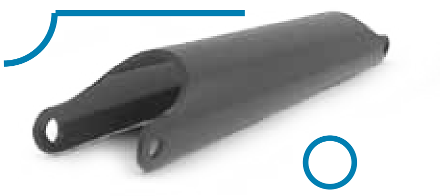
Ill. 3.33. to 3.36. shows a part of the development process of the arm elements.

The early concept for the arm (ill. 3.30.) is transformed into a load-bearing version (ill. 3.32.).

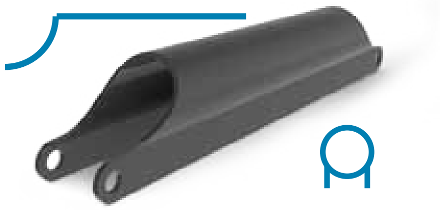
ill. 3.30.



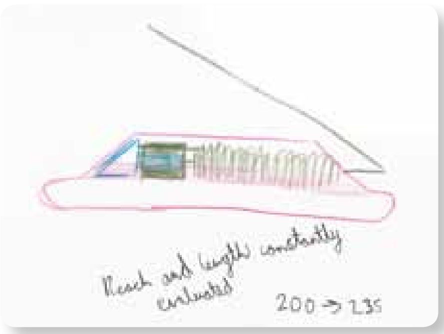
ill. 3.31. Principal sketch for the load-bearing functionality of the parallelogram.



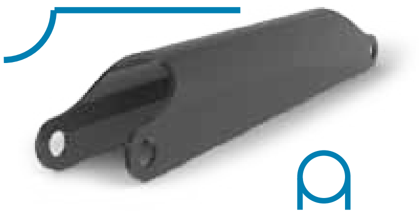
ill. 3.33. The initial idea featured a round profile.



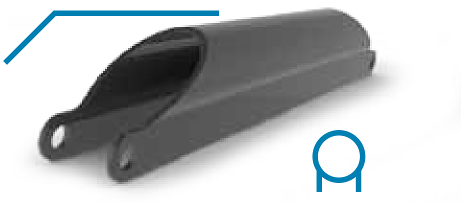
ill. 3.34. An altered design where the straight sides are moved towards center provide a better nest for the spring.



ill. 3.32. Detailed sketch of the tightening mechanism.



ill. 3.35. The holes of the round profile would not mate correctly with the corresponding part, hence an evolved model featuring straight sides.

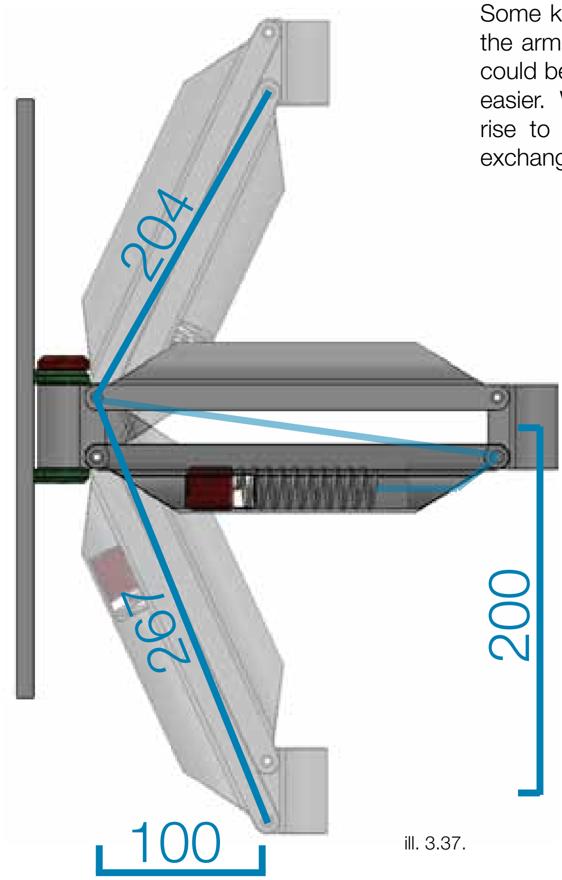


ill. 3.36. A straight side-cut corresponds to the required freedom of movement for the arm.

The 250 mm arms stretch the spring 63 mm from the lowest to the highest position which seems an appropriate amount of movement for the spring (ill. 3.37.).

To be able to adjust spring tension, a knob can be rotated when switching tools or after user preference. At 26 mm, the diameter of the knob is slightly small compared to the recommended 25.4 to 38 mm (Tilley 1993, p. 43) and grip could be lessened when wearing gloves.

The initial model with several small grooves (ill. 3.38.) is therefore revised with fewer larger grooves to increase grip (ill. 3.39.) thereby also communicating that the knob rotation requires several revolutions.



ill. 3.37.

It is considered to place the knob on the underside to increase ease of rotation with gloves the advantage seemed minor compared to weakening the moment of inertia. The solution still provides the option to grip the knob from both sides and rotating.

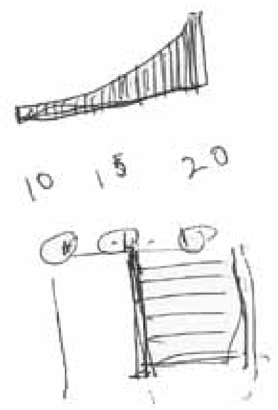
Furthermore a scale (ill. 3.40.) could be integrated to enable quick change of spring tension for the desired weight (such as when switching the tool).

Alternatively a throw lever or similar mechanism could also be integrated to quickly change the spring tensions between predefined loads (ex cutter and spreader).

Some kind of locking mechanism to keep the arms lowered when changing the tool could be integrated to make the exchange easier. Without a load, the arms would rise to the highest position, making the exchange difficult.

ill. 3.38. Numerous small grooves indicate precision and slow movement.

ill. 3.39. Fewer, larger grooves indicate lesser precision and faster movement.



ill. 3.40. A scale allows the user to quickly set the desired spring tension.

Principle to detail - rail and joints

Rail

The rail works by providing a track in which the mounting point slides. The rail features a locking mechanism to keep the mounting point from moving unwanted.

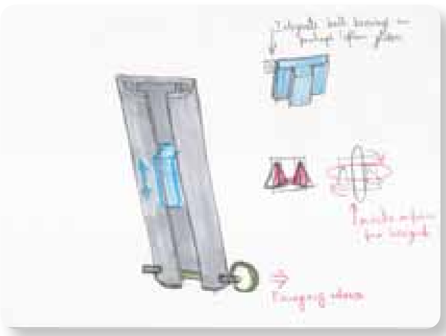
Several shapes for the rail are considered, but an ”inside” rail (ill 3.41.) was abandoned in favor of an ”outside” rail (ill. 3.42.) which feature less protruding elements.

The rail feature holes in which a corresponding locking mechanism protrudes. Push-button activation is only necessary in downwards direction as lifting the tool above the reach of the arm would simply pull up the mounting point to a higher position.

A pushbutton placed on the mounting point releases the locking mechanism and the mounting point moves downward. The button is pushed downwards in the same direction as it is intended for the mounting point to move.

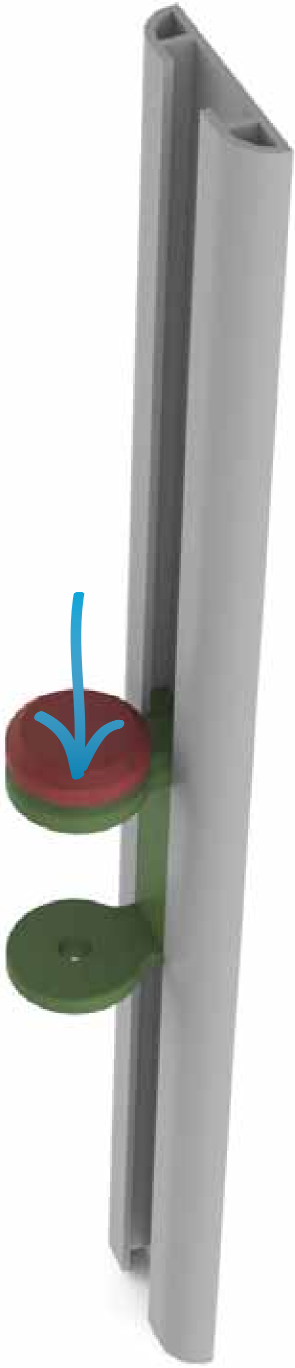
ill. 3.41. Initial sketches for the rail. Several shapes and mechanisms were considered.

ill. 3.43. Push button to release.



ill. 3.42. The chosen solution for the rail. No sharp edges and a secure solution. A ”quick release”-function is considered.

ill. 3.44. An earlier more complicated button that required activation in a less intuitive and more difficult approach.



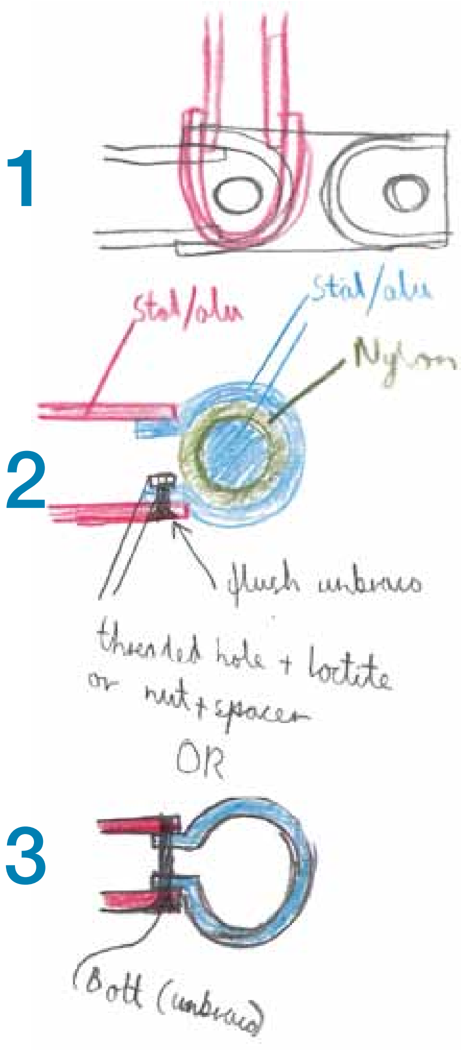
ill. 3.45.

Joints

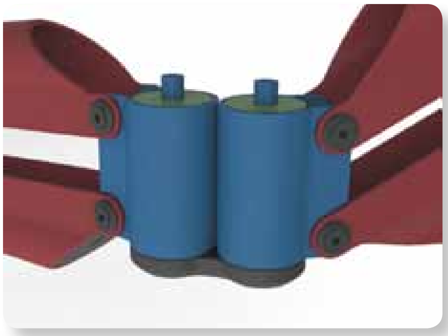
The two articulated arms are connected with joints that allow movement in a horizontal plane (ill. 3.49.) and through the arms in the vertical plane (ill. 3.47.).

If possible, the arms and joints should be produced in aluminum, to lower weight. Contrary to an early solution (ill. 3.46.#2), the bolts and that fix the arms and joints together rest in threaded steel studs to minimize wear and tear in the aluminum holes (ill. 3.46.#3).

The joints for horizontal movement feature large bushings to minimize friction (ill. 3.49.). Nylon or Delrin (POM) bushings could be used as they are low maintenance through self-lubrication, have low water absorption and are chemically resistant (Wikipedia2 2009 and Wikipedia3 2009)

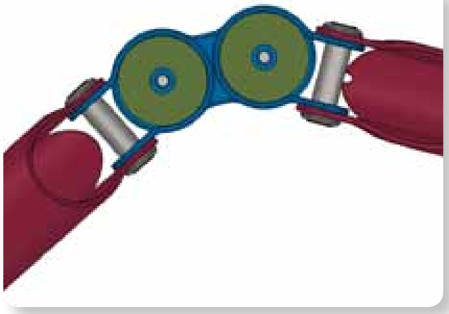


ill. 3.46. Sketches of the various solutions for joints.

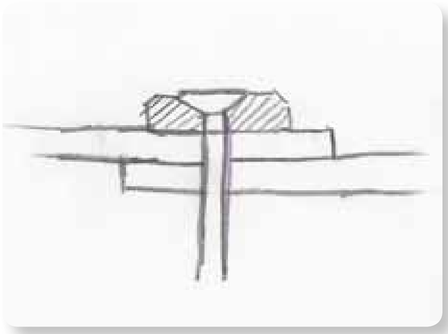


ill. 3.47. Sketches of the various solutions for joints.

ill. 3.48. Sketches of the various solutions for joints.



ill. 3.49. Early 3D-model of the middle joint connecting the two arms.



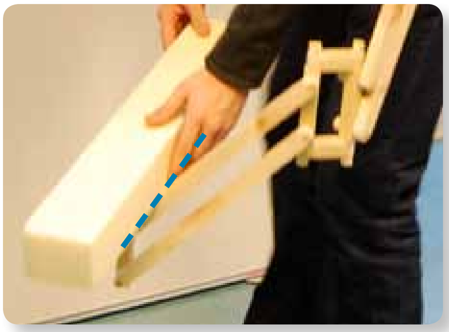
ill. 3.50. A sketch on the detail around the threaded screws.

Principle to detail - tool joint

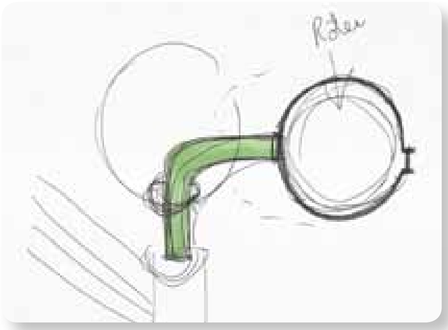
As experienced when using the mockup model of the arm, the tool interfered with the arm when the tool is in the lowest position (ill. 3.51.). By adding an extended joint to the tool mount (ill. 3.52.), the problem is minimized and a new handle appears (ill. 3.53.).

The joint requires at least 180 degrees rotation of the tool to retain use in regular cutting scenarios. To obtain this rotation, a solution based on ball/roller-bearings is perceived to be necessary (ill. 3.55.).

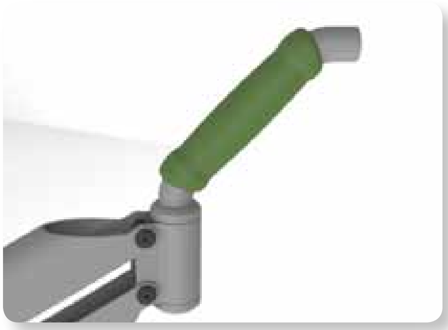
Mounting a roller-bearing solution in the same place as the existing handle is found to be extremely difficult as there is no way to slide it on without disassembling a large portion of the tool. An alternate solution is chosen since a solution consisting of two halves is deemed too complicated (ill. 3.56.).



ill. 3.51. ill. x.x The ”tool” interferes with the arm in the lower positions.



ill. 3.52. An extended joint removes the problem and provides a new handle to operate the tool.



ill. 3.53. A further iteration of the extended joint and integrated handle.

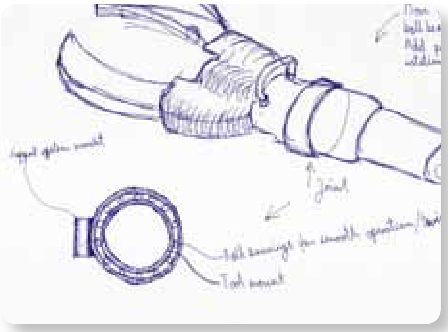
ill. 3.54. A 3D mockup modelled from technical drawings of the RS 165-65 cutter.

The alternate solution moves the mounting point further towards the back of the tool around the widest part of the main body of the tool. Thereby, simplifying the mounting procedure and reducing the complexity of the bearing construction.

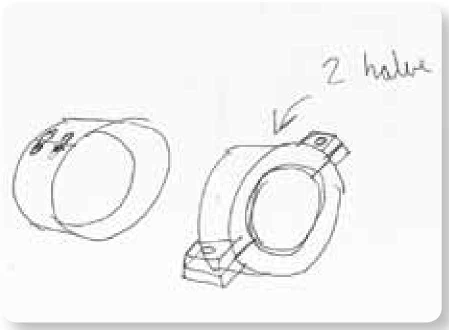
This solution also leaves the existing handle intact and thereby only introducing very few changes to the operation of the tool. It also retains similar operation, should the user choose to disengage the tool from the system.

The solution will however move the mounting point away from the center of gravity of the tool. The mounting point is only slightly offset and is not perceived to be a large problem for the user to correct with only slight force applied.

The ”extra” handle is simplified to a mere joint in an effort to the reduce the ”Swiss Army Knife”-syndrome, where multiple similar functions are applied instead of fewer more successful ones.



ill. 3.55. A roller bearing provides easy rotation of the heavy tool.

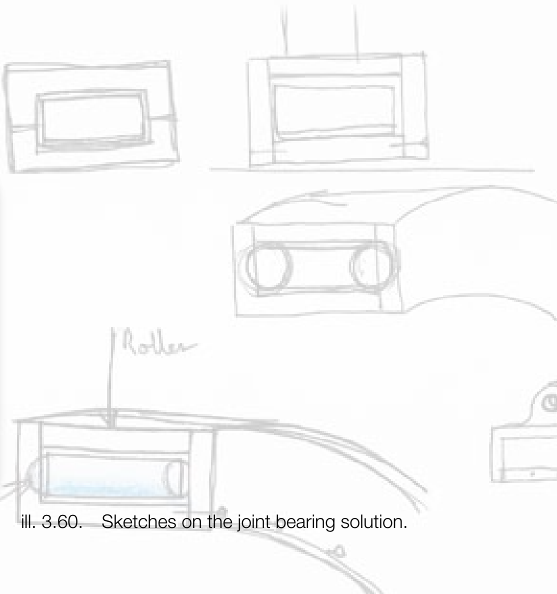


ill. 3.56. Sketches on a solution that through two halves enables mounting in position of the existing handle.

ill. 3.57. Locking rings are used to keep the roller bearing in place.

ill. 3.58. An early iteration of attaching the bearing to the arm. The coupling does not have a succesful visual coherence.

ill. 3.59. A simpler more elegant solution that visually coordinates with other elements on the arm.



ill. 3.60. Sketches on the joint bearing solution.

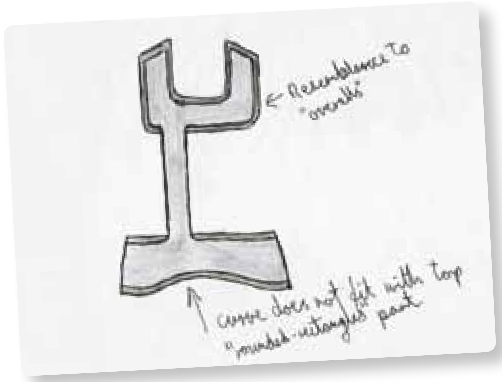
Principle to detail - harness

The earlier sketches of the vest/harness consisted of a close replica of the waist belts used on hiking backpacks. The belts feature a curved design that does not correspond successfully with the visual style of the upper part of the harness (ill. x.61). The belt was also too thick in the lower groin area where the hips require room especially when kneeling (as experienced with the mockup models).

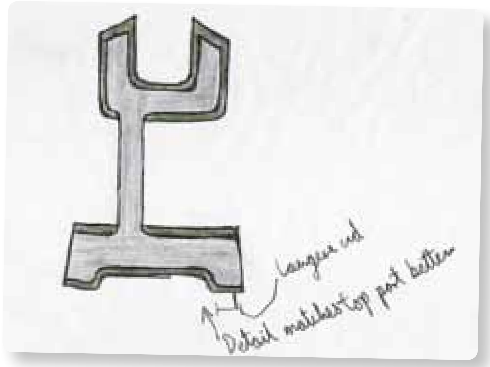
To increase visual coherence and improve hip clearance, the curved line was change to a straight. This allowed both wide belts on the side and clearance on the front although front clearance needed to be improved even further (ill. 3.62).

Anatomy

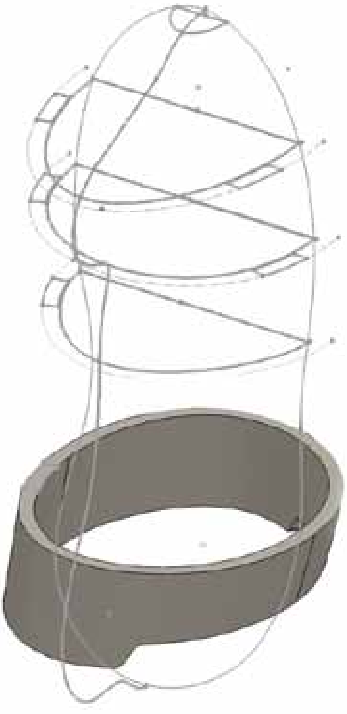
To design a solution that would realistically fit a fire fighter, a 3D model of the torso of and operator was modeled in 3D (ill. 3.65). The model is based on anatomical data (Tilley, Alvin R. et al, 1993) corrected by contemporary standards for human height (Statens Institut for Folkesundhed 2007). The model does however not feature the rather thick layers of clothing carried by a firefighter.

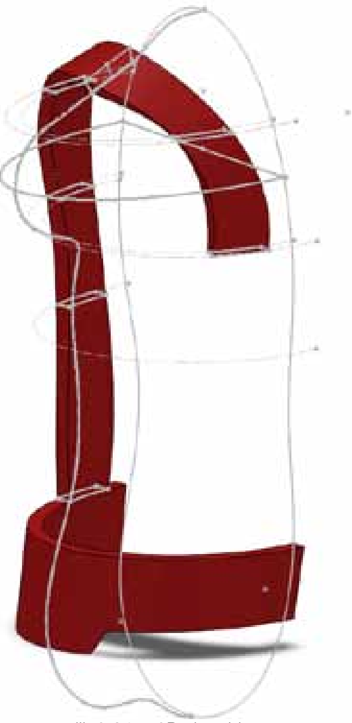


ill. 3.61. Sketching on the harness system.



ill. 3.62. An improved harness with more visual coherence.


ill. 3.63. 3D sketching.

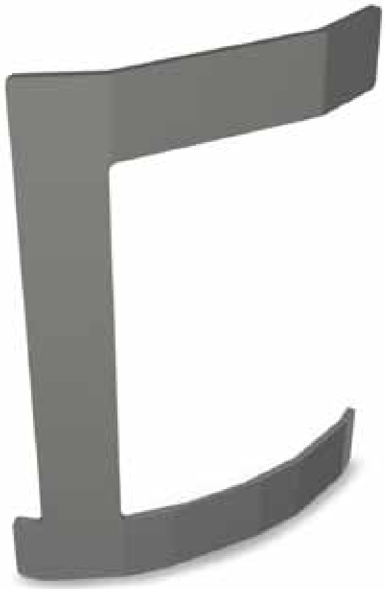

ill. 3.64. 3D sketching.


ill. 3.65. 3D sketching.

Padding

Ergonomic shapes are often composed by curved lines that fit the human body. The padding follows the curvatures of the torso in an effort to provide a pleasurable experience for the operator. A difficult task to model without fault in SolidWorks, the primary program used for 3D-modeling. 15 mm padding is used based on the various trials.

The front mounted steel plate features several bends to fit the human body better (ill. 3.69)



ill. 3.69. 3D sketching.

ill. 3.66. 3D sketching.

ill. 3.67. 3D sketching.

ill. 3.68. 3D sketching.

Straps and buckles

The padding is supported by webbing which transfers the loads from the frontal mounted steel plate. The tension locks and buckles are greatly inspired by the tightening straps featured on hiking backpacks.

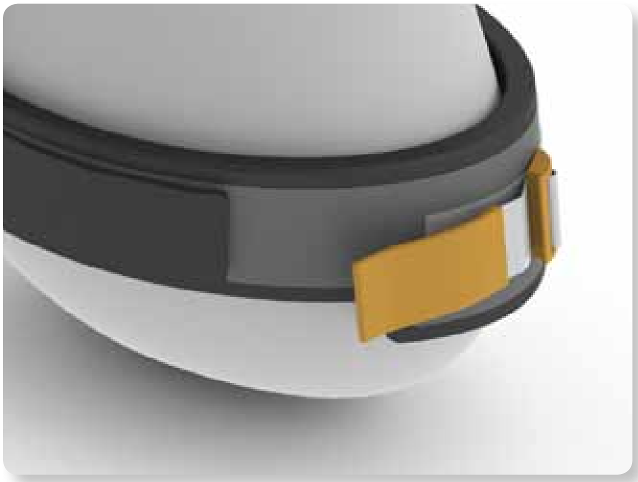
By adding reflective material to the straps, a visual detail is added and the feature is sustained even though the padding covers some the reflective material on the jacket.

ill. 3.70. ITW Nexus (military grade) buckle

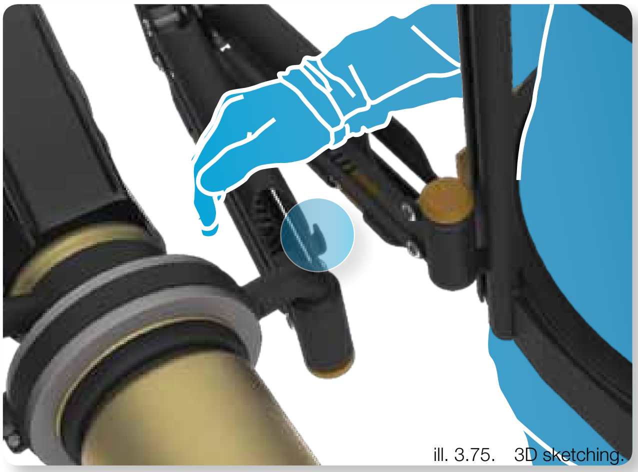
ill. 3.71. Visit to Toursport for inspiration

ill. 3.72. Upper straps featuring reflective material.

ill. 3.73. Visit to Toursport for inspiration



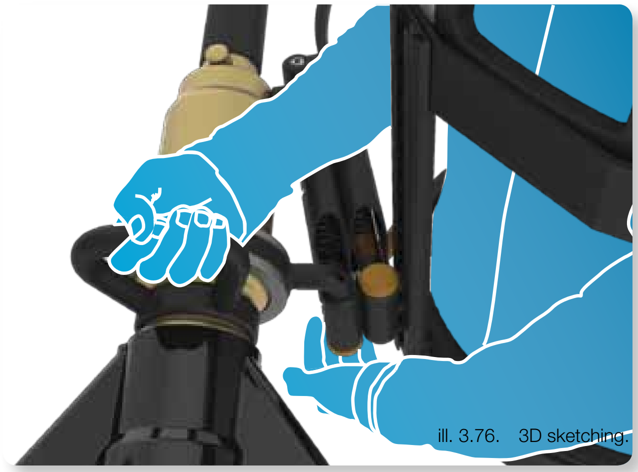
ill. 3.74. Wide hip straps to tighten the waist belt.



ill. 3.75. 3D sketching.

Arm lock

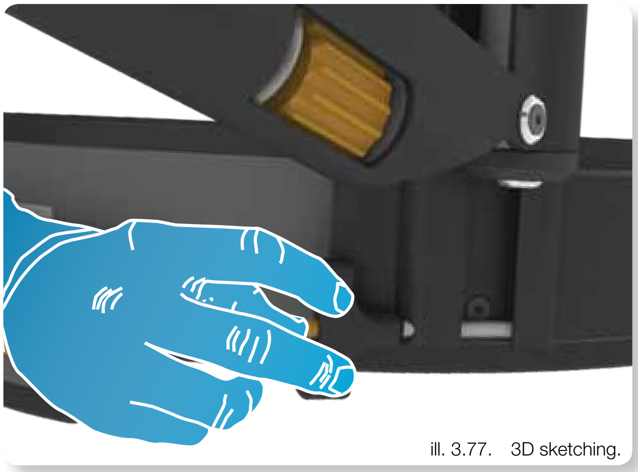
To allow the user to be able to disengage the lifting mechanism of the arms and thereby lift the tool out of the arm, a small protruding clip is added to one of the arms. When engaged with the other arm, the arms lock and allow the tool to be lifted without the arm following.



ill. 3.76. 3D sketching.

Release button

With the arm lock engaged a push button similar to the one on the rail is integrated. Pushing the button releases the tool, which can be lifted by the operator or another firefighter.



ill. 3.77. 3D sketching.

Rail end-release

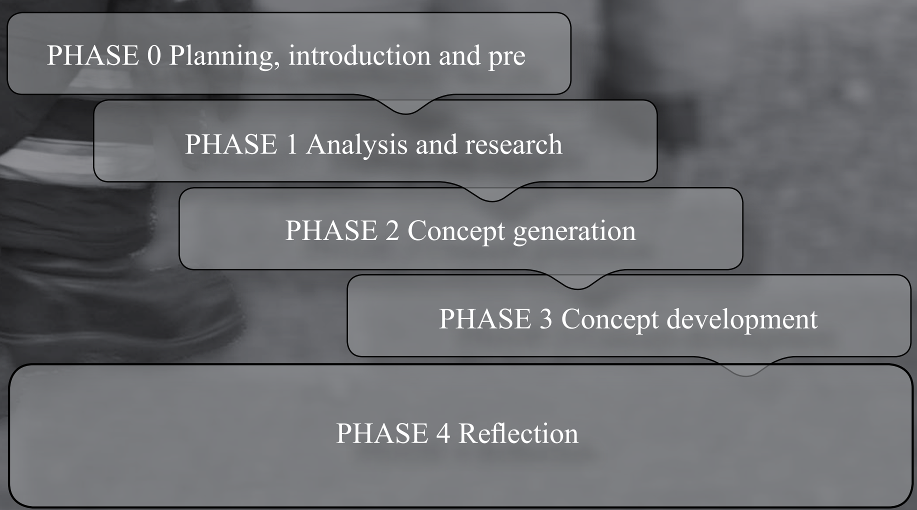
If needed, the complete arm assembly can be released from the rail by ejecting a pin at the lower end of the rail and retracting the arm mounting point while pushing the downwards pushbutton.

ill. 3.78. 3D sketching.

Colors

Although many colors were considered, the context of use consists of many different colors and in many aspects is a “noisy” environment. The main color is a discrete charcoal black and a brighter orange color is used to highlight functions.

Phase 4 - Reflection



Phase 4 reflects upon the process of the entire project. The initial stated goals for the project are evaluated and the project is brought into a larger perspective with regards to the final solution and the project seen in a larger context.

ill. 4.1. Firemed in action.

Discussion

The following chapter discusses the process, the scope and reflects upon how it affects the result.

Planning

As the project is not initiated by a specific assignment (such as when working in close cooperation with a company), the project planning phase is not very explicit. The phase articulates the project goals which on this basis are general and although not vague are mainly circumstantial. The actual project definition therefore stretches into the research phase.

Research and analysis

The research and analysis phase summarizes a large basis of knowledge based on both observing practice and theoretical foundation which is used in the following design phases.

Theoretical information such as statistics, training manuals, video material build up an understanding of the use of hydraulic rescue tools as well as the surrounding factors e.g. planning and frequency while practical aspects of the products are realized by interviews and observing users.

The choice of project and hereby problem to solve is largely based on problems uncovered during the situated interview. The problem of hydraulic tools being too heavy is solved by means of a support system.

As the project evolves, knowledge of hydraulic tools increases and the problematic aspects of their design is uncovered. In retrospect, a support system could be regarded as a treatment of symptoms while a development of for instance a lighter tool could be regarded as a (partial) cure. A longer and more thorough research and analysis phase could have uncovered this aspect earlier on in the process.

Concept generation

The concept proposed in the generation phase consists of several rather complex elements, that rely on unknown factors which require intensive testing to validate.

The complexity of the solution leads to a situation where detailing requires numerous iterations, testing and models to reach a successful result in comparison to a simpler solution. This does not devaluate the quality of the concept, but reduces the level of detail obtained in this project.

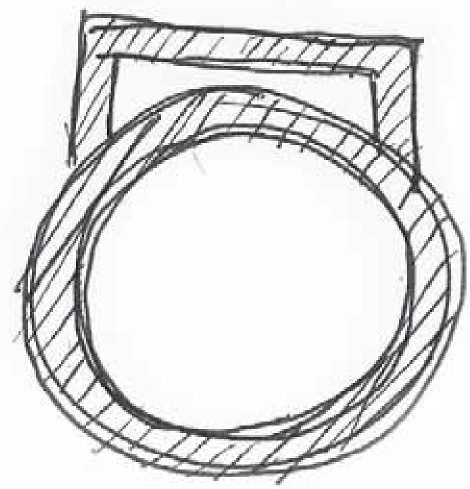
Concept development

The concept development phase features extensive testing of physical modeling. Although time-consuming, the models are a necessity to validate the concept.

An example of the aforementioned reduced level of detail is observed in the production aspects of the product. For instance far simpler, more feasible produced profiles could be used to achieve the same functionality and perhaps an improved visual appearance of the arm elements (ill. 4.2).

In most situations "standard" solutions are used to obtain the wanted level of detail without jeopardizing the holistic requirements of the product.

Another example could be that fitting the system to other tools such as the cutter or tools from other manufacturers is not considered in detail.



ill. 4.2. An improved profile.

Conclusion

The following chapter concludes upon the project and the initial stated goals.

Success?

The primary initial goal for the project of creating a semi-technical solution that is easily tangible has been fulfilled. The problem and following solution is easily explained and the project fulfills the requirements of designing for ergonomic and functional challenges.

The project succeeds in supplementing my portfolio both visually and technically as it also presents the majority of my design skills such as user research and analysis, sketching, physical models, 3D modeling and documentation as well as knowledge of production and materials.

The stated problem of hydraulic tools being heavy and difficult to handle has been solved by supporting the weight of these tools onto larger and stronger muscle groups on the user. Transferring the forces allows the user to work more efficiently by offering more precision, less physical stress and thereby higher performance.

Lessening physical stress allows the operator to continue operation for extended periods of time and thereby further increase performance.

User Centered Design

User Centered Design is the focus when carrying out situated interviews and observing users. The base problem around which the project revolves, evolves from the situated interview and is based on the very words of the users.

Through experiments and observation, the empirical approach has been followed in all of the phases of this project. The observation of users and understanding their use of the products contributed to a solid foundation upon which to build a solid concept.

Form Follows Function

The Form Follows Function approach is based on an empirical approach as well. The extensive testing of design ideas through full scale models during concept development defines the functions, layout and the frame in which styling and aesthetic considerations evolve.

The models aid in understanding the ergonomic requirements for various aspects of the solution. As an example, the reinforcing spring steel in the waist belt was deemed necessary on the basis of one of these physical experiments.

The models shine light on problem areas that theoretical considerations would not.

Innovation

As expectantly stated in the introductory chapter, innovation in this project is regarded to be on a high level. An new product has been developed that solves a problem using new elements and modified existing technology.

Reflection

The chapter reflects upon the process in regards of the result and on the influence of the project in a larger educational perspective.

The result

Benefits

The benefits of the hydraulic support system are quite clear. In a larger perspective, increased performance will allow firefighters to work faster and thereby minimizing the time persons are trapped. The support system could free people not only faster, but also safer through increased precision and thereby more efficient cuts and spreads.

Thereby the support system would be a factor in saving more lives or minimizing the effects of physical and psychological trauma.

Tipping point

The support system faces two major challenges that could hinder a product success.

Price. The solution could become too expensive held up against the benefits.

The fire station at Oluf Borchs Gade featured a large number of hydraulic rescue equipment and accessories varying in complexity and it is not believed that the complexity and cost of production of the hydraulic support system would increase beyond an unreasonable level. Keeping the price at “a reasonable level” is purely approximated from the fact that the solution is based on known simple manufacturing technologies and relies on passive inexpensive components.

A relatively large investment cost could possibly be held against benefits such as fewer sick days, minimizing injuries and hospital bills of patients etc.

A second twofold challenge consisting of complexity in use and flexibility in use, could represent a difficult hindrance.

It is important that the support system is not overly complicated in use both during planning, setup and in flexibility when actually using the product. It must not be time-consuming and difficult to set up the support system, to change tools, to change the mounting point of the rail etc.

Furthermore all of the functions must be intuitive and easy to use. Evolving the current model into a satisfactory condition would require extensive user testing.

Market

The product has been designed with a focus on a Danish context. The immediate surrounding markets are very similar and it is assumed that the product would feature well in the majority of the European market. Globally, economies are very different. As an example, in the united states many firemen are volunteers and funding for equipment is very low.

A lesser technical low-budget solution could be developed to approach these markets or they could be abandoned in favor of more lucrative markets.

SolidWorks

The design profession and the methods and tools are of a constantly changing character. The primary modeling tool used for this project has been SolidWorks. Through intense use and practice, SolidWorks has become a highly efficient tool from the sketching phase throughout the detailing phase, for testing through digital models and for product renders.

The program has been very helpful in making on-the-fly calculations of for instance weight, testing movement of components etc. during the modeling phase and thereby incorporate changes continuously.

Program features such as the Toolbox (a large catalogue of standard components such as bolts, nuts and bearings) are a great advantage and adds realistic component choices to detailing.

By allowing quick calculations of technical aspects and the use of standard components, SolidWorks contributes to designing an integrated solution even on a detail level.

Using SolidWorks requires an alternative way of thinking. When modeling a part, you must first thoroughly consider the end result and then consider the easiest path to exactly that result before modeling. The parametric and relative geometries make it very difficult to make larger changes to an existing part although very easy to make minor changes.

The requirements for high precision and fully defined shapes/sketches therefore is a disadvantage for use when sketching and evolving initial ideas.

Individual vs. group work

Ironically the master thesis project is the first major project I have carried out as an individual (disregarding the 9th semester internship and corresponding report).

Several conclusions can be made on the comparisons of group work versus individual work.

As an individual you work more efficiently in many situations. It is my experience that productivity does not rise directly in relation to a rise in members of persons attached to a given task.

What is clear whether talking of a simple task or a complete semester project, is that quality insurance is better when working in groups. Discussions are more vivid resulting in better arguments for all of the project aspects.

I without a doubt prefer group work or collaborative working. The option of continuous feedback is an extreme aid in fulfilling project goals although it depends a lot on the type of assignment.

Group work and studying at Aalborg University has involved fun, friendships and an impressive synergy effect which I have appreciated greatly during my studies.

Core competences

One of the stated goals of the introduction is to present my core competences as an industrial designer.

Defining your own profile is a very abstract challenge that relies on many different contextual factors, but my initial definition of a product designer that is enthused by the design of semi-technical products with the corresponding competence still stands.

I enjoy many aspects of designing, but I prefer when design phases become more concrete with actual user problems or the use of physical/virtual models in the design phase. Herein lies all of the tangible arguments such as integrating expression and ergonomics with production and material properties. I find Integrated Design one of the primary learning goals of this education as it contains the essence of combining a civil engineer and artist in one.

Illustrations

Illustrations that are not mentioned in the list are of own creation.

Phase 0

0.7.: www.centervall.dk

0.9.: Based on Knudstrup 2005

Phase 1

1.14.: www.YouTube.com

1.15.: www.centervall.dk/gallery/oevelse_frivillig_roskilde.html

1.16.: www.centervall.dk/gallery/hojskole_alle.html

1.17.: FireRescue1.com

1.20.: Christensen 2009

1.30.: http://www.weber.de/wr/en/rettungsgeraete/download-aggregate-e50-t-sah20.php

1.33.: http://www.weber.de/wr/en/rettungsgeraete/download-schneidgeraete-rs165-55.php

1.34.: http://www.weber.de/wr/en/rettungsgeraete/download-spreizer-sp49.php

1.35.: http://www.weber.de/wr/rd.php

1.37. – 1.43.: Weber-Hydraulik 1, 2004

1.44.: Weber-Hydraulik 1, 2004

1.45.: http://www.weber.de/wr/rd.php

1.55.: http://en.wikipedia.org/wiki/Kano_model

1.56.: http://4pack.files.wordpress.com/2009/07/bicycle-riding.jpg

1.57.: Composed from several pictures:

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2.14.: http://www.lumpfani.co.za/images/stedicam/large/STEADICAM_1907.jpg

2.16.: http://photos.gps.free.fr/steadycam/steadycam%20II/Steadycam%20II%20guimbal%202.jpg

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