IMPROVEMENT OF OPERATORS ENVIRONMENT IN EXCAVATOR

Master degree in Transportation design

Jon Håkansson 2004

Institute of Design, Umeå University
In collaboration with Volvo Construction Equipment and Epsilon Perspectives Design
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21. Cab and joystick Mock Up
22. Package of Fuelcell powerplant and elevating cabin
OVERVIEW OF COMPONENTS

Valve package regulating hydraulic pressure to cylinders and hydraulic engines

Engine

Boom

Hydraulic cylinder

Counterweight

Dipper arm

Superstructure

Hoses for hydraulic fluid

Drive wheel

Tool Attachment

Rotator

Track

Track tension adjustment
BACKGROUND

**Excavators**
Excavators are being used in all kinds of construction work, where a flexible machine for moving material is needed. They are built with a 360 degrees rotating undercarriage, on top of that sits the superstructure with engine and hydraulic system. Mounted on the superstructure sits the boom and the cabin, the boom could be split in two or three pieces and in the end of it, the tool attachment is placed. The main controls in all excavators are the joysticks which controls the joints in the boom and the rotator. They come in sizes from 1 to over 500 tons and can be grouped in two main categories:

**Crawler Excavators**
Equipped with steel tracks for travelling in rough terrain, from mud to rock. These machines are not allowed to drive on public roads, because of the steel tracks and therefore they have to be transported on a truck to the site. The tracks are controlled with pedals and levers (the operator has the opportunity to choose). Main field of work is rock handling, road construction, pipelaying, waste handling and above ground mining.

**Wheeled Excavators**
Four wheels instead of tracks makes wheeled excavators legal for road transport. They are limited to sizes up to 20 tons, a limit due to the road regulation of maximum 10 tons per axle. These machines have the normal features like any other road vehicle, like headlights, brakelights, turningsignals etc. It has a steeringwheel that controls the front wheels, the steeringwheel is also the biggest difference inside the cabin between the two types of excavators. Main field of work is roadconstruction, digging pipes and cables in city environment, cargohandling, safetywork in tunnels and mines etc. The big advantage with the wheeled version is the mobility. The disadvantage is that it’s not as stable as the one with tracks, though this problem is limited with the help of outriggers.
VOLVO EC- AND EW SERIES

Crawler Excavator Volvo EC series

Wheeled Excavator Volvo EW series
VOLVO CONSTRUCTION EQUIPMENT

VCE is one of the world's leading manufacturers of earthmoving machines, a total of more than 150 different models of excavators, wheel loaders, motor graders and articulated haulers are produced. Production plants are located in Sweden, Germany, France, the U.S, Canada, Brazil and Korea. With 170 years, Volvo Construction Equipment is the oldest industrial company in the world still active in the field of construction machinery.

Among the users, Volvo are considered as cost effective and reliable.

VCE Core values: Safety, Efficiency, Environment and Comfort.
COMPETITORS

Volvo’s main competitors among excavator brands are:

Caterpillar (USA)
Komatsu (Japan)
Liebherr (Germany)
Fiat Hitachi (Japan)
PROBLEMS IN GENERAL

The biggest problem with excavators in general is ergonomics and the operators environment. The machines are not built so that the operator can have full visibility towards the tool at all times, when using the full range of the boom the operators back and neck twists into uncomfortable positions. The A pillars are wide and takes away a lot of the field of vision, but still they are not strong enough if the machine falls over. A lot of the controls in the cab are placed underneath the armrests where they are hard to see and to reach. The pedals is a problem, they are operated both at the front and the back and causes a lot of muscular stress, there are also difficulties when it comes to cleaning the small space between pedals and floor.

Because of the big forces when digging and the often bumpy terrain, full body vibrations is a major issue, this problem is reduced but not completely solved with rubber suspension between the cab and the superstructure. Other issues are: noise (especially the area around the machine) and pollution (major problem at urban- and underground worksites).

Since the operator can’t transport the crawler excavators themselves between worksites, they might have to stand still, waiting for a trailer, this affects the cost, as well as the trailer fee itself.

The full boom range EW 180
STUDY VISITS

LKAB Iron ore
Full day studyvisit at the 1000 m level in Malmberget, together with two operators doing safety work with Volvo EW 160 (16 ton wheeled excavator). Their task is to remove loose rocks from walls and ceiling after the explosions, before the drilling takes place again.

The job is risky because of falling rocks, and they have to go slowly forward, scraping the ceiling bit by bit, making sure nothing falls on the machine. They are complaining a lot about the visibility, especially right side rear view, but also about poor work lights. The biggest problem though is the fact that they have to lean forward and bend the neck backward to be able to see the tool when scraping the ceiling. One of the operators have remaining neck problems due to the work conditions.
**EW 230 with elevated cab**
Visit at a garage, having a look at a Volvo EW 230 equipped with an elevated cab. This function reduces the body position problem mentioned above, but not entirely. The cab elevates about two meters but does not tilt, which would be desirable.

Eventough the cab elevates, the operator have to bend the neck to see the tool when boom and dipper arm is in upper position.
Komatsu Forest
There are some types of machines used in other areas that have similar configuration and/or operators environment as excavators. Therefore I made a visit to Komatsu Forest, looking at harvesters and forwarders used in the forest industry. My impression was that these machines were quite sophisticated in some ways, for example they have inbuilt computers for measuring the logs for best cost efficiency. Joysticks are used, just like in excavators, but with a lot more functions close to the operators hands. The roof pillars are thin and the machines offers very good visibility. The cab is mounted on a two axis hydraulic joint, which keeps the cab horizontal at all times.
Lapplandsflyg
Another joystick controlled vehicle with high demands on visibility is helicopters. I went to have a look at Bell helicopters. These machines have high visibility, even downwards, but the construction is from the 1960’s and the cockpits feel very old with hundreds of buttons and switches.

Floor window

Instrument panel in Bell helicopter

Joystick
**VCE Democenter Eskilstuna**
At Volvo’s customer center I had the opportunity to see the whole machine range, have a testdrive and a discussion about problems and ideas with my tutor, Jonny Lindblom. One major impression of the Volvo excavators is that the interior quality is far from the exteriors, which feels very solid and robust. A lot could be done in order to raise the expression of quality and making the interior more fresh and up to date. While testdriving I realized that I was sitting on the front part of the seat, leaning forward. According to my tutor, that’s a common problem.
CONCLUSION

According to the report *Ergonomic on-Site Assessment of Excavator Work*, one big problem is the risk of falling accidents when entering and exiting the cab. The solution could be lowering the cab to the ground in front of the machine, this could also help during cleaning of windows. The mechanism needed for this operation could also be used for adjusting the cabin in height and tilting it, in order to solve the problem with neck and back injuries.

In Umeå I had a meeting with professor Ivan Westerlund at SLU (Swedish Agricultural University) who taught me about ways to reduce vibrations by different undercarriages. It would be possible to have a principle similar to the terrain vehicles and tanks produced by Hägglunds. They are equipped with an active suspension system, making it possible to drive in high speed with track-undercarriage.

By using this technique it would be possible to merge the two different excavators into one, a stable machine while working and a comfortable fast machine during transport. A fuel cell powerplant would be well suited, considering sound level and pollution in urban environment and especially underground worksituations. With less need for maintenance the risk for falling accidents gets minimized.

As a bonus, maybe the waste water could be used for spraying, to avoid dust when needed. Today’s underground-operating machines are tied up with a water hose which affects the mobility to a high level.

Since I want to concentrate on a flexible machine adapted for road transport, my benchmark is the Volvo EW 180, their biggest wheeled excavator, produced today.
IDEATION PHASE

My ideation started with sketching on how to avoid the problems of hazardous body positions, solutions both on exterior and interior. The first sketches for exploring the idea of having a tilting seat and an armrest following the movement of the joysticks to avoid unconscious lifting of the shoulder.
Pedals attached to tilting seat, inline with footrests.
Possible cab movement, trying to get more harmony between the counterweight, superstructure and main body. Exploring idea about swingarms attached to corner wheels.

Moving cab that in upper position blends in to the form with the rest of the machine.
The sketch to the left has a nice boarder between superstructure and counterweight which I decided to keep.
Mechanisms for lowering and tilting the cab.

Swingarms with adjustable hydraulic pressure for different modes, stiff while working and soft during transport.
Sketching on undercarriage in order to get it to function, hydraulic drives inside of the rear wheel and track tension adjustment behind the front wheel.
CAB AND JOYSTICK MOCK UP

In order to determine the space needed inside the cabin and in what angles it feels acceptable to sit inside it, a mock up was made. An adjustable seat was mounted as well as two different joysticks made of clay for trying my idea of armrests and joysticks made as one piece.

Acceptable range of tilting

Trying the idea of a see through display, which could be used for rear cameras, camera on dipper arm, work orders, machine status, GPS etc.

Clay joysticks
PACKAGE OF FUELCELL POWERPLANT AND ELEVATING CABIN
HALF WAY PRESENTATION AND DISCUSSION

At this point, a meeting took place with the tutors Jonny Lindblom (VCE) and Hans Zachau (Epsilon Perspectives design) at VCE customer center. I had positive response to my ideas, though after discussions we decided to concentrate on the interior and especially the seat. Stand up seats are better suited for the human body, thanks to a wider angle between spine and femur. This sitting position gives you a better postural control and reduces the stress on your neck and lower spine. In this case the knees also works as shock absorbers, reducing the body vibrations. Another advantage with a stand up seat would be when the cab tilts forward, your body is in an upright position, almost standing up and more weight is added to the feet. It is a fact that variations in bodypositions reduces fatigue and the risk of injuries. After discussing the joysticks we decided to go another way: It would be desirable to have the opportunity to change between different grips. When moving in rough terrain the operator needs something to hold on to, in that case the joystick should be a hand full with some resistance in the movements. When doing finetuning, a knob on top of the joystick could be used, controlling the same functions. This would also add to the variations mentioned above.

To the right: Sketches of a stand up seat, this would give the opportunity to fold away the steeringwheel underneath the seat (if a steeringwheel is necessary)
NEW JOYSTICKS

New version of joysticks, with the knob on top.
Different lengths on armrests.
A working prototype of the seat, exploring different graphics. The lowerpart of the seat is meant for supporting the legs when cabin tilts back. The sidesupports should be adjustable to fit different body types.
USER TEST

Operator testing the seat prototype and the preferred joystick.

I made a user test with the seat and the joysticks, the operator liked the stand up seat idea, but mentioned that a good foot support is needed. He preferred the joystick shown on the left picture and liked the idea of putting the most frequently used functions close to the hands. When it comes to the length of the armrest, he would prefer something in between the two prototypes. The functions he thought is most important: work modes, tilting and elevating of the cab, forward/reverse, steering, operation of extra tool, tool rotator and horn.
FURTHER DEVELOPMENT IN ALIAS AUTOSTUDIO
THE RESULT

19 tons excavator with elevating, tilting cabin. Combined with a stand up seat for optimized ergonomics. Undercarriage with active suspension and rubbertracks makes it comfortable, flexible and mobile. These new features are shown in the exterior design together with a new more dynamic body shape. The geometry of boom and dipperarm are almost unchanged. The backlights are inserted into the counterweight splitline.
EFC 190 EXCAVATOR FLEXIBLE CRAWLER 19 TONS

In deep digging operations the cab can be moved forward and tilted. This increases the visibility as well as it offers a more comfortable body position, in combination with the stand up seat the operator gets into a standing position.
The cab position for operations above the machine. The operator has the opportunity to choose if the cab will adjust to the arm movements, or manually.
The cab position in transport mode.
When entering and exiting, the cab is lowered down in front of the machine minimizing the risk for falling accidents.
THE SEAT

Stand up seat with adjustable side supports to fit different body types.
The most frequently used controls are moved up to the joysticks. The knobs on top has the same functions as the joystick it self, in order to encourage the operator to vary grips.
DISPLAY

The transparent LCD is used in several different modes in combination with buttons on the joysticks:

Visual aid for rear view in combination with camera.

Visual aid for tool in combination with camera.

Vehicle status: indicators, warnings, amount of fuel left, oil pressure, temperature etc.

Cab office: writing/reading work orders, work reports, invoices.

Climate control.

Navigator.

Sound system.

Display in Vehicle Status mode
Rear view Mode

UNDERCARRIAGE

The Four wheels in the corners are attached to swing arms with hydraulic shock absorbers. The oil pressure is adjustable, which means that the machine shifts between different suspension settings depending on chosen mode. This function also allows the swing arms combined with sensors to adjust the machine to a horizontal level at all times.
PHYSICAL MODEL

This physical model is a working prototype of the seat for evaluation.
DIMENSIONS
ANGLE OF VISION

The recommended angle of vision reaches from a horizontal line to 30 degrees below.

Note the upright body posture in the lower cab position.
REMAINING WORK

The project will be displayed at the degree exhibition in Umeå and Stockholm. It will be presented to Volvo Construction Equipment 04 06 11 in Eskilstuna.
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Inga-Märit Hagner, Lars Brundin, Margaretha Marklund and Minori Nakata
Operation of wheel loaders
Sten Gellerstedt
Analysis of interaction quality in human-machine systems
Kaisa Nolimo Solman
www.volvo.com
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Tutors

Jonny Lindblom
Volvo Cabs AB
Hans Zachau
Epsilon Perspectives Design AB
Ajay Jain
SAAB Automobil AB