First studies of exoskeleton use in construction industry

SEC / APST / OPPBTP

Nicolas Froment
Direction technique, Prévention de l’usure professionnelle (PUP)

Mireille Loizeau
Médecin conseil, APST
Plan

I. Presentation of the study, the partners and the methodology

II. Key lessons of the three observed practices
   • Facilitate loads handlings
   • Alleviate operators of their work equipment weights
   • Alleviate operators during ceilings work with a sander

III. Summary and futures expectations
Study starting points

- **The OPPBTP** is keeping a permanent watch on innovations and new practices
  - Observations of the development of exoskeleton offers
    - Commercial arguments: reduction of musculoskeletal problems
  - Lack of scientific knowledge about this thematic

- Project about exoskeleton initiated by the *Syndicat des entrepreneurs de la construction (SEC)*
  - Companies and exoskeleton models already identified
    - **Type of exoskeleton: harness without motorization** with 1 or 2 arms
  - Partnership with the OPPBTP requested

- Common study project with gathered SEC / APST / OPPBTP
  - APST Health and safety department for construction industry
Study main principles

- **Objectives**
  - Generate useful knowledge about exoskeletons use
  - Identify food for thought to initiate extensive studies

- **Retained principle**: **comparative analysis** of the changes done
  - Activity observations **without** and **with** exoskeleton
  - Work sequences video recording
  - Operators interview
  - Analysis with the “CAPTIV” app
  - Interviews with companies to determine technical and organizational evolutions which could avoid using exoskeletons
Work hypothesis and metrology associated

- **Is it neutral to carry an exoskeleton?**
  - Postural compensation phenomenon?
    - Exoskeleton weight and bulk
    - Large distance of the load
    - Professional gesture: preservation or modification?
  - Angle measurements of the trunk and upper limbs
    - Test of electromagnetic sensors specific to the construction industry
    - Restrictions: electromagnetic sensors sensitivity

- **What about efforts reduction?**
  - Cardiographimeter
    - Restrictions: vibrations and electromagnetic radiations sensitivity
    - Touchy illustration depending on observations
Exoskeleton uses

- Uses being determined by SEC companies
  - **Use 1 : handling**
    - Movement with a load: Impossible to implant a breeze block storage pallet very close to the workspace
    - Does the use of an exoskeleton contribute to decrease the level of demands?
  - **Use 2 : Lighten the operator from its work equipment weight**
    - Use possible with chainsaw, chisel, grinder
  - Used in a company which have co-developed its own exoskeleton
    - **Use 3 : Ceilling work** with a sander
    - Arms above head
    - To reduce efforts and maintain work quality
Use 1
Breeze blocks handling
Handling use

- Type of exoskeleton
- Breeze block handling
  - Assembly
    - Possibility to take a breeze block over a pallet
    - Possibility to move up to 15 meters in a lineal distance
    - Possibility to install the breeze block during a wall construction
  - Disassembly
    - Possibility to take a breeze block over a wall
    - Possibility to move
    - Possibility to drop off the breeze block on the pallet
- Two types of breeze block
  - "light" breeze block = 12 kg  Assembly/Disassembly of 8 of them
  - "heavy" breeze block = 28 kg Assembly/Disassembly of 13 of them
Posture due to exoskeleton use

- Operators arms held up by the “exoskeletons arms”
- But:
  - Load kept away from the body
  - Forward attracting force
  - Offset by back movements
Usual charging port posture

- Load pressed against the body as close as possible from his center of gravity
- Required a sustained effort over the exoskeleton arms to maintain the load at the operator’s natural position
Professional gestures modifications

- Research of the most adapted way to hold a breeze block
Professional gesture modifications

- Operator arms immobilized during movements without load
  - Decrease recovery strategy

- “Exoskeleton arms” blockade during movement
  - Restrictive and additional gestures to engaged/trigged the “exoskeleton arms”
« light » breeze blocks : assembly/disassembly task

Without exoskeleton (7’ 06’’)
With exoskeleton (14’ 40’’)

29,2 % à 4,8%
2’ 04” à 42”

1 % à 49,4 %
8” à 7’ 15”
« heavy » breeze blocks : assembly task

Without exoskeleton (7’ 56”)

With exoskeleton (19’)

18,2 % à 7,4%
1’ 27” à 1’ 24”

11,3 % à 63,2 %
54” à 12’ 00”
Summary

• This non-motorized exoskeleton with a load manual prehension isn’t adapt to handling tasks requiring any movement
  ✓ Spending more time
  ✓ Offsets movements
  ✓ Increased heart rate

• Looking for other solutions to help handling and which include gripping, movements and position of breeze blocks on the wall
Use 2
Lighten the operator from its work equipment weight

Without exoskeleton = 4’ 06”

With exoskeleton = 5’ 41”
Main analysis

- Need of specific system for each equipment
- The arm design influenced postures as well as the gripping of equipment

Safety
- Feeling of « being attached », to not have anymore the control of the work gesture
- News safety rules (individual and collective)
- Maybe considered a specific training? A preliminary time of taking in hand?

Benefit when work is at shoulder-high
- Adaptability limited work construction industry
Use 3 Ceilings work with a sander
Main analysis

- Real decrease of the effort asked
  - Operators feel a decrease of about 60%
  - 800 m² ceiling: from 5 to 1.5 days
  - Quality like the original
  - Delicate control of the gesture amplitude

- Design step by step depending on the task analysis requirement
  - Recognition of a “hard” position
    - ✓ Share between operators and management
  - Decreasing efforts while keeping work quality and work gesture
  - Approach step by step
    - ✓ Research, test and assessment of adapted equipment
    - ✓ Improvement of the solution with the maker
Summary and discussions
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- Teachings about this kind of exoskeletons
  - Restricted contributions for construction industry
    - Except if the work is done at shoulder-high
  - Heading for helping equipment to carry work equipment
    - Preservation of the professional gesture
    - Adapted to construction industry

- Methodology
  - Starting from knowledge of the task and of a production process global analysis to determine appropriate means
    - Actual exoskeletons do not necessarily correspond to the most adapted solution nor to the priority
Summary and discussions

- First-generation of professional exoskeletons
  - Time of « trial and error »
  - Important evolutions required before any real use to help human to work

- To better future actions
  - Structure knowledge and experience feedback
  - Establishment of an cross-sectorial observatory about exoskeletons
    - National level ? European level ?
  - Construction industry observatory in progress of structuration by the OPPBTP
Thank you for your attention