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## Proceedings

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# PLENARY SESSION



# SESSION A: EARTH-MOVING AND TRANSPORTATION MACHINERY

## SESSION B: PRODUCTION TECHNOLOGIES

# Simplified Life Cycle Assessment of a Conveyor Belting

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*This paper deals with the simplified life cycle assessment (LCA) of a bucket wheel excavator (BWE) conveyor belting. Belting is the most important component of a belt conveyor. Simplified LCA was conducted with the Ecodesign Assistant (EA) and the Ecodesign PILOT (EP) software tools. Conveyor belting was recognised as ABE hybrid type product, whose 'raw material', 'manufacture' and 'end of life' stages are significant in its life cycle. After the second iteration, the conveyor belting was recognised as a 'raw material' and 'manufacture' intensive product. Further analysis considered strategies for possible product improvement suggested by the EP tool.*

*This particular analysis of conveyor belting is part of a complete LCA of the BWE belt conveyor which should provide a basis for establishment of the methodology for conducting LCA studies of a BWE or similar types of belt conveyors.*

**Keywords: Simplified Life Cycle Assessment, Ecodesign Assistant, and Conveyor Belting**

## 1. INTRODUCTION

Belting is the most vital component of the belt conveyor and an element characterised by the lowest life. It participates with 50-60% in total investment costs of a belt conveyor [1]. This particular belting is the main component of a belt conveyor which is constituent element of the BWE SchRs 1201. Since BWEs consume large amounts of electric energy, and the belt conveyor is a part of this large system, any contribution to its energy efficiency and minimisation of energy consumption leads to significant energy and cost savings and towards sustainability.

For terms such as life cycle, LCA and product types please refer to [2, 3], and for terms such as sustainability, sustainable development, energy efficiency and energy saving to [2, 4].

The analysis presented herein was conducted through several iterations using EA and EP software [5, 6]. Initial results had shown that conveyor belting was an ABE hybrid type product. After refining, the second iteration led to an AB hybrid type product, which is 'raw material' and 'manufacture' intensive. Improvement strategies recommended by EP in first and second iteration were almost identical. The third iteration comprised more detailed energy input calculation during 'manufacturing' stage. However, product type and recommended improvement strategies remained as they were in the second iteration.

## 2. DESCRIPTION OF THE PRODUCT

The product analysed in this paper was the BWE SchRs 1201 conveyor belting type EP 500/3. The belting properties must ensure sufficient tensile strength and adequate flexibility in both longitudinal and transverse directions as well as sufficient life. Typical conveyor belting is a multilayer flat composite [1]. Thus, it is consisted of top and bottom rubber covers and rims and carcass (core). This particular belting carcass is consisted of 3 reinforcing textile plies made of polyester (warp yarns) and polyamide (weft yarns), see Figure 1. Rubber cover grade is N (natural rubber). Belt length is 16 m, with belt width of 1.6 m and troughing angle of α=30°. Belt speed is v=3.9 m/s.

Estimated conveyor belting life was 5.5 years.

Determined functional unit of the product was transportation of 3465 $m^3$/h of brown coal.

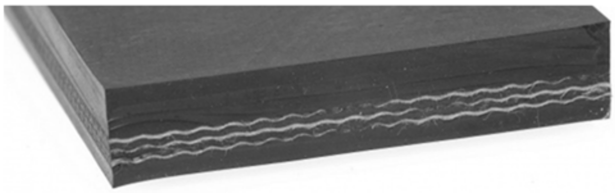

*Figure 1: EP 500/3 conveyor belting cross section*

## 3. THE FIRST ITERATION OF ANALYSIS WITH ECODESIGN ASSISTANT

### 3.1. Raw Material Stage

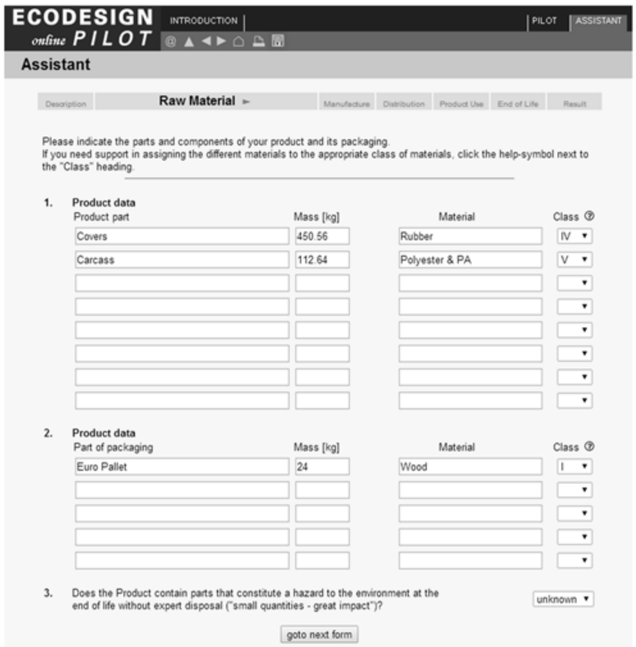


*Figure 2: Raw material stage form*

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For purpose of the analysis with EA, the product was divided into following structural parts:

- covers,
- carcass, Figure 2.

Total belting weight was 563.2 kg.

Material classes for each part of the product are determined in correlation with EA material class table [6]. At this point it was assumed that returnable euro pallet was used for packaging.

3.2. Manufacturing Stage

The manufacturing process differs for various types of beltings, but it is commonly comprised of:

- making of a basic rubber compound,
- making of cover sheets from raw rubber batches by calendering or extrusion (injection moulding),
- confectioning the rubber sheets with tensile member (adding reinforcing plies),
- curing in a press - vulcanization.

Making of a basic rubber compound is achieved by mixing rubber with carbon black (a form of paracrystalline carbon that has a high surface-area-to-volume ratio), plasticizers, chemicals and vulcanizing agents in mixing unit [7].

During the calendering process raw rubber batches are run through the rollers, while high temperature and pressure are applied as well. Since the injection moulding consumes more energy than calendering it was considered here as manufacturing process for raw rubber cover sheets.

Confectioning the rubber sheets with tensile member is a repeatable process dependant on a number of reinforcing plies. During this process, rubber sheets are run through the rollers alongside with reinforcing plies. Confectioning process is performed on the same machines as in calendering process [7].

Vulcanization involves the curing process in a press at temperature of 150 °C and pressure of 1.2 MPa (for EP belting) [8].

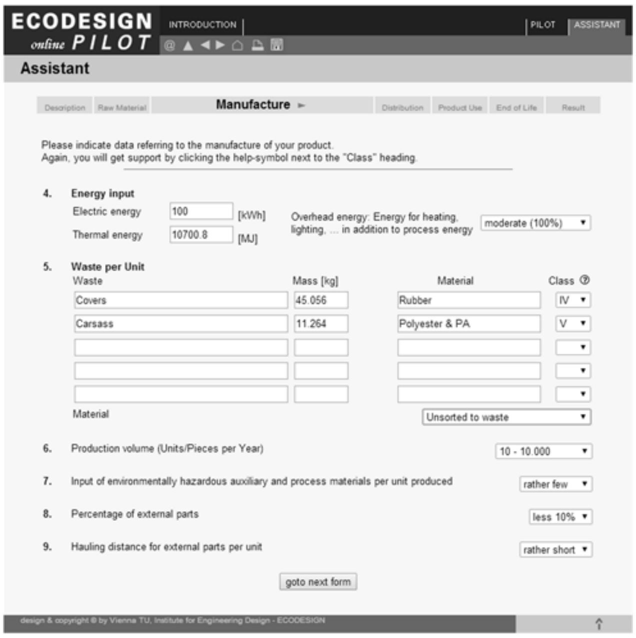


*Figure 3: Manufacturing stage form*

In absence of specification data for all of the machines in this production chain, the calculation of consumed energy in manufacturing stage was limited to a calculated energy needed for injection moulding of rubber sheets and vulcanization of 16 m of belting, Figure 3.

Calculated thermal energy input was 10700.8 MJ in accordance with specific energy consumption (SEC) of hydraulic injection moulding machine of 19.0 MJ/kg [9] and previously determined total weight of the belting of 563.2 kg.

The average electric energy input for vulcanizing 16 m of belting was aproximately 100 kWh in accordance with vulcanizing machine power requirements which were 30 kW and its production rate of 0.04-4.7 m/min [8, 10].

Waste material per unit was estimated to be 10% of the part's mass and it was dumped unsorted to waste. It was summarised for all rubber parts and presented with a single value. This issue will be improved during the second iteration.

The amount of energy required for heating and lighting was estimated as moderate. The estimated production volume was 10-10000 units per year. Percentage of external parts was ‘less 10%’. Hauling distance per unit was determined as ‘rather short’. Input of environmentally hazardous auxiliary and process materials per unit produced was assumed to be ‘rather few’.

3.3. Distribution Stage

Since the production facility is situated close to the place of product utilization, the average transportation distance for product distribution was estimated to be 20 km. The product was transported by truck. Euro pallet was recognized as returnable packaging.

3.4. Product Use Stage

Electrical motor is the only component of a belt conveyor which consumes electric energy. Therefore belting does not need any material or energy input per use. Calculated use frequency of belting was 325 uses per year. The only thing that could be discussed here is possible material spillage as a waste material per use. That issue was not considered here.

3.5. End of Life Stage


*Figure 4: End of life stage form*

The disposal of different parts of the product has been considered at the 'end of life' stage. Here, it has been assumed that no parts will be reused, reconditioned or recycled. This is the worst case scenario. Only euro pallet was recognized as returnable packaging intended for reuse, see Figure 4.

3.6. Result

Conducted analysis resulted in an ABE hybrid type product, see Figure 5. 'raw material', 'manufacture' and 'end of life' stages are significant.


*Figure 5: Result of the first iteration*

Four main improvement strategies were suggested:

- S2 – Reducing material inputs,
- S3 – Reducing energy consumption in production process,
- S5 – Avoiding waste in the production process,
- S19 – Recycling of materials,

and 10 secondary improvement strategies:

- S1 – Selecting the right materials,
- S4 – Optimizing type and amount of process materials,
- S6 – Ecological procurement of external components,
- S9 – Optimizing product use,
- S10 – Optimizing product functionality,
- S11 – Increasing product durability,
- S15 – Improving maintenance,
- S16 – Improving reparability,
- S17 – Improving disassembly,
- S18 – Reuse of product parts.

Each one of the listed improvement strategies is followed by adequate checklists of the EP.

## 4. THE SECOND ITERATION OF ANALYSIS WITH ECODESIGN ASSISTANT

Most of the forms in the second iteration are identical to forms from the first one. Only the forms that distinguish from the first iteration will be presented here.

4.1. Raw Material Stage

Belting is usually wound on a wooden core and wrapped with polypropylene strips and placed on a euro pallet. Thus, a wooden core was added as a part of packaging in the second iteration of the analysis, see Figure 6. Core diameter was 250 mm with 110 mm square hole and length equal to belt width (1600 mm). The wood density is approximately 500 kg/m$^3$. Polypropylene strips were neglected.

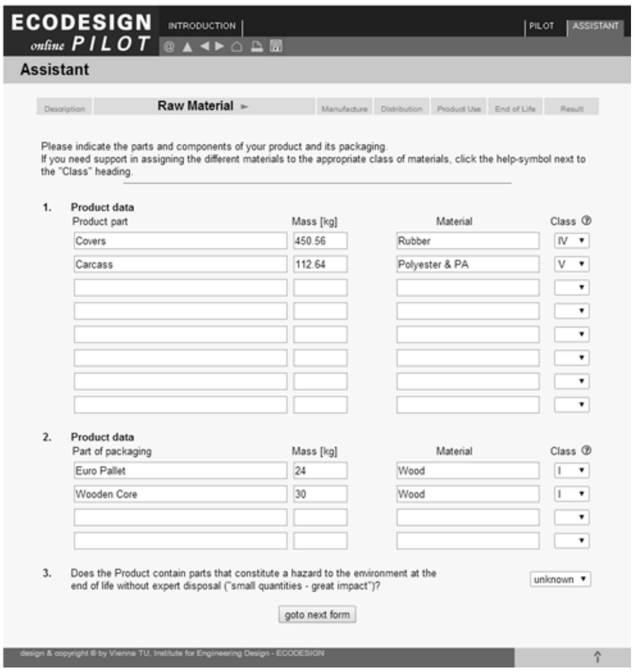


*Figure 6: Raw material form for the second iteration*

4.2. Manufacturing Stage

Compared to the first iteration waste material is being partially recycled here.

4.3. End of Life Stage

The conveyor beltings are the second largest rubber waste problem after the used tyres. Previously, disposal to landfill was presumed. Instead of dumping, the rubber conveyor belting can be reconditioned. Thus, the energy and resources needed for virgin (primary) rubber production could be saved. Conveyor belting reconditioning involves removal of a worn belting surface with special buffing machine and then re-application of the new rubber top and bottom covers followed by the re-vulcanization of the entire belting. According to this procedure, the scraped worn rubber is disposed to landfill or it could be recycled, while the belting carcass is being reused, see fig 7.

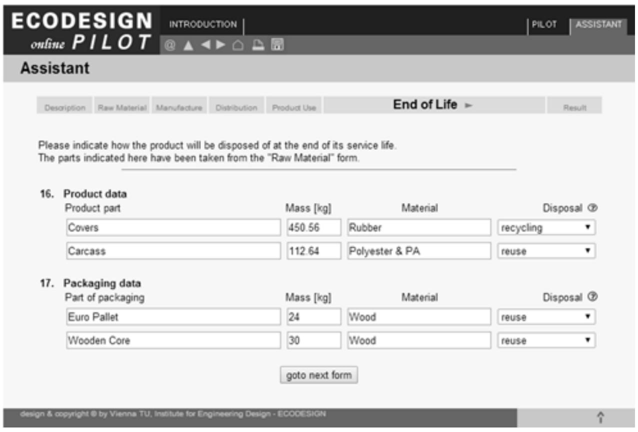


*Figure 7: End of life stage form for the second iteration*

### 4.4. Result of the Second Iteration

Because of the changes made in 'end of life' stage, the second iteration of the analysis resulted in an AB hybrid type product. The differences between the recommended improvement strategies in the second iteration compared to the first one were the absence of one main improvement strategy – S19, while the improvement strategy S5 became the secondary improvement strategy. However, the improvement strategy - S19 was already covered by the changes made in the 'end of life' stage referred to reconditioning of the belting, see Figure 8.


*Figure 8: Result of the second iteration*

## 5. THE THIRD ITERATION OF ANALYSIS WITH ECODESIGN ASSISTANT

Further analysis involved a more detailed calculation of thermal and electric energy consumption during the 'manufacture' stage. The additional calculation comprised the mixing mill and the confectioning process power requirements. As already stated, the confectioning process is performed on calendering machines.

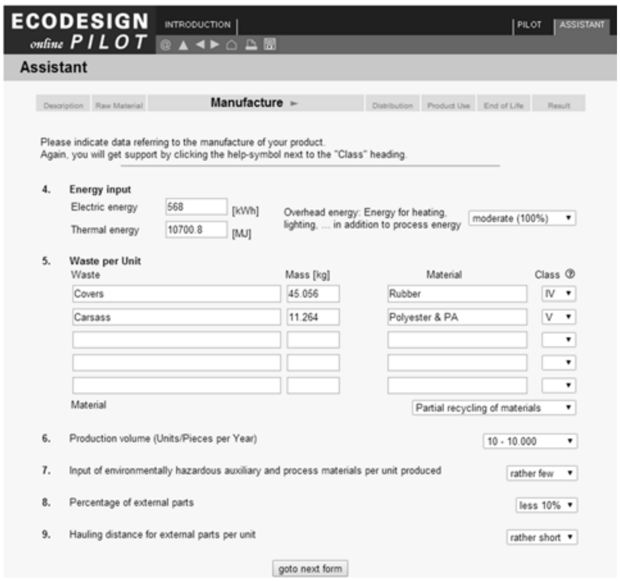


*Figure 9: Manufacturing stage form for the third iteration*

Appropriate mixing mill models for the production of 450.56 kg of rubber compound for 16 m of belting were SHDX-MM 22 "X60" and SHDX-MM 26 "X84" [11]. Batch capacity range for the first model was 90-110 kg and 160-180 kg for the second model. Mixing time per batch was 45 min. Thus, the average energy consumption for making the basic rubber compound was aproximately 450 kWh.

Since this particular belting has 3 reinforcing plies, the confectioning process has to be repeated 3 times. According to [8], the energy consumption range needed for the calendering 16 m long belting was 0.7-16.4 kWh. The average value of 6 kWh multiplied by 3 cycles resulted in the energy consumption of 18 kWh.

According to the previous calculations, the electric energy consumption has increased by 468 kWh. Therefore, the total electric energy consumption has risen to 568 kWh.

### 5.1. Result for the Third Iteration

Although the total electric energy consumption was increased, the 'result' form remained identical as it was in the second iteration. The belting product type as well as the recommended improvement strategies remained unchanged.

## 6. ANALYSIS WITH ECODESIGN PILOT

The improvement strategies provided by EA were further considered within EP. They are not presented in this paper entirely. Instead, they are discussed as tasks, measures and recommendations which are to be conducted in order to improve the product's functionality and energy efficiency, as well as environmental performance.

The final iteration resulted in two main strategies, see Figure 8. Since they have the highest priority, they will be considered first.

When it was considered if the product was made of recycled material, it has been concluded that it was not. This could be easily improved by specifying the use of a secondary rubber and carcass materials, Figure 10. On the other hand, the secondary rubber, polyester and polyamide do not have the same properties as virgin materials. Really recyclable material as a secondary material preserves the characteristics of a virgin material to a sufficient degree (if necessary by adding a new material). Therefore, the use of secondary materials in this case should be carefully considered before approval.

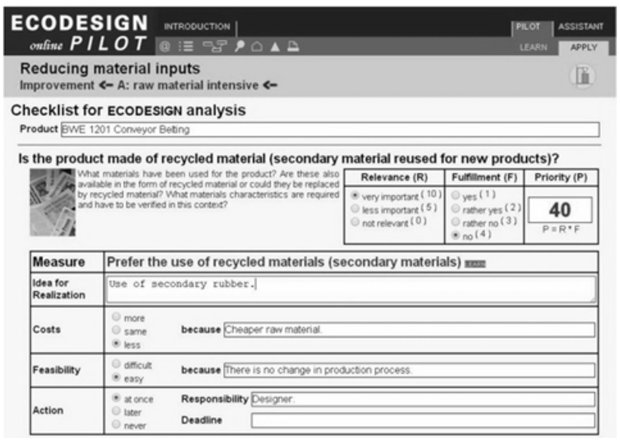


*Figure 10: Highest priority task for the main improvement strategy S2*

During the second iteration, the reconditioning of the belting has been taken into account. Recycling rate could be maximised by recycling scraped worn rubber (top and bottom cover). In that way there can be formed closed material cycle. The higher the recycling rate the greater the benefit for the environment and the higher economical efficiency of the overall process of reconditioning and/or recycling. Also, demand on resources and waste production can be reduced by using recycled materials.

Unfortunately, for proper functioning conveyor belting has to be a multilayer flat composite. Composite structure of the belting makes forming of closed material cycle difficult. Thus, composite structure of the belting is its main advantage and main disadvantage at the same time. Some improvements could be made by special design of beltings, but this is usually connected with much higher investment costs.

The use of toxic substances should be avoided during 'Manufacture' stage. Thus rubber compounds should not be made of oils containing polycyclic aromatic hydrocarbons (PAHs), and substances listed in Annex XIV of the Regulation No 1907/2006 (REACH) and listed in the Candidate List of substances of very high concern (SVHC) [12].

Although rubber cover material grade is N (natural rubber) and its environmental impact is minimal, it is desirable to examine different bio-polymers for possible application in the belting production. Particular attention should be paid to anti-friction properties and the belting surface quality in general.

Conveyor belting is extremely exposed to soiling and wear, which can cause very adverse effect on material transportation and conveyor functioning in general. Therefore, conveyors are usually equipped with plows and/or other belt cleaning devices. It is of great importance that these cleaning devices work properly, as well as they are adequately selected, which is a very delicate issue. If not, increased wear or even belting damage could occur. Besides belt cleaning devices, preventing material build-up forming could be accomplished by application of an adequate belting surface. Therefore, investigation of different materials with good wear and tear as well as sticky material repellent properties could be worth an effort. In order to identify the best materials for belting production, the investigation based on multi-criteria analysis should be applied [1].

Since belting is exposed to increased wear it could be labelled or equipped with some sort of indicators of remaining service life. This should be implemented alongside adequate maintenance concept. Common maintenance concepts are:

- Reactive or breakdown maintenance – 'run it till it breaks' concept,
- Preventive maintenance or time-based maintenance,
- Predictive maintenance or condition-based maintenance,
- Pro-active maintenance and
- Reliability-centered maintenance.

Maintenance costs are directly related to chosen maintenance concept [13]. An adequate maintenance concept should provide high level of reliability. Use of protection and belt tracking devices may contribute to increased reliability. The weak point of the belting is its splicing. Therefore, special attention should be paid to the belting splice and its realization.

Elastic properties of the coverings have no great impact on the flexibility (elasticity) of the belting. On the other hand, the number of reinforcing plies and their thickness has essential impact on the elasticity and thickness of the entire belting [1]. By achieving the adequate stiffness of the belting, the indentation rolling resistance as well as the flexure resistance of the belt could be minimised. Thus, a so-called energy saving belt could be produced. This kind of belting can save significant amounts of energy during its phase of utilization. Besides that, it could have significantly prolonged life because of the same reason.

Belting production procedures differ from one to another manufactures, but they are always similar and the difference in energy consumption in this stage depends mostly on the used machines. Speaking of energy efficiency, it could be improved by using state-of-the-art machines for each of the production processes. This increases the investment costs, but can result in reduced utilization costs on a long term base. Another way to achieve energy efficient manufacture is through constant monitoring and optimization of the process parameters by means of computerized process control.

When considering minimization of overall energy consumption of the production site, the analysis of energy flows and concomitant costs should be done. One possible approach to a reduction of the overall energy consumption consists in cascading the utilization of heat at different temperature levels; another one is using combined heat and power plants (CHP) for the generation of heat and electricity. By reusing the waste heat as process heat efficiency levels of more than 80% can be realized [6].

Waste in the production process could be avoided by closing the material cycle. It can be done through material separation and recycling during the production process. Reuse and recycling of rubber products, as well as recycling procedures are described in [2].

## 7. CONCLUSION

Particular issues considered within this paper were recycling and similar procedures, energy saving beltings, material build-up and wear reduction, investigation of possible application of new or different of type materials into production process, maintenance and protective devices, energy efficiency and possibilities for energy consumption reduction during the production stage.

Recycling and reconditioning issues could be solved by closing material cycles at the 'End of Life' and during production stage.

Certain improvement could be achieved by selecting or engineering the materials with superior characteristics regarding environmental performance, dirt repellence and wear resistance. Also material properties could ensure sufficient stiffness/flexibility of the belting and result in energy-saving belt.

Possible energy savings and energy efficiency improvements during the production stage were analysed. State-of-the-art machines, heat management and constant monitoring systems were proposed as a possible solution for this issue.

Analysis in EP has shown that energy and, consequently, cost savings, as well as environmental improvements, could be accomplished by conducting provided recommendations. Complete LCA analysis is needed to provide more precise data and better recommendations and solutions.

Further research will be focused on investigation of the different types of drive systems and accessories as well as on connecting [3], [4] and [14] with this paper and with each other. This should provide insight into environmental performance and other characteristics of complete belt conveyor system and serve as a basis for the complete LCA of a belt conveyor.

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