ENVIRONMENTAL ADVANTAGES OF USING HIGH STRENGTH STEEL

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ABSTRACT

This paper covers determination of environmental data for a large number of steels as well as validation of models for Life Cycle Assessment (LCA) of environmental savings when advanced high strength steel is used instead of ordinary steel for weight optimization of structures.

As expected, a LCA of the production of selected carbon steel and stainless steel grades shows that the environmental impact of a given weight of steel increases with increasing steel strength and alloying content. However, since increased strength leads to reduced weight, the total environmental impact will be considerably reduced.

Environmental data and LCA models have been used on a general case study on road vehicles and in two specific case studies - a storage tank and a spiral dewaterer for mines.

Analysis of a huge number of existing real life upgrading cases have been performed and these case studies show that achieving at least 20 % weight reduction for parts in which conventional steel is replaced by high strength steel is realistic. It also indicates that there is an even greater potential, especially for passive structures.

The environmental value of advanced high strength steel is described as a merit rating which expresses how the environmental savings relates to the additional specific environmental burden that is caused at production of high strength steel compared to ordinary steel.

A preliminary estimate shows that every million tonne of advanced high strength steel that replaces conventional steel in the European road vehicle fleet results in a life time saving of 8 million tonne CO_2-emissions and 30 TWh non-renewable energy recourses. Over 90 % of these savings are related to the use of the vehicles.

The above results emphasize the importance of including the use phase in the LCA in order to recognize the environmental potential of advanced high strength steel.

KEY WORDS**:** advanced high strength steel/weight reduction/LCA/LCC/environmental savings

INTRODUCTION

Recent statements by researchers on the connection between the Global Warming and CO_2-emissions have emphasised the need for limiting this impact on the environment. Application examples have demonstrated that there is a great potential for considerable weight savings and environmental savings by using advanced high strength steel. These examples can be found in many industrial sectors, including the transport sector that contributes to about 20 % of the global CO_2-emissions. Especially in this sector, in which at least 90 % of the environmental impact is related to the use of the vehicle, there is a large potential for reducing these emissions by developing lighter structures. The introduction of these steels on the market has taken a rather long time and has been in the nature of a technology push largely by steel producers, in cooperation with steel users and research institutes [1]. Many measures have been taken at the interface between the steel manufacturer and the steel user to increase knowledge and technology transfer [2, 3, 4, 5]. Some common efforts by the world steel industry have also been made, such as in the ULSAB (Ultra Light Steel Auto Body) and ULSAB-AVC (Advanced Vehicle Concepts) projects [6, 7].

This paper covers work performed in project 88044 “The environmental value of high strength steel structures” since the start in 1 January 2007. The project is part of the “Steel Eco-Cycle” program hosted by Jernkontoret, Swedish Steel Producers' Association and funded by MISTRA. The research has been carried out with input from SSAB EMEA, Outokumpu Stainless, Sandvik, IKEA and IVL, which have contributed by collecting data for upgrading cases and data for compiling a cradle-to-gate-database for steel production. Information has also been collected within the network of the steel using industry consisting of Volvo Car Corporation, Volvo AB, Volvo Construction Equipment, Scania, Saab, HIAB, Metso Minerals, Bombardier and Green Cargo.

GOAL AND SCOPE

The goal with this research is to develop and validate methods for Life Cycle Assessment and Life Cycle Cost (LCA and LCC) when using advanced high strength steel. Further the result shall broaden the effect of reduced environmental impact by developing engineering tools for knowledge transfer.

Cradle-to-gate LCI:s have been performed for conventional steel and high strength steel from SSAB EMEA, Outokumpu Stainless and Sandvik Materials Technology. LCA has been performed on active structures like cars, trucks, trailers, earth moving equipment, trains, ships and passive structures like cisterns, tanks, shelves, and furniture in different case studies.

MODELS AND MATERIALS

LCI on the production of different steel grades is performed and relationships between environmental impact, steel type and steel strength have been evaluated. Models for LCA of high strength steel structures have been developed and the potential for environmental savings is exemplified by specific case studies and a general case study for the road vehicle fleet.

A huge number of real life upgrading cases have been studied to investigate how well the higher yield strength of the high strength steel can be transformed into lower weight.

The steel grades included are carbon steel and stainless steel as hot rolled and cold reduced sheet material. The high strength carbon steels are micro-alloyed cold forming steels, dual phase steels and martensitic steels. Some grades of microalloyed and dual phase steels are hot dip galvanized. The high strength stainless steels are duplex steels and steels that are temper rolled. Three of these steels are especially developed for pipes used in Urea production. Furthermore, structural carbon steel and abrasion resistant steel as heavy plate are included. These steels are quenched and tempered steels with fairly low alloying element content. The high strength steels have yield strengths between 350 to 1400 MPa.

LIFE CYCLE ASSESSMENT

When considering the environmental value of high strength steel, it is important to analyse the whole life cycle. The life cycle phases are production of raw materials, alloys, fuels and electricity (upstream), production of steel products (Gate to Gate in the steelwork) as well as downstream phases as production of steel structures, use of steel structures, dismantling/scrapping and recycling, Figure 1. The LCA also includes all related transports.

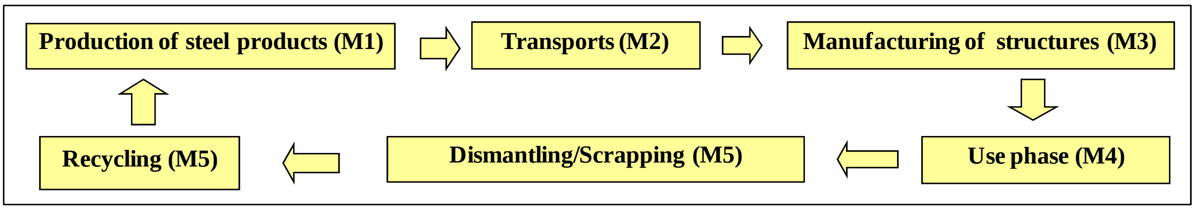


Figure 1. The life cycle phases of the full LCA of steel products

The LCA is mainly performed as a differential analysis, in which structures of advanced high strength steel are compared with structures of conventional steel. The analysis is then possible to relate to particular steel sheet components of the structure, where conventional steel has been replaced by advanced high strength steel.

The cradle-to-gate analysis of steel production is performed by the Swedish Environmental Research Institute, IVL. It covers raw material extraction, steel production, slab heating, rolling, annealing, quenching, tempering and related transportation. Most of the raw materials, the fuels and electricity, are traced back from the cradle. General data, mainly from the Gabi database [8], have been used for raw materials, alloying elements, and transportation. Data for electricity production have been compiled based on statistics from International Energy Agency (IAE) and LCI-data from the EcoInvent database [9]. Electricity produced according to Swedish average electricity production has been used for all processes located in Sweden.

The LCI-study is based on a weight reference unit - kg of steel. This is, of course, not the relevant basis for comparing the environmental impact from structures of high strength steel with conventional steel, since a smaller amount of high strength steel is used for a specific function. The total LCA is however built up as a modular system, and this unit is the most appropriate to use as input data in the module analysis. In the total LCA, the end result is per functional unit e.g. “production and use of one truck during its life time”.

When assessing the environmental value of high strength steel in structural applications, it is appropriate to differentiate between passive and active structures. For passive structures, it is the production of steels, manufacture of structures and related transport, together with the service life and end of life features that contribute in the LCA. For active structures, the environmental impact during the use phase also has a substantial influence on the LCA result. One main issue for both passive and active structures is to evaluate how well the higher yield strength of the high strength steel can be transformed into lower weight. It is also important to know whether some part of the increased yield strength of the high strength steel is used to increase performance in terms of higher payload, improved crash resistance, longer life, improved dent resistance or improved abrasion resistance, corrosion resistance, etc.

For active structures, it is investigated how much of the weight reduction can be transformed into lower energy use during the use phase. It is then important to find out, especially for vehicles in the transport sector, whether the transport is weight critical or volume critical. If the transport is weight critical, a weight reduction could be directly converted into an increased payload, with corresponding decreases in environmental impact and a lower cost for a certain amount of goods transported. Some examples of such structures are different types of vehicles for construction work, such as wheel loaders, heavy trucks and dumpers as well as timber transport vehicles, tanker trucks and cranes.

For volume critical transport, the lower weight leads to reduced energy needed and thereby lowers the environmental impact. However, it is normally impossible in this case to convert all weight reduction into reduction in energy, since some of the energy supplied is utilized to overcome air resistance (drag) and losses in transmissions, and to operate auxiliary systems. The energy flows related to weight are kinetic energy during acceleration and braking, potential energy losses in uphill and downhill travel and rolling resistance.

The use of advanced high strength steel structures can also improve energy absorption, dent resistance and wear resistance, as well as the working environment due to lower weight of structural parts during production and transport. It can also result in easier and less costly manufacturing due to smaller welds with less filler material and reductions in process steps such as heat treatment, thus reducing both environmental impact and cost.

RESULTS FROM THE CRADLE-TO-GATE OF STEEL PRODUCTION

The results are presented in terms of Global warming potentials (GWP as kg CO_2-equivalents) as a function of the yield strength. The GWP-value mainly consists of CO_2-emissions, which is why it is referred to as such in the result discussion, but emissions such as methane and nitrous oxide also contributes. More detailed results are reported in [10].

Figure 2 shows the results during steel production as a function of yield strength for SSAB EMEA Luleå - Borlänge steel. For these steel grades, the type of steel influences more than the yield strength, since the chemical composition has the greatest effect.

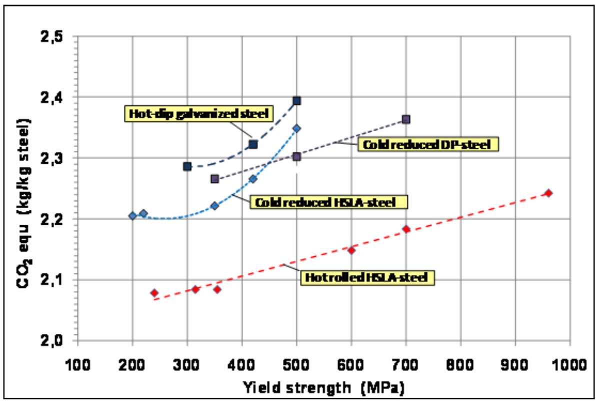


Figure 2. GWP [kg CO_2 equivalents/kg steel] as a function of yield strength for steel production at SSAB EMEA Luleå-Borlänge.

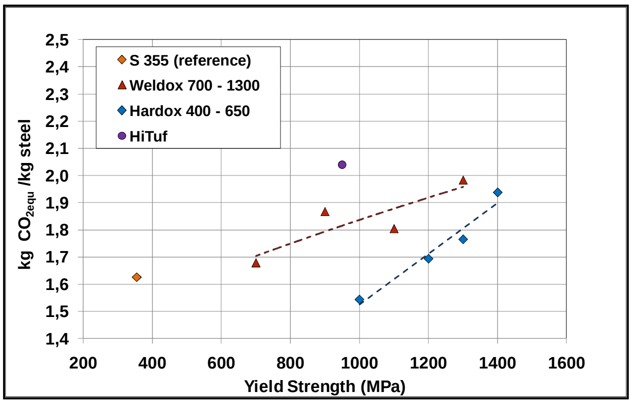


Figure 3. GWP [kg CO_2 equivalents/kg steel] as a function of yield strength for steel production at SSAB EMEA Oxelösund.

In general the values for cold reduced steels are somewhat higher than for hot rolled steels, since the yield is lower and since the process also includes cold rolling and annealing. The values for hot-dip galvanized steel are higher than for cold reduced steel since more alloying is needed to reach certain strength in the HDG process. The influence of yield strength is comparatively small for all these steels and could be described fairly well by the linear equations. The corresponding values for steels from SSAB EMEA Oxelösund, Outokumpu Stainless, Avesta and Sandvik Steel are shown in Figures 3, 4 and 5. For the steel grades produced by SSAB EMEA Oxelösund there is also a tendency of increasing GWP impact with increasing strength.

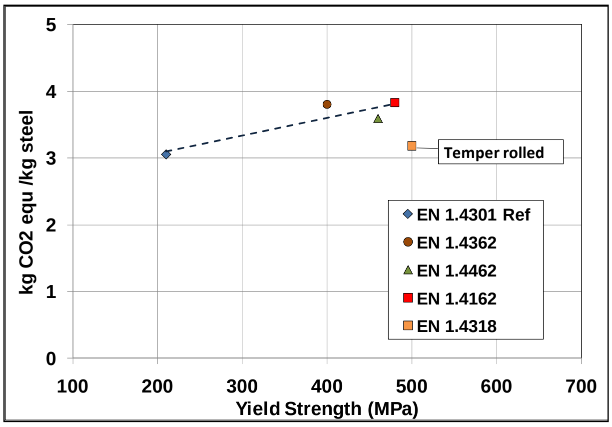


Figure 4. GWP [kg CO_2 equivalents/kg steel] as a function of yield strength for steel production at Outokumpu Stainless.

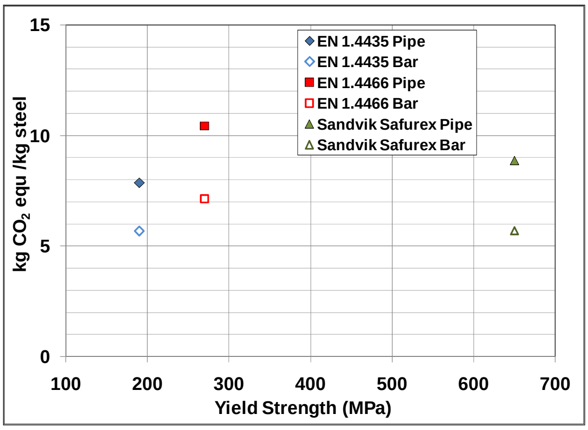


Figure 5. GWP [kg CO_2 equivalents/kg steel] as a function of yield strength for steel production and production of bars and pipes (6 inches) at Sandvik Steel.

The process metallurgy for producing high strength steel is continuously being optimized. This has an effect on the environmental impact and it is especially evident for the stainless steels which are highly alloyed and where the share of alloying element being virgin raw material compared to alloys in scrap can vary quite a lot. A newly developed grade which normally have a large share of virgin alloys show high values of CO_2, values that will decrease with time when the grade is more established.

For the Sandvik steels shown in figure 5 there is no clear tendency of increased environmental impact with increasing strength but rather an influence of alloy content. This is shown by the results for grade Safurex which has a lower content of nickel. Stainless steels show a much higher general level of GWP than carbon steels because of larger alloy content. The GWP-value for the steel from the steel works (prior to the bar and pipe production) is on a level of 4 - 5.5 depending on steel grade. The higher values for bar and pipe (ranging from 6 - 10) is mainly related to yield losses in the manufacturing processes. The GWP-values for pipes is larger than for bars due to higher yield losses when producing pipes than bars.

The LCI of steel production shows that in general other types of emissions are closely related to the CO_2-emissions and that this relationship is almost independent of steel grade at a specific production site [10].

In order to obtain a background for further analysis of the influence of increased steel strength on possible weight reduction, a number of real life cases have been collected and analyzed.

Data on the relative weight as a function of relative steel strength after upgrading from conventional steel to advanced high strength steel is shown in Figure 6 and the results seem to fit an earlier found relation, the Root formula.

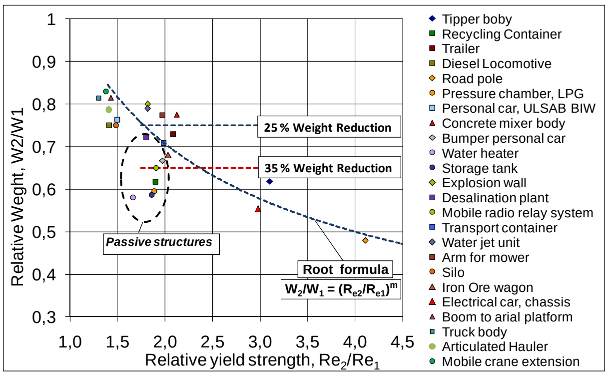


Figure 6. Summary of weight reduction (WR) for upgrading cases.

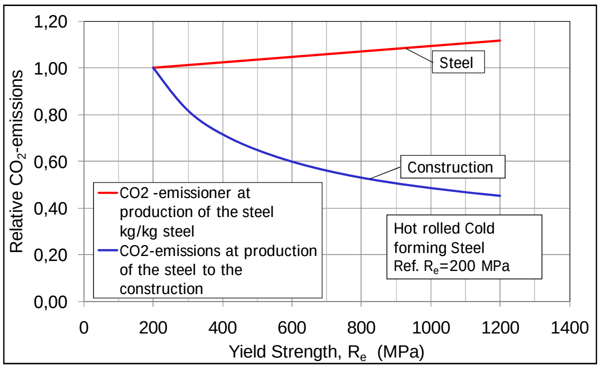


Figure 7. Relative GWP [kg CO_2 equiv.] for production of the steel and for lighter constructions in high strength steel.

The environmental saving obtained for structures in which conventional steel has been replaced by high strength steel are shown in Figure 7 and covers the LCA module M1, steel production. The graph is valid for Domex LA/MC hot rolled steel with data according to Figure 2, and assumes that the relationship between weight reduction and yield strength for upgraded parts follows the Root formula.

CASE STUDIES

In order to make a full LCA of environmental savings when using advanced high strength steel instead of conventional steel, three case studies have been carried out. One general case study has been performed on the road vehicle fleet. In this case the structures are active ones, where the main part of the environmental savings is related to the use of the vehicle. The second case is a passive structure, a storage tank for storing mortar slurry, where the main environmental impact is associated with the production of the steel material, transport and erection of the tank structure on site. The LCA is based on the LCI-data for different steels summarized in previous chapters. Thirdly a case study has been performed on a spiral dewaterer, used to collect dressed ore from slurry in mines. This is a passive structure where conventional mild steel has been replaced by Domex 650 MC steel resulting in many advantages. Data for the spiral dewaterer have been supplied by Metso minerals in Sala, Sweden.

For structures, it is important to assess the environmental performance during the whole life cycle and the assessments in the case studies follow the modules M1 to M5 shown in Figure 1. All case studies reported below are described in detail in [10]. As for the cradle to gate study in the previous section, the results are presented in terms of Global Warming Potentials (GWP) (as kg CO_2-equivalents), but are referred to as “CO_2-emissions”. For the case studies the results are expressed per functional unit of the structure.

Road vehicles

The environmental savings of using advanced high strength steel is first exemplified by analyzing motor vehicles for road transport. Statistics are studied on vehicle registrations/year and vehicles in use presented by the European Automobile Manufacturers' Association, ACEA [11] and the International Organization of Motor Vehicle Manufacturers, OICA [12]. The total number of vehicles produced in the world is 70 million per year. The vehicle fleet consists of passenger cars (72 %), light commercial vehicles (22 %), trucks (5 %), and buses and coaches (1 %). The environmental value of advanced high strength steel has been illustrated by a case where 1 million tonne of advanced high strength steel replaces 1.3 million tonne of conventional steel in the European vehicle fleet, Table 1. This corresponds to a weight reduction on upgraded structural parts of 25 %. In this case study only the phases steel production (M1) and use (M4) are considered.

Type of Vehicle	Total amount of steel regarded ktonne		Weight reduction ktonne	Specific CO_2 emissions steel production		Life time CO_2 savings ktonne		Total life time CO_2 savings ktonne
	AHSS[1]	Conv		AHSS	Conv	M1 Steel	M4 Use phase	M1+M4
Cars	560	747	187	2,23	2,12	331	3712	4043
Light Commercial Vehicles < 3,5 ton	114	152	38	2,33	2,19	67	1125	1192
Medium Heavy Vehicles>3.5t <16 t	30	40	10	2,21	2,10	18	168	186
Heavy Trucks >16 t, VC[2]	216	288	72	2,20	2,10	129	1510	1639
Heavy Trucks >16 t, WC[2]	54	72	18	2,20	2,09	32	755	787
Buses >16 t	26	34	9	2,20	2,09	15	205	220
Total	**1000**	**1333**	**333**	**2,23**	**2,12**	**592**	**7475**	**8067**
1) AHSS = Advanced High Strength Steel		**Total life time CO_2 saving, ktonne, (M1+M4)**						**8067**
2) VC= Volume critical transport, *WC=Weight critcal transport*		**Total life time saving in energy resouses, GWh, (M1+M4)**						**33094**

Table 1. The environmental value of introducing one million ton of advanced high strength steel into the European vehicle fleet.

The analysis shows that if 1 million tonne of advanced high strength steel replaces 1.3 million tonne of conventional steel in a road vehicle fleet it results in life time savings of 8 million tonne CO_2-emissions. Further 33 TWh of non-renewable energy recourses are saved. Over 90 % of these savings are related to the use of the vehicles.

Storage tank

A storage tank has been upgraded by replacing conventional stainless steel with a high strength duplex stainless steel, Figure 8. The tank is mainly used for storing marble slurry and similar liquids. It is designed for liquid with a density of 1.3 kg/dm^3. Data for the tank before and after upgrading is shown in Table 2. The tank wall segments are manufactured in a workshop and are erected on the site where the tank will be in operation.

Figure 8. A stainless steel storage tank in the course of erection.

Data for storage tank in stainless steel	Steel grade	$R_{p0,2}$ min [MPa]	Total weight [ton]	H [m]	D [m]	Vol [m^3]	Plate width [m]	Design stress [MPa]
Before upgrading(1)	**EN 1.4301**	**210**	**57.4**	**14**	**17**	**3178**	**2**	**140**
After upgrading(2)	**EN 1.4162**	**450**	**38.3**	**14**	**17**	**3178**	**2**	**260**
(1) Conventional stainless steel (EN 1.4301; 18.1 % Cr & 8.3 % Ni) - ref case								
(2) Duplex high strength stainless steel (EN 1.4162; 21.5 % Cr & 1.5 % Ni)								

Table 2. Data for the storage tank.

Before upgrading, the first circumferential sheet from the bottom is 16 mm thick, the second is 13 mm, the third is 11 mm, the fourth is 9 mm, the fifth is 7 mm, and the two remaining sheets are 6 mm thick. After upgrading, the first sheet is 9 mm thick, the second is 7 mm and the remaining 5 sheets are 6 mm thick, which constitutes the minimum thickness according to the standard. The total weight reduction of the storage tank was 19.1 tonne or 33 %.

Steel production (M1)

This module includes the production of the steel used for the storage tank. The steel sheets are delivered to site in the correct sizes, i.e. there are no yield losses on site. The yield losses are small when the steel sheets are cut, and are almost the same before and after upgrading. These losses have therefore been excluded in the analysis. The steel consumption is therefore assumed to be equal to the weight of the tanks as shown in Table 2.

Transport of steel (M2)

Since this case is a more general one and no particular erection site is chosen, the transport distance for steel sheets to the site is assumed to be 1000 km. A truck is chosen as the type of carrier used.

Manufacture of the tank (M3)

The tank is assembled on the site where it will be in operation. It is welded together from 2 m wide steel sheets, and 7 sheets are required for the height of 14 m.

The horizontal weld length is 320 m and the vertical length is 35 m. The consumption of welding wire is 825 kg before and 419 kg after upgrading. The production of the welding wire has been approximated with the production of the corresponding steel grade. The energy consumption for welding is 8247 kWh before and 4186 kWh after upgrading.

Use of the tank (M4)

The environmental aspects related to the use of the tanks could be differences in maintenance, corrosion resistance and service life. In this case, the life is at least 30 years both before and after upgrading.

Recycling (M5)

Scrap added in the steel production process is, as mentioned, regarded as free of environmental burden, in the cradle to gate analysis (M1 phase). However, in this case a full LCA is performed which means that the environmental burden of the scrap used in the steel production must be considered as well. In the recycling phase (M5), a burden is added on the input of scrap and a credit for the amount of recycled steel is subtracted. This leads to a negative net result for M5 i.e. a “Net credit”. The reasoning behind this procedure which is based on recommendations from Eurofer [13] is described in detail in [14].

Impact assessment results

The total impact assessment results for the storage tank are presented in Figure 9. Only Global warming has been chosen to illustrate the results, since the other impact categories show the same pattern as Global warming.

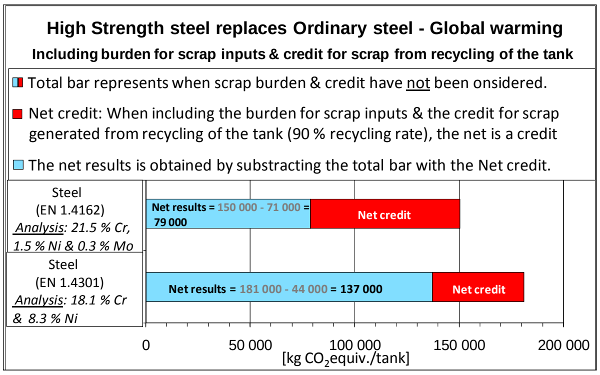


Figure 9. Total Global warming results for the storage tank [kg CO_2 equivalents/tank].

Total cost LCC	Before upgrading Steel grade: EN 1.4301		After upgrading Steel grade: EN 1.4162	
	Total cost [Euro]	% of total	Total cost [Euro]	% of total
M1 Steel production	147881	56	106406	60
M2 Steel transport (1)	---	---	---	---
M3 Manufacturing	116886	44	69903	40
Total cost	264 767	100	176 309	100
(1) Included in the material cost				

Table 3. Life cycle cost of the storage tank.

After scrap compensation, the upgraded case with the duplex steel EN 1.4162 shows a saving in GWP-emissions of 42 % compared to the reference case with conventional stainless steel EN 1.4301.

Contributions within the life cycle chain

Since the storage tank is a passive structure, there is normally little impact on the environment during the use phase (M4). That is why the main impact in this case is related to steel production, which contributes 99 %. The impact from the transport of the steel and the manufacture of the structure only corresponds to about 1 %.

Life cycle cost

Table 3 shows a summary of the life cycle cost of the storage tank. By upgrading the material in the tank to a duplex advanced high strength stainless steel, the life cycle cost can be reduced by 33 %. Almost half of that reduction is due to the weight reduction.

Spiral dewaterer

A spiral dewaterer for mine processing has been redesigned and upgraded from mild steel with R_e=220 MPa to high strength steel Domex 650 MC with R_e= 650 MPa**.**

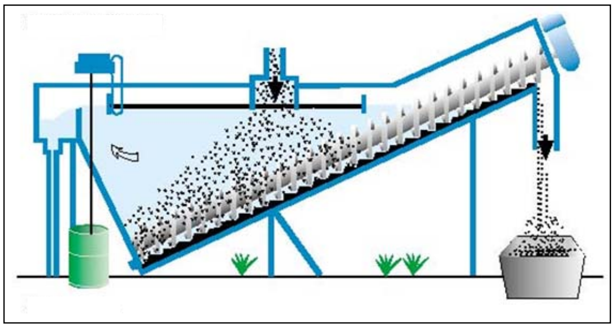


Figure 10. Spiral dewaterer for mining, operation principle.

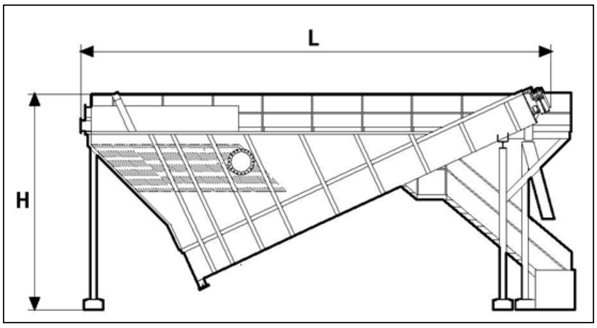


Figure 11. Old design of the spiral dewaterer.

The operating principle for the spiral dewaterer is shown in Figure 10**.** The old design in mild steel had a lot of external stiffeners in order to withstand the hydrostatic pressure from the water and had a rather flat design of the tank, Figure 11. Upgrading from mild steel to high strength steel Domex 650 MC and curving the side plates made it possible to withstand the water pressure without external stiffeners. This resulted in fewer parts (230 to 80) and decreased the weight considerably, Table 4.

Data for dewaterer	Steel grade	Number of parts	$R_{p0,2}$ min [MPa]	Total weight [ton]	L [m]	H [m]	Weight of tank [ton]	Total weight reduction %	Weight reduction of tank %
Before upgrading$^{(1)}$	Mild steel	230	210	23	14	6,4	9.7	-	-
After upgrading$^{(2)}$	AHSS	80	650	17	14	6,4	6.7	26	31

(1) Conventional milds steel, ref case

(2) Advanced high strength steel, Domex 650 M

Table 4. Data for the Spiral dewaterer.

The LCA has been performed in analogy with the previous case going through the phases M1 to M5 i.e. including the environmental burden of credit for scrap. The analysis has been performed with the newly developed software, EcoSteel, which output results for this case study are shown is Figure 13.

The introduction of longitudinal bolted flange joints instead of welding reduced the manufacturing time from 880 h to 570 h corresponding to a cost saving of 18600 €. The time for assembly on site was also reduced from 240 to 48 hour corresponding to a cost saving of 11520 €. All together this lead to a total cost reduction of 40%. The new design of the dewaterer is shown in Figure 12.

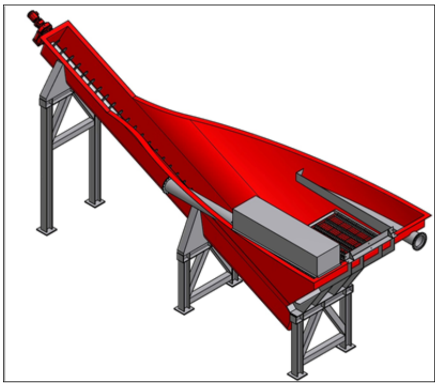
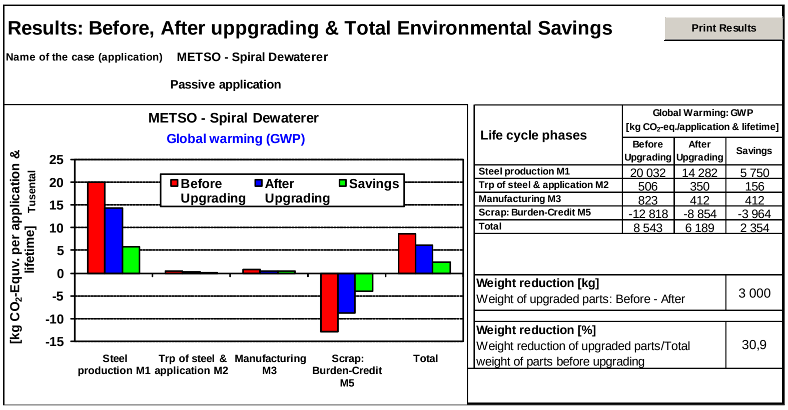


Figure 12. New design of spiral dewaterer.



Results: Before, After uppgrading & Total Environmental Savings

Name of the case (application) METSO - Spiral Dewaterer

Passive application

Life cycle phases	Global Warming: GWP [kg CO_2-eq./application & lifetime]		
	Before Upgrading	After Upgrading	Savings
Steel production M1	20 032	14 282	5 750
Trp of steel & application M2	506	350	156
Manufacturing M3	823	412	412
Scrap: Burden-Credit M5	-12 818	-8 854	-3 964
Total	8 543	6 189	2 354

Weight reduction [kg] Weight of upgraded parts: Before - After	3 000
Weight reduction [%] Weight reduction of upgraded parts/Total weight of parts before upgrading	30,9

Figure 13. Environmental savings (GWP) for one spiral dewaterer made of high strength steel instead of mild steel, output from the EcoSteel software.

The total weight reduction for the spiral dewaterer was 26 % and for the tank alone 31%. The total GWP- saving is 2354 kg CO_2-equvivalents per unit, which corresponds to 28 %.

ENVIRONMENTAL VALUE – RELATIVE APPROACH

In order to facilitate the understanding of the environmental value of advanced high strength steel, a general merit rating has been defined. It is done by normalizing the results from the case studies by relating the environmental savings to the additional specific emissions which occur when advanced high strength steel is produced instead of conventional steel, Figure 14. Such figures of merit are here called the “*CO_2-balance*”. The outcome of an analysis of the “*CO_2-balance*” will of course vary from one field of application to another. Furthermore the relative environmental savings (the merit number) will be larger for active than for passive structures and can be as high as 50 for active and as low as 2 for passive structures.

The *CO_2-balance* for the case studies reported above and in reference [10] is shown in Figure 15 indeed confirm the large difference between active and passive structures. The merit number is defined so that if the value is above one there is an environmental advantage in terms of CO_2-emission savings to perform the upgrading to advanced high strength steel.

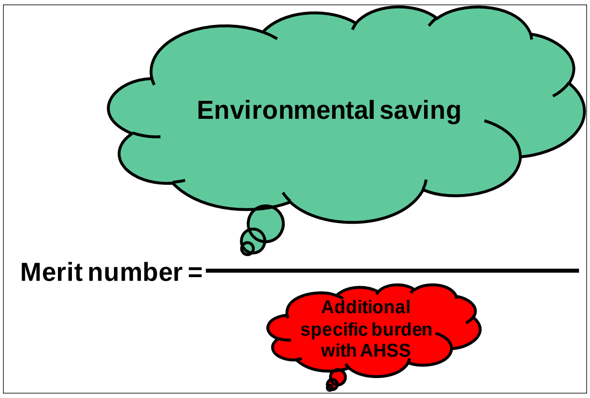


Figure 14. Merit number for the CO_2-balance.

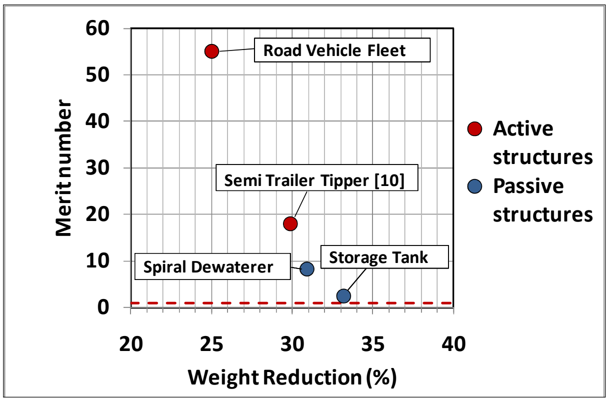


Figure 15. Merit numbers for case studies.

CONCLUSIONS

The Life Cycle Assessment of the production of the selected carbon steel and stainless steel shows, as expected, a small increase in environmental impact with increasing steel strength when expressed per unit of steel weight. This means that high strength steel grades often have a larger environmental impact compared to conventional steels when just considering the "cradle-to-gate" results per tonne steel. This is generally due to larger alloy content and/or more complex process routes. However, since increased strength leads to reduced weight, the total environmental impact will be considerably reduced.

Real life upgrading cases show that it is possible to achieve a 25 % weight reduction for parts in which conventional steel is replaced by advanced high strength steel. The analysis also indicates that there is an even greater potential, especially for passive structures.

A preliminary estimate shows that every million tonne of advanced high strength steel that replaces conventional steel in the European road vehicle fleet results in a saving of 8 million tonne CO_2-emissions and 33 TWh non-renewable energy recourses in a LCA, including the use phase. Over 90 % of these savings are related to the use of the vehicles.

Case studies on a storage tank show that, if advanced high strength steel is used instead of conventional steel, the CO_2-emissions could be reduced by 43 % and the cost by 30 % over the life cycle.

The case study with a spiral dewaterer in carbon steel, which like the storage tank is a passive structure, show a CO_2 reduction of 28 % and a reduced cost of 40 % when conventional steel was replaced by high strength steel.

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