STAINLESS STEEL
TANK CONSTRUCTION FOR ALTERNATIVE FUELS

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Abstract
Industry has to develop and obtain the necessary knowledge and technologies to meet the demands of a constantly changing market. Among the required aspects we are to find technical solutions towards the lack of natural resources and the need to preserve the environment. Based on a continuous research Portinox has developed alternative fuel tanks made of stainless steel, the leading structural material with excellent properties for optimum product designs.
In the following we present the approach and development of a polymorphic stainless steel tank for automobiles.

Portinox was founded in 1965 as a family enterprise producing industrial sinks made of stainless steel. As from 1978, when the firm joined the Teka Group organization, the company has experienced a spectacular growth and to date has been consolidated as one of the pioneer enterprises in the transformation of stainless steel.

The company's activity comprises five product divisions: beer kegs, decorative cooker hoods, pressure containers (domestic LPG and automotive LPG).

As manufacturers of components for the automobile industry, our developments and constructions of new products are aiming to meet the following targets:

- To participate in energy saving within the whole vehicle stages: manufacturing, life cycle and elimination.
- To contribute to the reduction of contaminating gas emissions through the vehicle.
- To design and manufacture for recycling and re-utilization.

All these objectives have to combine for an overall interaction, without any negative influence of one objective on the others.

From our commitment with the environment, and based on a leading material we have developed a stainless steel tank to contain LPG (Liquefied Petroleum Gas), and we are working on the development of a tank series for CNG and Hydrogen, for the automotive sector.

Our tank developments, as generally is the case for all new products to substitute already existing ones, are based on the following questions:

- Which aspects have to be changed with regard to existing products?
- What are the expectations of our customers?
- Which new and future laws, regulations and normative have to be complied?
- Which technical progress can be achieved with the new product?

Figure 1.

The analysis of these questions directly leads us to the description of the new product:

What is to be improved on presently existing products?

The answers are automatically reflecting the negative aspects of existing products, as are among others:

- High weight and therefore increased fuel consumption and pollution through gas emissions.
- High consumption of manufacturing energy due to heat and surface treatments as well as of production energy of steel.
- No corrosion resistance without special coatings.
- Can be installed only inside the vehicle so that useful space is wasted for tank storage.
- Limited re-utilization.

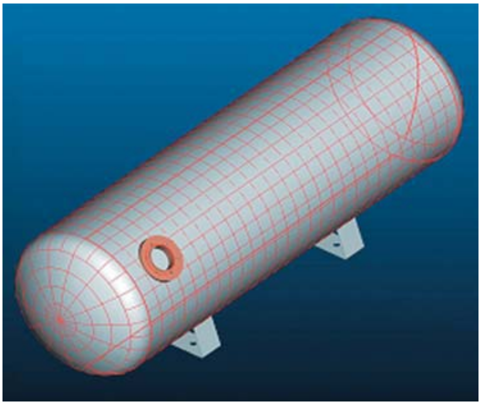

Figure 2.

What is the customer expecting from us?

- Product safety.
- Functional and space saving product.
- Energy reducing product.
- Economical product.
- Ecological product.

Which new and future laws, regulations and normative are to be complied with, and what problems are implied?

- R67.01 Directive for the construction of LPG equipment.
- R 110 Directive for the construction of CNG equipment.
- Directive 2000/53 EC regarding old vehicles.
- Kyoto protocol.
- PZEV (Partial Zero Emission Vehicles) Directive regarding emissions in California.
- ISO 11439 . . . .

At present the use of stainless steel is forbidden in some standards, as e.g. R 110. The problem for us as manufacturers is that there is little support for us from the stainless steel producers' side to change these standards.

For a company as ours, with a simple structure, it is difficult to fully participate in the CEN and ISO work.

Which are the technical achievements in line with the new product?

- Improvement of the material quality, for special applications and industrial use.
- Development of stainless steels adapted to the needs of the automobile industry.
- Development of new automatic welding methods.
- Utilization of new simulation software for deep drawing processes.
- Improvement of finite element calculations thanks to more efficient processing.
- Combination of stainless steel and carbon fibre.

Figure 3

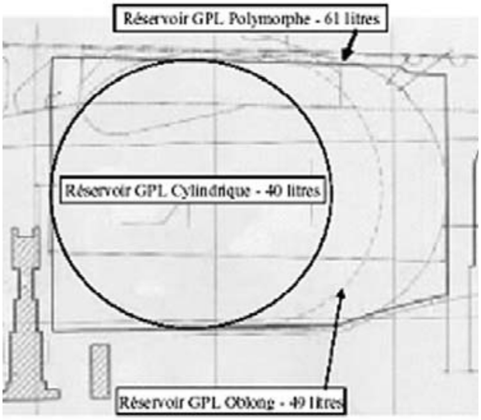

Figure 4.

In order to achieve the aims described at the beginning, there have been developed new technologies under the use of new materials for this application – as is stainless steel. The novelty basically consists in the design of a polymorphic tank (not cylindrical, toroidal, etc.) using stainless steel hardened by hydroforming.

With the design of the polymorphic tank the following positive aspects are obtained:

- Weight reduction in approximately 50%, which results in less fuel consumption and thus reduction of gas pollution.
- Less energy consumption during manufacturing as additional heat treatment is not necessary and there is 50% less weight.

- High resistance to corrosion without the necessity of coatings.
- Polymorphic geometry adaptable to the available space, placing the tank on the bottom of the vehicle.
- Excellent re-utilization and 100% recycling.

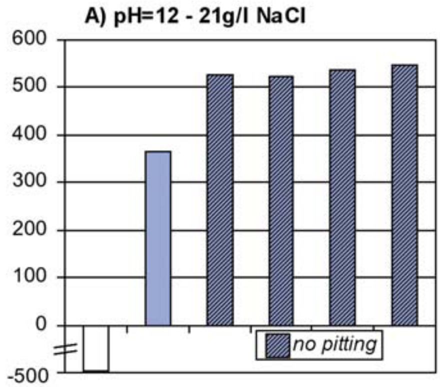

Figure 5.

The reason for using stainless steel in the automobile industry explains itself easily from the mechanical and anticorrosive material characteristics, resulting in turn the material from our process a lighter material than aluminium.

This conclusion is confirmed through the fact that regarding both the active resistance (pressure) as well as passive resistance (impact), less weight is needed with stainless steel than with aluminium:

Table I. Mechanical resistance.

Material	Elastic limit /yield stress) σ_0 (N/mm^2)	Density r (Kg/dm^3)	Specific resistance (σ_0/ρ)
Stainless Steel	880	7.9	111.4
Aluminium	275	2.7	101.8
Carbon Steel *	465	7.8	59.6

Source: Stainless Steel – A new "Light Metal" for the Automotive Industry by Jorma Kemppainen / Vice President – Euro Inox, Brussels, Belgium.
* Source: Portinox

The specific resistance of cold worked stainless steel is higher than the specific resistance of the so called light alloys.

Table II. Impact resistance

Material	Density ρ (g/cm^3)	Absorbed energy (J/cm^3)	Absorbed energy (J/g)
HSLA Steel	7.8	98	12.5
Aluminium	2.7	55	20.4
Austenitic stainless steel	7.9	300	38.0

Source: "A Step Forward in Passive Safety" by Hans Nordberg, Sheffield Hallam University, Sheffield.

Table III. Deformation characteristics

Material	Young Module E (Gpa)	Density ρ (Kg/dm^3)	Specific rigidity (E/ρ)
Stainless steel	200	7.9	25
Aluminium	70	2.7	25

These mechanical characteristics of stainless steel, hardened by means of cold forming, allow reducing the wall thickness of the tank and therefore make it significantly lighter.

This results in less consumption and therefore less pollution through gas emission.

The weight reduction is approximately 25 kg on the stainless steel tank in comparison with the traditional material which results in a total weight reduction on the vehicle of 2%. The below figure shows that the consumption decreases in 1,5 %, equivalent to 340.000 tons less per year in case of modifying the total national vehicle park.

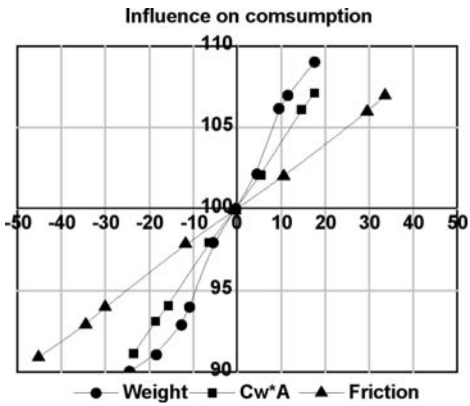

Figure 6.

Additionally to the weight advantage due to the use of stainless steel, the polymorphic design allows an ideal use of space availability resulting in the following optimization:

Table IV. Design characteristics.

LPG Deposit	Mass (kg)	Water capacity (lts.)	Mass/ Volume (kg/lts.)
Cylindrical	26.7	55.0	0.47
Oblong	28.9	50.3	0.57
Torical	34.0	57.0	0.59
Polymorphic REN Laguna II	25.2	76.9	0.33

The material furthermore extraordinarily complies with the requirements of the EC Directive 2000/53:

* Principle of re-utilization
* Correct elimination
* Protection of the environment

A Life Cycle Analysis made on a similar product, gives an orientation regarding the tank life cycle. The analysis was made on a butane gas bottle made of stainless steel which is compared with a standard bottle made of carbon steel.

The study was made according to ISO 14040, through an independent institute, and evaluates the impact of the product on the environment during its entire cycle, from its manufacturing until its elimination. The numbers given are costs in ecological points.

Table V. Life Cycle Analysis.

Comparative Data	St. Steel Bottle	Standard Bottle
Environmental cost during manufacturing	623	1283
Valve manufacturing	1910	1910
Costs associated to use	658	842
Transport related costs	405	555
Elimination related costs	1070	3018
TOTAL	4666	7608